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"I'll remember everything no matter what!": The role of metacognitive abilities in the development of young children's prospective memory

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A B S T R A C T

Prospective memory (PM), the ability to remember to carry out future intentions, is a critical skill for children's daily activities. Despite this, little is known about young children's awareness of their PM ability (metamemory), how metamemory is affected by PM task difficulty, and how metacognitive abilities might be related to metamemory. The current study examined the effect of task difficulty on children's PM predictions, actual performance, and postdictions and relations among episodic memory metamemory, metacognitive control, and executive functioning. Children aged 4 to 6 years ($N = 131$) made PM predictions, completed an easy or difficult PM task, and then made PM postdictions. Children also made predictions and postdictions for their performance on an episodic recall task and then completed an independent measure of metacognitive control and two measures of executive function (working memory and inhibition). Results showed that (a) children's PM increased with age and was worse in the difficult PM task condition, (b) PM predictions and postdictions did not increase with age and only PM postdictions were affected by PM task difficulty; (c) children's PM and episodic recall predictions and postdictions were more accurate with age, (d) children's PM postdictions best predicted PM performance, whereas predictions best predicted episodic recall task performance, and (e) children with better metacognitive control had better PM and more accurate PM predictions. These results are discussed in terms of young children's optimism surrounding their memory performance and the emergence of early metacognitive abilities.

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Introduction

To function successfully and independently in academic and social contexts, children must become proficient in recalling past experiences and information (retrospective episodic memory [RM]; Burgess & Shallice, 1997) and remembering to carry out their future intentions (prospective memory [PM]; Einstein & McDaniel, 1990). Daily RM errors, such as forgetting a new friend's name and forgetting a teacher's instructions, can have negative social or academic consequences. Similarly, PM failures, such as forgetting to hand in homework on its due date and forgetting to meet a friend on the playground at recess, might compromise a child's academic performance or friendship quality. To avoid the negative consequences of both RM and PM errors, memory strategies can be recruited to help children encode, store, and retrieve information from the past or carry out their future intentions successfully. However, to use strategies effectively, children must first be aware of their memory ability in order to know *if* and *when* such memory strategies might be helpful. An accurate awareness of one's memory ability may allow children to better anticipate and monitor their performance and then select and use strategies appropriately to improve their memory performance.

Metacognition, the knowledge and regulation of one's cognitive activity (Flavell, 1979), is often separated into two components: metacognitive monitoring that allows a child to assess mental states and metacognitive control to adapt behavior according to monitoring signals (Nelson & Narens, 1990; Shenhav et al., 2017). Within the domain of PM specifically, several theoretical accounts exist to capture the overlap between metacognitive abilities and PM performance. For example, Smith (2016) described PM as inherently metacognitive in nature due to the fact that one must form an intention to remember in the future. Similarly, Kuhlmann (2019) described the interconnectivity between metacognitive control and metacognitive monitoring in PM. Specifically, Kuhlmann described how one's monitoring can inform control (e.g., knowing an intention is hard to remember might lead you to use external memory aids) but that control can inform monitoring as well (e.g., if that external memory aid fails to work, you might update your beliefs about the efficacy of memory aids). Metacognitive abilities play an important role in metamemory; to have an accurate picture of their memory performance, individuals must be able to assess their own cognitive states (monitoring) and then select appropriate strategies (control) to promote successful memory. Both the multiprocess theory (McDaniel & Einstein, 2000) and the preparatory attentional and memory processes (PAM) theory (Smith, 2003) posit a role for controlled processes in PM (at least under demanding conditions) such as monitoring one's performance. Both theories emphasize the role of individuals' awareness of the PM task demands in allocating attention to the PM and ongoing tasks and recruitment of strategic versus spontaneous processing. Thus, it is important to understand the role of metacognitive processes in the development of PM because these processes are a central component to theoretical accounts of PM.

Knowledge of memory states and processes specifically is referred to as metamemory (Flavell, 1979). Metamemory is further broken down into declarative and procedural metamemory. Declarative metamemory is defined as explicit knowledge about memory performance and strategies, whereas procedural metamemory refers to an ability to monitor and control one's memory performance. Children with better declarative metamemory tend to also have better memory performance (e.g., Fabricius & Hagen, 1984; Henry, 1996; Kurtz & Weinert, 1989; Schneider, Borkowski, Kurtz, & Kerwin, 1986); thus, it seems that better declarative metamemory might support superior memory performance. For example, Schneider et al. (1986) found that 9-year-old children's declarative metamemory scores significantly predicted their episodic recall performance. In addition, longitudinal studies have found that 6- and 8-year-olds with better declarative metamemory also tend to use more complex and a wider variety of memory strategies as they age, suggesting that greater awareness of one's own memory may support memory performance via greater use of memory strategies (e.g., Grammer, Purtell, Coffman, & Ornstein, 2011; Schlagmüller & Schneider, 2002). Notably, the majority of these studies have focused on declarative metamemory of 8- to 12-year-olds (e.g., Schlagmüller & Schneider, 2002; Schneider et al., 1986) using questionnaires that ask children about their RM performance broadly (e.g., Grammer et al., 2011) as opposed to asking children about specific memory task performance that might tap into procedural metamemory. Of the studies that have examined procedural metamemory for specific tasks, researchers have often measured children's predictions or postdictions (reflections) on their memory performance (e.g., Cottini, Basso, Saracini, & Palladino, 2019; Kvavilashvili, & Ford, 2014; Redshaw, Vandersee, Bulley, & Gilbert, 2018).

Making predictions and making postdictions about one's memory performance are two ways to capture children's procedural metamemory, yet they differ in important ways. Whereas children might draw on past memory performance in order to make an accurate prediction, postdictions offer an opportunity to reflect on memory performance that has just occurred. That is, whereas predictions do not necessarily rely on a past memory trace (because the intention has not yet been executed; Kuhlmann, 2019), postdictions likely rely on very recent past memory performance (and thus recruit retrospective memory processes for the recent past). It might be the case that postdictions more generally might rely on episodic memory for past memory performance, whereas predictions might encourage children to engage in guessing or wishful thinking about their future performance (Schneider, 1998). Interestingly, young children often overestimate their performance regardless of feedback (O'Leary & Sloutsky, 2019) so it is not necessarily the case that children incorporate their actual memory performance into their postdictions of performance.

Children's predictions and postdictions of their retrospective memory performance

How accurate are children's RM performance predictions and postdictions? The findings are mixed (e.g., Destan, Hembacher, Ghetti, & Roebers, 2014; Kvavilashvili & Ford, 2014; Schneider, 1998; Schneider, Visé, Lockl, & Nelson, 2000). For example, Schneider et al. (2000) found that 6-, 8-, and 10-year-olds' predictions were significantly related to how many items they remembered immediately or after a short delay. In contrast, studies with 4- to 6-year-olds show that RM predictions and postdictions both are overestimated but that postdictions tend to be more accurate than predictions (e.g., Bertrand, Moulin, & Souchay, 2016; Schneider, 1998). Similarly, Kvavilashvili and Ford (2014) found that 5-year-olds significantly overestimated their RM performance in their predictions (but the authors did not measure children's postdictions). In sum, young children seem to be optimistic and unrealistic in their RM predictions and postdictions, but their postdictions are more accurate than their predictions, suggesting that their procedural metamemory benefits from direct RM experience.

