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Why do young children forget to carry out their intentions? Exploring retrospective memory and executive contributions to 3- and 4-year-olds' prospective memory failures

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A B S T R A C T

The current study examined two possible reasons why 3- and 4-year-olds forget to carry out prospective intentions. According to the Executive Framework of Prospective Memory (PM) Development (Mahy et al., 2014b), very young children struggle with encoding, storing, and retrieving the content of their intention. In contrast, older children can remember their intention, but still fail to carry it out, suggesting that their failures might be executive in nature (i.e., due to a failure in PM cue detection). One hundred and three 3- and 4-year-olds completed a PM task where they had to put a particular card in a box behind them. Children (n = 86) who forgot to fulfill their intention were asked follow-up questions to determine whether they forgot the content of their intention (retrospective memory failure) or failed to detect the PM cue (PM cue detection failure). Children also completed independent measures of episodic retrospective memory and selective and sustained attention. Results showed that: (1) 3-year-olds often forgot the content of their intention, (2) 4-year-olds mostly remembered the content of their intention but rarely reported detecting the PM cue, (3) episodic retrospective memory was related to children's ability to answer the retrospective memory question, and (4) selective and sustained attention was unrelated to children's ability to answer the PM cue detection question. Four possible interpretations for why 4-year-olds were so poor at detecting the PM cue and implications for future work are discussed.

Preschool children are forgetful. Whether it is forgetting to bring their hat and mittens home from daycare or forgetting to wash their hands after using the bathroom, children's forgetfulness has important consequences for many areas of functioning. The ability to remember to carry out a future intention is known as prospective memory (PM; Einstein & McDaniel, 1990), which undergoes significant development during the preschool period (e.g., Kliegel & Jäger, 2007; Mahy & Moses, 2011). PM is a crucial milestone in cognitive development that has implications for the development of children's independence and functioning in academic and social domains, as well as their safety and well-being (Mahy et al., 2014a). For this reason, understanding *why* young children often forget to carry out their intentions is a crucial step toward determining how it can be better supported during the preschool years. Thus, the goal of the current study was to investigate two potential reasons for why young children might forget to carry out their future intentions: (1) forgetting what the intention was (retrospective memory failure), and (2) failing to detect the PM cue when it appears.

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Young children's PM is often measured in laboratory settings (e.g., Kvavilashvili et al., 2001), using tasks that tend to fall into two broad categories: event-based tasks where children must carry out an intention after a certain event occurs (e.g., retrieving mittens from their cubby before leaving school) and time-based tasks where they must carry out an intention at a certain time or after a specific amount of time has passed (e.g., retrieving mittens from their cubby at 3:30 or in 30 min). To date, the examination of PM and its development in early childhood has mainly focused on event-based PM tasks due to young children's limited ability to tell time. In a typical event-based PM task (see Kvavilashvili et al., 2001), children are assigned a prospective intention that is embedded in an ongoing task (e.g., sorting cards but needing to remember to place a certain card in a box behind them). Once children are instructed on how to perform the ongoing task and the PM task (and their understanding of these tasks is confirmed), a short delay interval is introduced in order to promote forgetting. After this delay interval, children begin the ongoing task, typically without any reference to the PM task. PM cues are embedded within the ongoing task, and it has been suggested that these targets should comprise less than 10% of ongoing items (see Brandimonte et al., 2001). At the end of the task, children are often asked memory control questions, specifically about whether they can report what they were supposed to do. These questions are critical in that children who cannot report what they had to do are usually excluded from the analyses because their errors seem to stem from a retrospective memory failure rather than a PM failure (where they remember in general what they have to do but fail to carry out that intention at the appropriate time).

In the literature, two main abilities that support prospective remembering are widely recognized (e.g., Smith et al., 2010): (1) retrospective memory required to encode, store, and retrieve the content of the intention (i.e., remembering what you have to do), and (2) executive functioning required to interrupt the ongoing task, detect the cue, and carry out the prospective intention at the appropriate point in time. In fact, memory control questions at the end of the PM task are typically used to control for errors that are purely retrospective in nature by excluding children who cannot report the content of their intention from further analyses.