Children's predictions and postdictions of their PM performance

PM develops rapidly during the preschool years (e.g., Kliegel & Jäger, 2007; Mahy & Moses, 2011), but children still struggle to successfully carry out their intentions into middle childhood (e.g., Kerns, 2000; Shum, Cross, Ford, & Ownsworth, 2008). Little is known about children's PM metamemory and its developmental trajectory during early childhood. Furthermore, the limited available research reveals mixed findings (e.g., Cottini et al., 2019; Kreutzer, Leonard, Flavell, & Hagen, 1975; Kvavilashvili & Ford, 2014; Redshaw et al., 2018). For example, an early study showed that when 4- to 11-year-olds were asked to state all the PM strategies they could generate, older children produced more strategies and could better describe how the strategies could improve PM performance compared with younger children (Kreutzer et al., 1975). These findings suggest that there is a developmental increase in the generation and understanding of PM strategies (declarative metamemory) during the preschool to middle childhood years. But is an increase in declarative metamemory accompanied by an increase in PM prediction and postdiction accuracy (procedural metamemory for a specific PM task)?

Research on the accuracy of children's PM predictions and postdictions reveals inconsistent findings. For example, 66% of 5-year-olds accurately predicted whether they would (or would not) remember to carry out a single PM intention, suggesting that young children can make accurate PM predictions (Kvavilashvili & Ford, 2014). However, in a study with 7- and 8-year-olds, PM predictions (responding yes or no to whether they *would* remember to fulfill their intention five times) were unrelated to actual PM performance, yet 86% of children's postdictions (responding yes or no to whether they *had* remembered to fulfill at least one of their five intentions) were accurate (Cottini et al., 2019). Furthermore, children's individual postdictions (i.e., how many of the five cues they would fulfill the intention for) were also significantly related to PM performance. In our own lab, preschool-aged children's awareness of their PM after completing a task (akin to a postdiction) seems to be limited. For example, after forgetting to carry out a PM task, 4-year-olds reported the content of their PM intention with ease but indicated that they did not see the PM cue, thereby not recognizing that they had seen the PM cue but had forgotten to fulfill the intention (Mahy, Mazachowsky, & Lavis, 2018). These findings suggest that preschoolers have a limited ability to reflect on their PM performance accurately. Notably, most studies have required children to make yes/no PM predictions based on whether they think they will remember to carry out their future intentions or not rather than making a prediction using a continuous scale (i.e., indicating the number of times they will successfully carry out their future intentions). The yes/no PM prediction format limits response variability and may contribute to low prediction accuracy. The majority of studies with children have focused on PM predictions and have not explicitly examined PM postdictions (e.g., Kvavilashvili & Ford, 2014; Redshaw et al., 2018; but see Cottini et al., 2019).

The effect of difficulty on children's predictions of memory performance

An additional gap in the literature is whether children's PM predictions and postdictions are affected by task difficulty. Hicks, Marsh, and Cook (2005) proposed an attention allocation policy in which individuals decide how to approach the task at intention formation that covaries with the expected difficulty of the PM task. According to this claim, individuals' PM predictions should be affected by PM task difficulty and more difficult tasks should be allocated more attentional resources than simple tasks. However, there has been mixed support for this policy; findings with adults suggest that PM performance predictions are inconsistently affected by task difficulty (e.g., Cherkaoui & Gilbert, 2017; Hicks, Franks, & Spitler, 2017; Meeks, Hicks, & Marsh, 2007; Rummel & Kuhlmann, 2018). Despite the existing adult literature, no study has examined whether children are aware that a more difficult PM task will likely result in worse PM performance compared with an easy PM task prior to any task experience.

It is well established that young children perform worse on more cognitively demanding and difficult PM tasks compared with easier ones (e.g., Kliegel et al., 2013; Kvavilashvili & Ford, 2014; Mahy, Moses, & Kliegel, 2014b), but only one study has investigated how task difficulty affects PM predictions in children. Redshaw et al. (2018) asked 6- to 13-year-olds to practice completing a PM task of varying difficulty and then to make a prediction of how many PM intentions they would fulfill during a difficult PM task (intention with three targets) or an easy PM task (intention with one target). Children's PM predictions were significantly affected by task difficulty, with children underpredicting their PM performance in the difficult task but accurately predicting their PM performance in the easy task. Furthermore, children were more likely to make use of reminders during the difficult task compared with the easy task, suggesting that children as young as 6 years considered task difficulty when using reminders. A limitation of this study was that it did not include PM postdictions, so it is unclear how postdictions are influenced by PM task difficulty; however, children's predictions in Redshaw et al.'s (2018) study were more akin to postdictions (compared with predictions in the absence of any task experience) given that children had a chance to practice the task prior to making PM performance predictions.

Redshaw et al.' (2018) findings align with some of the findings on the impact of difficulty on RM predictions. For example, Destan et al. (2014) found that 5- to 7-year-old children predicted they would remember more of the simple Japanese characters compared with the difficult ones and that children's predictions corresponded with their actual RM performance. In contrast, Kvavilashvili and Ford (2014) found that 5-year-olds predicted that they would remember a stuffed animal's name regardless of whether it was an easy name to remember ("Mr. Rainbow") or a difficult one ("Mr. Tainbow"). Despite children's optimistic predictions, there was a significant impact of task difficulty on children's actual memory performance, with 94% of children accurately recalling Mr. Rainbow's name but *none* of the children accurately recalling Mr. Tainbow's name. Thus, although task difficulty has a clear impact on RM performance, the impact of task difficulty on young children's RM predictions is less clear. Notably, no work has examined the impact of task difficulty on young children's predictions *and* postdictions of their PM performance.

The role of executive functioning and metacognitive abilities in children's metamemory

The self-regulatory abilities that allow children to continuously monitor and update information, inhibit prepotent responses, and switch their attention between different tasks are called *executive functions* (Diamond, 2013). Three main executive functions have been proposed: working memory/updating, inhibition, and set shifting (Miyake et al., 2000). Mahy, Moses, and Kliegel (2014a) outlined the important role that executive functions play in children's PM in their executive framework of PM development. This framework suggests that from 4 years of age, executive functions play a critical role in driving children's PM development. Indeed, this prediction has been supported by findings showing that (a) 4- and 5-year-olds' PM performance was positively related to children's working memory, inhibition, and set shifting and that (b) inhibition accounted for age-related PM increases in young children (Mahy et al., 2014b).

In addition to the three executive functions described above, Mahy and colleagues also suggested that monitoring of the external environment for the PM cue and internal monitoring of one's intentions both play an essential role in successful PM performance. In other words, children's ability to monitor their performance on a PM task (procedural metamemory) might also increase children's external monitoring during a PM task, thereby enhancing PM performance. For example, Mahy et al. (2018) found that 4-year-olds who forgot to fulfill a PM intention were much less likely to report that they had seen the PM cue compared with 3-year-olds (who often forget what their PM intention was altogether), suggesting that 4-year-olds' PM failures are likely driven by a failure to detect the PM cue in the external environment, whereas 3-year-olds failures seem to be driven by failures in encoding, storing, or retrieving the intention. It is possible that young children's poor metacognitive monitoring and control (e.g., not continuously reminding themselves to look for the PM cue) might contribute to failures in detecting the PM cue in the external environment, ultimately leading to PM failures.

Executive functioning, PM, and metacognitive control have been found to be significantly positively related in 8-year-olds (Spiess, Meier, & Roebers, 2015, 2016). In a longitudinal study, executive functioning (but not metacognition) was found to predict 8-year-olds' PM performance 7 months later (Spiess et al., 2016). In addition, Geurten, Lejeune, and Meulemans (2016) found that executive functioning was predictive of 4-, 6-, and 9-year-olds' time-based PM performance but that relation was mediated by time-monitoring ability. Thus, it is clear that executive functions are positively related to children's PM performance and also play a role in driving PM development. Furthermore, metacognitive monitoring and control are related to PM, and may also play a role in driving PM development and mediating the relation between executive functioning and PM performance (similar to how time monitoring mediated the relation in Geurten et al., 2016).

PM and executive functioning are significantly positively correlated during early and middle childhood (e.g., Atance & Jackson, 2009; Ford, Driscoll, Shum, & Macaulay, 2012; Mahy & Moses, 2011), and (as outlined earlier in this article) procedural metamemory and PM are positively related as well (Cottini, Basso, & Palladino, 2018; Kvavilashvili & Ford, 2014; Spiess et al., 2015, 2016). It is possible that for executive functions to enhance PM performance, children first must be aware of the limitations of their memory, knowledge, and abilities in order to effectively recruit executive abilities when necessary in a PM task (in line with predictions of the PAM and multiprocess theories of PM).

Limitations in the existing literature

There are several limitations in the current literature on the relations among PM, procedural metamemory, metacognitive abilities, and executive functioning during early childhood. First, no studies have investigated the effect of difficulty on preschool children's PM predictions and postdictions (but see Redshaw et al., 2018, for findings with older children). Thus, it remains an open question whether children's PM predictions and postdictions are sensitive to task difficulty prior to any experience with the PM task. Second, there is limited research comparing predictions and postdictions of PM and RM performance during early childhood given that many studies have investigated either predictions *or* postdictions of RM *or* PM in young children (e.g., Cottini et al., 2018; Kvavilashvili & Ford, 2014). To our knowledge, no study has compared predictions *and* postdictions of children's PM *and* RM across the preschool years. Finally, the majority of studies on children's metamemory have asked children to make binary (yes/no) PM predictions and postdictions that might have limited variability in children's responses. No study has examined *both* PM predictions and postdictions using a continuous response scale (asking children *how many* PM cues they will or did successfully carry out the PM intention for; but see Cottini et al., 2019, for continuous PM postdictions and Redshaw et al., 2018, for continuous PM predictions). The current study attempted to fill several of these gaps in the literature in order to capture a more complete picture of the role of metacognitive abilities in young children's PM performance.

The current study

Broadly, our study sought to examine the role of metacognitive abilities in the development of PM. This overarching goal was accomplished by examining (a) young children's procedural metamemory, as measured by their PM and RM performance predictions and postdictions, (b) the impact of task difficulty (salient vs. nonsalient PM condition) on children's PM performance predictions and postdictions, and (c) the relations among children's memory performance, metamemory accuracy (in PM and RM tasks), metacognitive control, and executive functioning.

We predicted that (1) children would have worse PM performance and lower predictions in the difficult (nonsalient cue) condition compared with the easy (salient cue) condition of the PM task, (2) older children would have more accurate memory predictions and postdictions than younger children, (3) predictions and postdictions would be more accurate for PM than for RM (replicating Kvavilashvili & Ford's [2014] findings), (4) PM and RM predictions would be more accurate than postdictions across all ages (based on Mahy et al., 2018, suggesting that children lack awareness of their PM performance after the fact, and Kvavilashvili & Ford's [2014] findings that 5-year-olds' PM predictions are quite accurate), (5) children with better metacognitive awareness would be more accurate in predictions and postdictions for both memory tasks (PM and RM), and (6) executive functioning would predict PM performance in children, but the relation would be mediated by metacognitive control performance.

Method

Participants

A total of 148 4- to 6-year old children (55 4-year-olds, 45 5-year-olds, and 48 6-year-olds) participated in the study. Children were excluded for the following reasons: being unable to answer a control question that confirmed understanding of the PM task instructions (n = 12), parental report of an attention-deficit/hyperactivity disorder (ADHD) diagnosis (n = 3), and experimenter error (n = 2). The final sample consisted of 131 children: 47 4-year-olds (25 girls and 22 boys; M_{age} = 54.19 months, SD = 3.39), 41 5-year-olds (20 girls and 21 boys; M_{age} = 66.27 months, SD = 3.44), and 43 6-year-olds (25 girls and 18 boys; M_{age} = 78.45 months, SD = 3.70). An a priori power analysis using G*Power 3 (Faul, Erdfelder, Lang, & Buchner, 2007) determined that a sample size of 111 was sufficient to detect a medium effect size (f = 0.3, power = .80, and alpha = .05). Data collection was interrupted by the COVID-19 pandemic, so despite the original goal of 150 participants, we proceeded with a final sample of 131 participants, which was more than sufficient to detect medium size effects. Participants were predominantly Caucasian (80%) and from a middle-class background (51.9% had a family income of $75,000 or above). Participants were recruited from the Growing with Brock participant database maintained by five developmental psychology labs at Brock University and from local day-care centers in the Niagara region of Ontario, Canada.

Procedure

This study's methods were preregistered on the Open Science Framework (https://osf.io/4mf7b). All children were tested in a quiet area of the lab or day care center and their performance was videotaped after receiving parental consent and child assent to participate. Tasks were administered in the following fixed order: PM task, Simon Says task, episodic recall, metacognitive control task, and backward word span task. The tasks took approximately 20 min for children to complete. All procedures were approved by the Brock University research ethics board.

Measures

PM task

Children were introduced to a PM card sorting task (adapted from Mazachowsky & Mahy, 2020) where they were told that a zookeeper needed help in sorting animals into two cages (the ongoing task). Children were asked to sort animal cards into a yellow or blue box based on the color of a dot sticker on each card. Children were also told that the elephants had escaped from the zoo, so if they saw a picture of an elephant, they should place it in a white box behind them instead of sorting them into the cages (the PM intention).

Children were randomly assigned within age group to an easy or difficult PM task condition. In the easy condition with a salient PM cue, children were told that there would be 4 elephants in the stack of cards and that each elephant would be on a bright yellow background so they would be easy to notice. In the difficult condition with a nonsalient PM cue, children were told that there would be 4 elephants in the stack of cards and that each elephant would be on the same white background as the other cards so they would be hard to notice.

Immediately after this statement, children in both conditions were asked to predict how many elephants (out of four) they thought they would remember to put in the box behind them by pointing to the number of elephants they would remember on a visual scale (Fig. 1A). Children then were given three practice trials of the ongoing task to ensure that they understood how to sort the cards. Children were then asked to draw a picture for 1 min as a delay task. Next, the PM task began. It contained 40 cards in total with 4 elephant cards (that depicted distinct elephants) in the 13th, 20th, 26th, and 32nd positions in the stack. At the end of the task, children were asked a control question, "What were you supposed to do when you saw an elephant?", to ensure that they could recall the content of the prospective intention. Then, children were asked to make an overall postdiction of how many of the elephants they remembered to put in the box behind them (out of 4), again using the visual scale. Then, children were asked to make an item-by-item postdiction for each of the 4 elephant cues. They were shown each distinct elephant card (with a plain or bright yellow background, depending on the condition to which they were assigned) and were asked whether they had remembered to put that elephant card in the box behind them (individual item postdiction).

Children's performance on each of the four individual item postdictions was summed to create an individual item PM postdiction score out of 4. Children's PM prediction, actual PM performance, and PM postdiction (both overall and individual item) ranged from 0 to 4. Critically, only children who could answer the control question were included in the analyses for this task to ensure that errors were due to PM failures and not failures to remember the content of the PM intention (i.e., RM failures). A total of 12 children were excluded due to the inability to answer what they were supposed to do when they saw a picture of an elephant.

Simon says task

In this measure of inhibition (Strommen, 1973), children were asked to follow the experimenter's verbal instructions, but only when they were preceded by "Simon says." Children were first given a

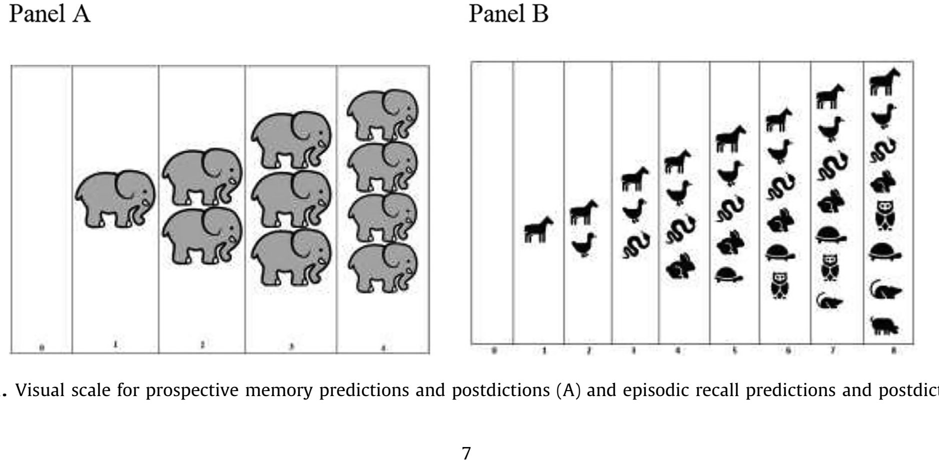

Fig. 1. Visual scale for prospective memory predictions and postdictions (A) and episodic recall predictions and postdictions (B).

practice trial in which an action (“Clap your hands”) was preceded by “Simon says” or not. This trial was repeated up to a maximum of three times to ensure that children understood the rules. If children failed the practice trial after three attempts, their data were excluded from analysis. Children then were given 10 trials; of these, 5 were non-imitation trials where they needed to inhibit following the experimenter’s command. Performance on each non-imitation trial was scored out of 3 (0 = commanded movement, 1 = partial movement, 2 = different movement, 3 = no movement) for a possible total of 15. Inter-rater reliability on 33% of the data (N = 43) was substantial, Cohen’s kappa = .801. A total fo 15 children were excluded for failing the practice trials (n = 11) or being uncooperative (n = 4).

Episodic recall

In this measure of episodic RM adapted from Naito (2003), children were asked to name and then study 8 line drawings of everyday objects for 20 s. Children were asked to predict how many of the items they thought they would remember at the end of the task (out of 8) using a visual scale (see Fig. 1B). After completing a 1-min maze as a filler task, children were asked to recall as many of the line drawings as they could. Then, children were asked how many drawings they thought they had remembered out of 8 (overall postdiction) with the help of a visual scale. To examine postdictions for each of the 8 items, children were then shown each drawing individually and asked whether they thought that they remembered the card or not (individual item postdiction). Children’s performance on each of the individual items was summed to create an individual item postdiction score out of 8. Children’s episodic recall prediction, episodic recall performance, and episodic recall postdiction (both overall and individual item) ranged from 0 to 8. No children were excluded from this task.

Metacognitive control task

This metacognitive control task was adapted from Roebers, Cimeli, Röthlisberger, and Neuenschwander (2012) and made appropriate for preschool children. Children were first trained to use a 5-point confidence scale (see Fig. 2). The experimenter began by describing what each face and number of the scale meant in terms of “sureness.” Children were told that the frowny face (labeled 1) meant “not sure at all” and that the really smiley face (labeled 5) meant “really, really sure.” Children were then asked to identity which face was “not sure at all,” “really, really sure,” and “not sure or unsure” (neutral face labeled 3). All children successfully indicated which faces matched these labels. Children were then shown 10 cards with pictures of common and uncommon animals on them (i.e., alpaca, seal, porcupine, panda, beaver, manatee, panther, squirrel, goat, and groundhog) and were asked to name the animal. After children named each animal, the experimenter provided the rating scale and asked children to indicate how confident they were in the animal name they had provided. The purpose of these confidence judgments was to encourage children to reflect on the accuracy of their naming in order to prepare children for judging whether that name was correct or incorrect in the next phase of the task (metacognitive control). Once children had named and made a confidence judgment for each animal card, they were then asked to sort each card in either a treasure box if they

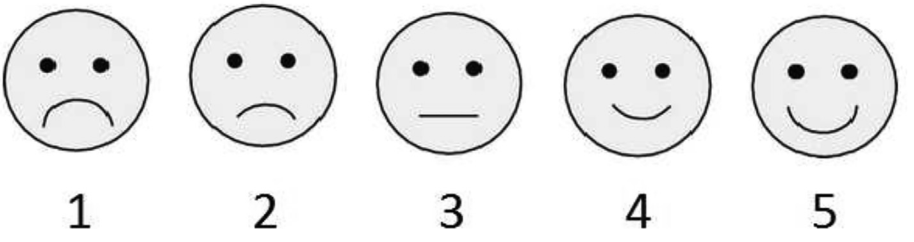

Fig. 2. Confidence rating scale for the metacognitive control task.

thought they had named it correctly or in a garbage can if they thought they had named it incorrectly. Children's responses were scored as correct if they named the animal correctly and placed it in the treasure box or if they named the animal incorrectly and placed it in the garbage can. Children's responses were scored as incorrect for any other combination. Children were given a score out of 10 based on how accurate they were in assessing their naming performance (by placing the cards in the garbage can or treasure box), which was our index of metacognitive control. The data of 1 child were excluded because the child was uncooperative.

Backward word span task

In this measure of working memory (Carlson, Moses, & Breton, 2002), children were asked to repeat words that a puppet said in a backward order. Children were given a practice trial where they needed to repeat two words in a backward order (fruit and zoo). Children's performance was scored based on whether they got at least one of two trials correct at each level of difficulty (from two to five words). Two trials were administered at each level of difficulty. Children's scores ranged from 0 (not able to repeat two words in a backward order over two trials) to 4 (able to repeat five words in a backward order on at least one of two trials). A total of 30 children were excluded for failing the practice trial, and 1 child was excluded for being uncooperative.

Results

Table 1 shows means and standard deviations for PM predictions, performance, and postdictions by age group and task difficulty condition. Table 2 shows means and standard deviations for episodic recall predictions, performance, and postdictions as well as for Simon Says, metacognitive control task, and backward word span task performance by age group. Initial examination of children's overall and individual item postdictions revealed that they were positively correlated in both the PM task and episodic recall task, $rs(131) > .27$, $ps < .003$. For the sake of brevity, going forward we report the overall postdiction scores only (referred to simply as postdictions) because these mirrored the way in which children made memory predictions (in an overall manner).

Effect of age and task difficulty on PM predictions, actual performance, and postdictions

First, to examine whether age and task difficulty had an impact on children's PM predictions, a 3 (Age Group: 4- vs. 5- vs. 6-year-olds) $\times$ 2 (Condition: salient vs. nonsalient) analysis of variance (ANOVA) was conducted on children's PM performance *predictions*. Results showed no significant main effect of age group, $F(2, 124) = 2.63$, $p = .076$, $\eta_p^2 = .04$, or condition, $F(1, 124) = 0.03$, $p = .856$, $\eta_p^2 < .001$, and no interaction between age group and condition, $F(2, 124) = 0.47$, $p = .625$, $\eta_p^2 = .01$.

To examine whether children's PM performance would be affected by age and task difficulty (nonsalient and salient cues), a 3 (Age Group: 4- vs. 5- vs. 6-year-olds) $\times$ 2 (Condition: salient vs. nonsalient) ANOVA was conducted. Results showed a significant main effect of age, $F(2, 125) = 5.70$, $p = .004$, $\eta_p^2 = .09$. Older children performed significantly better compared with younger children on the PM task. Tukey post hoc follow-up tests revealed that 6-year-olds ($M = 3.19$, $SD = 1.35$) performed significantly better than 4-year-olds ($M = 2.15$, $SD = 1.74$; $M_{diff} = 1.09$, $SE = 0.32$, $p = .003$) on the PM task; however, 4- and 5-year-olds' and 5- and 6-year-olds' PM performance did not differ ($ps > .246$). There was a significant main effect of condition, $F(1, 125) = 11.28$, $p = .001$, $\eta_p^2 = .08$, such that children

Table 1
Means (and standard deviations) of prospective memory predictions, performance, and postdictions by age and condition.

	Salient condition			Nonsalient condition		
Age in years	Predictions	Actual performance	Postdictions	Predictions	Actual performance	Postdictions
4	3.54 (1.02)	2.79 (1.59)	3.62 (0.97)	3.65 (1.03)	1.48 (1.68)	3.26 (1.39)
5	3.95 (0.22)	2.80 (1.70)	3.70 (0.80)	3.80 (0.70)	2.48 (1.60)	3.52 (0.87)
6	3.85 (0.37)	3.75 (0.79)	3.70 (0.73)	3.96 (0.21)	2.70 (1.55)	2.91 (1.31)

Table 2
Means (and standard deviations) of episodic recall and executive function task performance.

	4-year-olds	5-year-olds	6-year-olds
Episodic recall predictions	6.64 (2.28)	6.88 (1.87)	6.57 (2.27)
Episodic recall score	3.77 (1.34)	4.52 (1.12)	5.00 (1.29)
Episodic recall postdictions	5.55 (2.61)	5.61 (2.14)	5.62 (1.53)
Simon Says score	7.55 (5.66)	9.79 (5.02)	11.59 (3.85)
Metacognitive control score	5.91 (1.87)	7.00 (1.27)	7.21 (1.84)
Backward word span score	1.18 (0.59)	1.21 (0.59)	1.61 (0.69)

in the salient condition performed better on the PM task (M = 3.09, SD = 1.48) than children in the nonsalient condition (M = 2.21, SD = 1.67). There was no significant interaction between age group and condition on children's PM performance, $F(2, 125) = 1.22$, $p = .300$, $\eta_p^2 = .02$.

Finally, to examine the impact of age and task difficulty on children's PM postdictions, a 3 (Age Group: 4- vs. 5- vs. 6-year-olds) × 2 (Condition: salient vs. nonsalient) ANOVA was conducted on children's PM *postdictions*. Results revealed no main effect of age group, $F(2, 125) = 0.88$, $p = .419$, $\eta_p^2 = .01$, and no interaction between age group and condition, $F(2, 125) = 0.93$, $p = .399$, $\eta_p^2 = .02$. However, there was a significant main effect of condition, $F(1, 125) = 5.71$, $p = .018$, $\eta_p^2 = .044$, with higher PM postdictions in the salient condition (M = 3.67, SD = 0.84) compared with the nonsalient condition (M = 3.22, SD = 1.23).

Effect of age and task difficulty on accuracy of PM predictions and postdictions

To examine our second hypothesis that older children would have more accurate memory judgments for PM than younger children, we examined age effects in PM predictions and postdictions. Although we had originally intended to combine prediction and postdiction accuracy on each task to yield an overall judgment accuracy score, we decided to analyze them separately given conceptual differences between predictions and postdictions and our findings that PM predictions and postdictions were uncorrelated (see Table 4 below). We first calculated absolute difference scores between predictions/postdictions and actual memory performance for the PM task. These absolute difference scores represented PM prediction/postdiction accuracy, with higher scores representing worse accuracy (predictions/postdictions further away from actual performance) and lower scores representing better accuracy (predictions/postdictions closer to actual performance). Two 3 (Age Group: 4- vs. 5- vs. 6-year-olds) × 2 (Condition: salient vs. nonsalient) ANOVAs examined the effect of age and task difficulty on PM prediction and postdiction accuracy. We included condition in our analyses because it had a significant effect on children's PM performance and also on PM postdictions.

For PM prediction accuracy, there was a main effect of age group, $F(2, 124) = 5.15$, $p = .007$, $\eta_p^2 = .08$. Tukey post hoc tests revealed that 6-year-olds (M = 0.86, SD = 1.30) were more accurate than 4-year-olds (M = 1.83, SD = 1.30; 95% confidence interval (CI) [0.22, 1.72], $p = .007$) in their PM predictions, but 4- and 5-year-olds (M = 1.40, SD = 1.66) and 5- and 6-year-olds did not differ in their PM prediction accuracy ($ps > .23$). There was also a significant effect of condition, $F(1, 124) = 10.43$, $p = .002$, $\eta_p^2 = .08$. Children in the salient condition were more accurate in their PM predictions (M = 0.95, SD = 0.82) than children in the nonsalient condition (M = 1.78, SD = 1.64). There was no interaction between condition and age group, $F(2, 124) = 0.57$, $p = .57$, $\eta_p^2 = .01$.

For PM postdiction accuracy, there was a significant effect of age, $F(2, 125) = 6.38$, $p = .002$, $\eta_p^2 = .09$. Tukey post hoc tests revealed that 6-year-olds (M = 0.33, SD = 0.71) were more accurate than 5-year-olds (M = 1.07, SD = 1.63; 95% CI [0.01, 1.48], $p = .043$) and 4-year-olds (M = 1.34, SD = 1.68; 95% CI [0.30, 1.73], $p = .002$) in their PM postdictions, but 4- and 5-year-olds did not differ in their PM postdiction accuracy ($p = .65$). There was also a main effect of condition, $F(1, 125) = 4.29$, $p = .040$, $\eta_p^2 = .03$, with children in the salient condition having greater PM postdiction accuracy (M = 0.67, SD = 1.32) than children in the nonsalient condition (M = 1.16, SD = 1.58). There was no interaction between condition and age group, $F(2, 125) = 0.54$, $p = .58$, $\eta_p^2 = .01$.

Effects of age on accuracy of episodic recall predictions and postdictions

To examine the impact of age on episodic recall predictions and postdictions (the second part of our second hypothesis), we performed two one-way ANOVAs. We analyzed episodic recall prediction and postdictions separately because they were only weakly correlated (see Table 4 below). Age had a significant effect on the accuracy of these episodic recall predictions, $F(2, 128) = 5.00$, $p = .008$. Tukey post hoc analyses revealed that 6-year-olds ($M = 2.39$, $SD = 1.42$) were significantly more accurate in their episodic recall predictions than 4-year-olds ($M = 3.59$, $SD = 2.19$; 95% CI [0.29, 2.11], $p = .006$), but 5-year-olds ($M = 2.88$, $SD = 1.71$) did not differ from 4-year-olds or 6-year-olds ($ps > .16$). A similar age effect emerged for episodic recall postdiction accuracy, $F(2, 130) = 13.87$, $p < .001$. Follow-up tests revealed that 6-year-olds ($M = 1.14$, $SD = 1.32$) and 5-year-olds ($M = 1.95$, $SD = 1.67$) were more accurate than 4-year-olds ($M = 3.21$, $SD = 2.42$; 95% CI [1.12, 3.02], $p < .001$, and 95% CI [0.30, 2.21], $p = .006$, respectively), but 5- and 6-year-olds did not differ in episodic recall postdiction accuracy ($p = .12$).

Accuracy of predictions and postdictions for PM versus episodic recall task

To test our hypothesis that children's predictions and postdictions would be more accurate for the PM task compared with the episodic recall task (Hypothesis 3), we computed absolute difference scores between predictions/postdictions and actual performance and divided them by the total number of trials for each memory task. This produced absolute accuracy scores relative to the total number of trials in the PM and episodic recall tasks. Then, we conducted two dependent-samples *t* tests comparing (a) children's PM prediction accuracy with their episodic recall prediction accuracy and (b) children's PM postdiction accuracy with their episodic recall postdiction accuracy. Children's prediction accuracy did not differ between the PM task ($M = 0.34$, $SD = 0.40$) and the episodic recall task ($M = 0.37$, $SD = 0.23$; $t(129) = 0.74$, $p = .46$). Children's postdiction accuracy also did not differ between the PM task ($M = 0.23$, $SD = 0.37$) and the episodic recall task ($M = 0.27$, $SD = 0.26$; $t(130) = 1.16$, $p = .25$).

Relations among children's predictions, postdictions, and actual memory performance

To examine whether predictions or postdictions were more predictive of children's PM and episodic recall performance (Hypothesis 4), hierarchical linear regressions were conducted for both PM and episodic recall tasks (Table 3). Children's PM predictions did not predict their actual PM task performance, but children's PM postdictions significantly predicted their actual PM performance. In contrast, in the episodic recall task, children's predictions independently predicted their actual episodic recall performance, but their postdictions did not.

Relations among metacognitive control and memory predictions and postdictions

To test our hypothesis that children with better metacognitive control would also have more accurate predictions and postdictions in both the PM and episodic recall tasks, prediction and postdiction accuracy scores (absolute differences between predictions/postdictions and actual memory perfor-

Table 3
Hierarchical linear regressions with children's performance predictions and postdictions predicting actual prospective memory and episodic recall performance.

	Prospective memory				Episodic recall			
	SE	*β*	*t*	*p*	*SE*	*β*	*t*	*p*
Step 1: Predictions	.21	.04	0.45	.656	.07	.22	2.50	.014*
Step 2: Predictions	.19	.03	0.31	.760	.07	.18	2.00	.047*
Postdictions	.12	.41	5.07	<.001**	.07	.09	1.01	.314

*$p < .05$.
**$p < .01$.

Table 4
Correlations among all behavioral measures.

	1	2	3	4	5	6	7	8	9	10	11
1. PM predictions	–	–	–	–	–	–	–	–	–	–	–
2. PM performance	−.03	–	–	–	–	–	–	–	–	–	–
3. PM postdictions	.05	.48**	–	–	–	–	–	–	–	–	–
4. Episodic recall predictions	.03	.06	−.08	–	–	–	–	–	–	–	–
5. Episodic recall	−.05	.09	−.23*	.26**	–	–	–	–	–	–	–
6. Episodic recall postdictions	.05	−.14	.04	.21*	.28**	–	–	–	–	–	–
7. EF composite	.10	.08	−.01	−.03	.30**	.01	–	–	–	–	–
8. Metacognitive control score	.02	.28**	.29**	−.05	.002	.10	.12	–	–	–	–
9. Simon Says score	.09	.06	−.03	−.01	.28**	.02	.99**	.11	–	–	–
10. Backward word span score	.12	.16	.09	−.14	.23*	−.09	.41**	.10	.29**	–	–
11. Child age in months	.02	.29**	−.02	−.05	.33**	−.01	.23*	.28**	.34**	.32**	–

*$p < .05$.
**$p < .01$.

mance) were correlated with children's metacognitive control scores. Metacognitive control was significantly negatively correlated with PM prediction accuracy, $r(129) = -.30$, $p = .001$, such that children with higher metacognitive control scores had more accurate PM predictions (smaller difference between PM predictions and performance). Importantly, this correlation remained significant after controlling for children's age in months, $r(125) = -.24$, $p = .006$, suggesting that this relation was not simply due to age-related increases in both PM prediction accuracy and metacognitive control ability but rather represents a relation between the underlying cognitive constructs. There were no significant relations between metacognitive control and PM postdiction accuracy, episodic recall prediction accuracy, or episodic recall postdiction accuracy, $rs(130) < -.15$, $ps > .09$, but it is noteworthy that all these relations were in the expected negative direction.

Relations among executive function, PM performance, and metacognitive control

Finally, we examined relations among executive function, PM, and metacognitive control to test our hypothesis that metacognitive control would mediate the relation between executive function and PM performance. First, an executive function composite was created by combining *z* scores on the Simon Says and backward word span tasks because they were positively correlated, $r(96) = .29$, $p = .004$. Correlations among the executive function composite score (Simon Says and backward word span tasks), PM task (predictions, performance, and postdictions), episodic recall task (predictions, performance, and postdictions), and metacognitive control tasks were examined (Table 4). Children's PM performance was significantly positively correlated with overall PM postdictions and metacognitive control performance. Because neither children's PM performance nor metacognitive control performance was related to the executive function composite, the requirements for the mediation analysis (examining the mediating effect of metacognitive control on the relation between executive function and PM) were not met and thus the planned analysis was not conducted.

Discussion

The current study examined the (a) impact that task difficulty had on children's PM predictions, actual performance, and postdictions, (b) development of children's procedural metamemory (predictions and postdictions) for PM and RM task performance, and (c) relations among metamemory, metacognitive control, and executive function during early childhood. PM performance increased with age and was worse in a nonsalient cue condition compared with a salient cue condition. Only children's PM postdictions were affected by task difficulty; children accurately postdicted worse PM performance in the nonsalient condition compared with the salient condition. Older children had significantly more accurate PM predictions and postdictions than younger children, and children in the salient condition had superior PM prediction and postdiction accuracy compared with those in the nonsalient condition. Similarly, children's episodic recall prediction and postdiction accuracy also increased with age. Children had similar accuracy for their predictions and postdictions between the PM and episodic recall tasks. Children's postdictions significantly predicted PM performance, whereas predictions significantly predicted episodic recall performance. There was a positive relation between children's metacognitive control ability and PM prediction accuracy that existed even after controlling for children's age in months. Surprisingly, executive functioning was unrelated to both PM and metacognitive control, but children with better metacognitive control also had better PM.

Age and PM performance

The finding that 6-year-olds outperformed 4-year-olds on the PM task is consistent with past literature showing gradual increases in PM performance over the preschool years (e.g., Ford et al., 2012; Kliegel & Jäger, 2007; Mahy et al., 2014b). That PM performance did not differ between 4- and 5-year-olds or between 5- and 6-year-olds is consistent with past literature (Mahy, Mazachowsky, & Pagobo, 2018; Mahy & Moses, 2011) and suggests that PM changes fairly gradually over the preschool period such that age-related increases are more substantial across a period of 2 years (between 4- and 6-year-olds).

Effect of difficulty on PM predictions, performance, and postdictions

As predicted, nonsalient cues resulted in worse PM performance compared with salient cues, which was in line with past research demonstrating an impact of cue salience on young children's PM performance (e.g., Kretschmer-Trendowicz & Altgassen, 2016; Mahy et al., 2014a). Although the current study employed a fairly powerful manipulation of cue salience (i.e., highlighting the entire background of the PM cue card in yellow), even more subtle manipulations of cue salience or distinctiveness effectively increase children's PM such as placing a red border around PM cues (e.g., Kretschmer-Trendowicz & Altgassen, 2016; Mahy et al., 2014b), the PM cue being a specific exemplar (vs. a broader category, e.g., the cue being described as a banana vs. a picture of fruit; Cottini et al., 2018), and having a focal central PM cue (Kliegel et al., 2013).

To date, there has been very little work examining the impact of task difficulty on children's PM predictions and postdictions. Although children's PM predictions in the current study were optimistic regardless of difficulty condition, children's PM postdictions were significantly lower in the nonsalient condition compared with the salient condition. Thus, children were able to take into consideration the difficulty of a task only when reflecting on their past PM performance. It seems that firsthand experience in completing an easy or difficult PM task might be necessary to improve judgment accuracy in young children. This idea is supported by Redshaw et al.' (2018) study in which 6- to 13-year-olds had the opportunity to practice completing the PM task *before* they made performance predictions. This practice resulted in fairly accurate PM predictions for the easy trials of the task. Although Redshaw et al.'s study did not include postdictions, the fact that children practiced the task beforehand made their predictions more akin to the postdictions of our current study. Furthermore, the fact that children were more likely to use strategies to improve their performance when completing the task a second time also supports the idea that children reflected on their previous performance and modified their behavior accordingly. In sum, our finding that 4- to 6-year-olds' PM postdictions are sensitive to task difficulty extends the findings of Redshaw et al. (2018) to a younger age group. More broadly, our findings are in line with adult findings showing that PM postdictions are generally more accurate in absolute terms than predictions (see Kuhlmann, 2019, for a review) and consistent with the suggestion that individuals might correct their initial predictions based on task experience.

Using a manipulation of RM task difficulty, Kvavilashvili and Ford (2014) asked 5-year-old children whether they would remember a familiar name of a stuffed animal (i.e., Mr. Rainbow; easy) or an unfamiliar one (i.e., Mr. Tainbow; difficult) and also found that children's predictions were unaffected by the difficulty of the RM task. Supporting their finding and extending it to the domain of PM, our results also show that children are unable to consider information about task difficulty in predicting PM performance; however, they seem to incorporate their experience with PM task difficulty in their postdictions.

A limitation of our study was that the difficulty of the PM task was only described verbally, which was perhaps too subtle to have an effect on children's PM predictions. In contrast to Kvavilashvili and Ford (2014), who asked children whether they would remember a familiar or unfamiliar name, the current study explicitly pointed out the relative difficulty of the task (i.e., the PM cues were described to children as easy or hard to notice). Still, children's PM predictions were not affected by this emphasis on task difficulty, perhaps because it was mentioned only once without any visual examples. An interesting direction for future work would be to show children pictures of salient versus nonsalient PM cues before they make their prediction to see whether this would have a greater impact. Perhaps a within-participants manipulation of PM task difficulty also might increase children's sensitivity to task difficulty and would have a stronger impact on PM predictions. Another possibility is that children simply did not understand the relevance of the difficulty information that we provided for their later PM performance given the limited metamemory abilities of preschoolers (e.g., Schneider, 1998).

Age and task difficulty effects on memory prediction and postdiction accuracy

Supporting our hypothesis that older children would have more accurate memory predictions and postdictions than younger children, both children's prediction and postdiction accuracy improved with age for the PM and episodic recall tasks. In previous studies with 6- to 13-year-olds, PM prediction accuracy (Redshaw et al., 2018) and RM prediction and postdiction accuracy (Bertrand et al., 2016; Schneider, 1998) also increased with age. It is possible that the increased accuracy of children's memory predictions and postdictions was driven by children's memory performance getting better with age (and getting closer to their optimistic predictions and postdictions) rather than their predictions and postdictions lowering with age to better approximate their actual memory performance. However, it is difficult to know how children made their predictions and to assess whether predictions become more accurate with age or whether performance simply increases with age to catch up with optimistic predictions. Regardless of what drove children's optimistic predictions, these findings are interesting in light of the fact that healthy adults typically are underconfident in their PM predictions (Kuhlmann, 2009) and seem to rely on their experience to make more accurate postdictions. It seems that over the course of the lifespan, memory predictions change from overconfident during early childhood to underconfident during adulthood, suggesting that as we gain more experience with our (often poor) PM ability, our confidence in our PM ability decreases.

Children had more accurate predictions and postdictions when they performed an easy PM task with salient cues compared with a difficult PM task with nonsalient cues. Thus, it seems that young children underestimate the impact of task difficulty (in this case cues that were harder to recognize) on their PM performance. An interesting direction for future work would be to examine at what age children become able to incorporate information about task difficulty into their PM predictions in particular.

Accuracy of predictions and postdictions

In contrast to our hypothesis that predictions and postdictions would be more accurate for PM than for RM, there was no difference in the accuracy of predictions or postdictions between the PM and RM tasks. Thus, it seems that children are equally optimistic about their memory performance for each type of memory task in their predictions and postdictions. Our results do not support Kvavilashvili and Ford's (2014) suggestion that children might have a better sense of their PM performance (vs. their RM performance) due to frequent feedback that children receive on PM performance in their daily life. Instead, our findings suggest that children are equally unrealistic about their PM and RM abilities. It is possible that this difference in findings is due to differences in methodology. In Kvavilashvili and Ford's study children predicted whether they would remember to perform a PM or RM task, whereas in our current study children predicted how many times they would remember to perform the PM and how many items they would recall in the RM task, which is much more difficult and might also rely on metacognitive awareness of attention and motivation. Furthermore, our study also manipulated PM task difficulty via PM cue salience, whereas Kvavilashvili and Ford's study did not. Notably, Kvavilashvili and Ford's finding that PM prediction accuracy was better for children who listened to a memory story (vs. a nonmemory control story) suggests that children who are primed to think about memory abilities were also more accurate in their PM predictions. Our finding that metacognitive control was related to PM prediction accuracy is in line with the idea that metacognitive abilities play an important role in PM prediction abilities in particular.

When we examined whether predictions or postdictions better predicted PM performance, only children's postdictions significantly predicted children's PM performance. Although not in line with past work in our lab suggesting that children are unaware of their PM performance after they have performed a task (Mahy et al., 2018), this is consistent with Cottini et al.'s (2019) finding that 7- and 8-year-olds' PM postdictions (but not predictions) were significantly related to their actual PM performance. Importantly, Cottini et al. asked children to make a yes/no PM prediction for whether they would remember to fulfill their intention all 5 times or not, whereas in the current study children predicted how many times they would fulfill their PM intention (out of 4). Regardless of this difference in methodology and different age groups between our study and Cottini et al.'s study, the results tell a consistent story: Children's PM predictions are less accurate than their PM postdictions. Thus, the use of a yes/no judgment rather than a continuous scale might not have limited prediction and postdiction variability as much as we previously thought. Future work should explore why young children's PM prediction accuracy varies so much across studies and in particular should examine differences in PM prediction accuracy based on whether children make binary (i.e., yes or no) or continuous performance predictions and postdictions.

The finding that predictions (but not postdictions) accounted for more variance in children's episodic recall performance was surprising given that episodic recall predictions were less accurate than episodic recall postdictions overall. Thus, despite children being more accurate in their episodic recall postdictions, individual differences in episodic recall predictions better mapped onto actual episodic recall performance. It is possible that both episodic recall predictions and actual task performance were capturing age-related variance in a way that postdictions failed to capture. An alternate possibility is that children with better episodic memory were also better able to pull information from past memory performance when making their predictions (resulting in better episodic recall predictions), in line with the constructive episodic simulation hypothesis (Schacter & Addis, 2007) that suggests we draw on past experiences to construct future scenarios.

Relations among executive functioning, PM, and metacognition

Metacognitive control was related to PM prediction accuracy only. This is in line with past research showing that children's awareness of their memory ability is related to PM performance (Spiess et al., 2015, 2016). Interestingly, there was not a relation between metacognitive control and PM postdiction, RM prediction, or RM postdiction accuracy. There seems to be something about making an accurate prediction about carrying out a future intention that relies more on one's awareness of one's own knowledge. This is supported by McDonald-Miszczak, Gould, and Tychynski's (1999) finding that older adults' metamemory was significantly predictive of their performance on PM tasks but not on RM tasks. Thus, it appears that metacognitive control might be specifically relevant for PM, likely due to the importance of metacognitive knowledge, monitoring, and control for independently carrying out a future intention successfully (and in the absence of external reminders).

In line with our prediction, children's metacognitive control (measured as children's ability to evaluate their knowledge of common and rare animals) was positively related to PM performance, supporting the idea that these cognitive processes are interrelated (e.g., Roebers & Feurer, 2015; Souchay & Isingrini, 2004) and develop in similar trajectories during early childhood (e.g., Ford et al., 2012). Our findings are some of the few to document a relation between metacognitive control and PM during the preschool years, suggesting that this relation emerges early in development before metamemory or metacognitive abilities are well developed. Our findings extend previous work showing that 4-, 6-, and 9-year-olds' time monitoring predicted their PM performance and that their scores on a metacognitive knowledge task explained a significant amount of variance in their time monitoring ability (Geurten et al., 2016).

The finding that executive function was unrelated to both PM and metacognitive control in the current study was surprising given past literature showing strong relations between executive function and PM during early childhood (e.g., Ford et al., 2012; Geurten et al., 2016; Mahy & Moses, 2011; Mahy et al., 2014b). We believe that this lack of relation was driven by the data loss from many young children who failed to pass the practice trials of the Simon Says and backward word span tasks. With significant data loss (15 children from the Simon Says task and 30 children from the backward word span task), particularly from the youngest children, there was limited variability in executive function scores in the current sample. To test this explicitly, we reexamined the correlations between PM and executive function without removing children who failed the practice trials, and significant positive relations between PM and executive functions emerged, $rs(131) > .25$, $ps < .011$. Thus, we believe that removing the children with the lowest executive function ability from our sample likely led to a lack of correlation between PM and executive function. Nonetheless, due to the lack of relation between PM and executive function and between executive function and metacognitive control, it was not appropriate to test our mediation model examining the role of metacognitive control in the relation between executive function and PM. Future work should continue to examine the relations among PM, executive function, and metacognitive abilities in order to understand what cognitive abilities help young children to monitor and control their behavior and memory in a PM context. Furthermore, researchers should be aware that young children (especially 4-year-olds) seem to struggle with the basic demands of tasks like the backward word span and Simon Says that are commonly used with preschool-aged children (see Carlson, 2005).

The current study contributes to our theoretical understanding of the relations between metacognitive abilities and RM and PM during early development. First, it suggests that young children's metamemory is quite poor, especially for predictions, but that after children have experience with the task their postdictions are more aligned with their actual PM performance. This suggests that postdictions may indeed rely on a different process than predictions. Second, children's metacognitive control of their knowledge is related specifically to PM prediction accuracy, suggesting that children with superior insight into their own abilities are also more accurate in forecasting their PM performance. Finally, the current findings support both the PAM theory and multiprocess theory that suggest an important role for conscious awareness in PM tasks and demonstrate that early in development metacognitive abilities are related to PM performance and the accuracy of PM predictions specifically.

Conclusion

Although children are optimistic about their PM and RM performance, children's PM postdictions are generally more accurate than their predictions. Interestingly, young children seem to incorporate their actual PM performance into their reflection on their performance and realize that a difficult task results in lower PM performance than an easy task. Children are more accurate in their PM and RM predictions and postdictions as they age and when a PM task is easier. For RM, individual differences in predictions best predict actual RM performance, possibly due to the fact that children are relying on their episodic memory for past instances of memory performance when forming RM predictions in line with the constructive episodic simulation hypothesis. This study suggests that metamemory judgments are still undergoing development during the preschool years but also documents a significant relation between PM and metacognitive control quite early in development. Future research should continue to examine children's predictions and postdictions of both PM and RM because insight into one's memory abilities is critical in order for children to know when to use reminders or strategies to aid memory performance.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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