In laboratory studies of children's PM, there is evidence to suggest that the majority of 2-year-olds fail to complete the PM action due to failures of retrospective memory. For instance, Kliegel and Jäger (2007) found that 67% of 2-year-olds could not remember the content of their prospective intention, suggesting that retrospective memory failures drive forgetting to carry out intentions early in development. Similarly, Ślusarczyk et al., 2018 found that two-thirds of 24-month-olds could not recall the instructions for a naturalistic PM task, supporting the claim that young children's forgetting is largely attributable to their limited retrospective memory capacity. By 3 or 4 years of age, the majority of children can remember the content of their PM intention, but still often fail to carry it out successfully. In other words, even though young children can report what they had to do, they are unreliable in carrying out their future intentions. For example, several studies have documented that 4-year-olds only successfully carry out their intentions about 50% of the time (e.g., Mahy & Moses, 2011; Mahy et al., 2016) despite all of the included children being able to report the content of their intention. Thus, developmentally, there is a shift from failing PM tasks mainly due to difficulty remembering the content of the intention (around 2–3 years of age) to difficulty carrying out the intention at the appropriate moment despite intact memory for the intention (around 4 years of age). However, in contrast to the standard memory control questions where children's retrospective memory for the intention is confirmed, to our knowledge, no studies have explicitly confirmed whether children *detected* the PM cue (i.e., whether they can report having seen the cue). Detecting the PM cue is a critical step in carrying out a prospective intention, as if you can recall the intention but fail to detect the cue, the PM action will not be initiated and will remain unfulfilled.

Given that 4-year-olds are unreliable in their PM performance, despite their relatively intact retrospective memory for the intention, what abilities might be driving their poor PM? Executive function, cognitive abilities involved in the control of thought and action (Zelazo et al., 1997), is likely involved in successful PM performance as many aspects of typical PM tasks rely on these abilities (Mahy et al., 2014b; Mahy, 2022). For example, planning is necessary to form a PM intention, and working memory is needed to refresh that intention and bring it into the focus of one's attention at the appropriate time. Several other facets of executive function are also implicated in the detection of the PM cue. Specifically, being able to effectively deploy one's attentional resources (i.e., monitoring) is crucial for identifying when a PM cue appears in the environment, and inhibition is required to prevent treating it like an ongoing task item. Finally, shifting is necessary in order to shift from the ongoing task to carrying out the PM task once the cue has been detected.

The possibility of executive function playing a key role in children's PM is supported by evidence showing that these abilities are related throughout childhood. Indeed, research has found that school-age children's PM performance is associated with working memory, inhibition, and shifting, depending on the nature of the PM task (Cheie et al., 2021; Kerns, 2000; Zuber et al., 2019). More importantly, age-related differences in PM across this period seem to be accounted for by these executive functions (Cheie et al., 2021; Zuber et al., 2019), suggesting that executive functioning may contribute to improvements in PM over time. This is further supported by a study by Spiess et al. (2016) in which it was found that 8-year-olds' executive functioning (a composite score of their working memory, inhibition, and shifting) predicted their performance on an event-based PM task eight months later. Taken together, these findings indicate that executive functioning may underlie increases in PM performance in school-age children.

Similarly, executive function and PM have also been found to be related in younger children (i.e., preschool children). Notably, these abilities both undergo rapid improvement across the preschool years (Carlson, 2005; Mahy & Moses, 2011), and certain facets of executive function seem to be associated with preschool children's PM performance. Working memory and inhibition, in particular, have been shown to be related to PM in 4- to 6-year-olds (Ford et al., 2012; Mahy & Moses, 2011; Mahy et al., 2014a). More recently, a study by Fuke and Mahy (2022) using parent-report questionnaires replicated the finding that PM is associated with executive function (measured both behaviourally and via parental report) in preschoolers. Further, executive function was a significant predictor of PM even when age was controlled for. It should be noted that this work is cross-sectional, and research has yet to examine whether executive function predicts preschoolers' PM over time. However, the current literature indicates that executive function may be a potential driver of young children's PM development.

Additional support for the idea that executive function plays a role in PM comes from the literature on task interference costs. Many studies have documented task interference costs in which the presence of a PM cue reduces ongoing task performance (decreased accuracy or task slowing). While there have been several explanations for why this occurs, they all generally focus on the fact that task interference occurs because PM depends on finite cognitive resources and that additional attentional resources are necessary to monitor and detect the PM cue (e.g., Einstein et al., 2005; Guynn, 2021; Marsh et al., 2006; Smith et al., 2017). Several studies have also examined attentional monitoring costs of a PM task in children by comparing ongoing task performance when a PM cue is present versus when one is not present (e.g., Cottini et al., 2021; Kretschmer-Trendowicz & Altgassen, 2016; Leigh & Marcovitch, 2014). Overall, preschool children as young as 4 years old show task interference costs, indicating that they use available executive resources to actively monitor for the PM cue (leading to worse ongoing task performance). This research provides further evidence that executive function and attention support young children's PM performance.

In light of these findings, Mahy et al. (2014b) developed a framework attempting to describe the role of executive functioning (and retrospective memory) in the development of PM in early childhood. According to the Executive Framework of PM Development (Mahy et al., 2014b), once a sufficient level of retrospective memory has been developed, children's PM performance will be predicted mainly by their executive ability. The rationale is that around 4 years old, children develop a basic level of retrospective memory that enables them to encode, store, and retrieve the content of their intention, allowing them to remember what they have to do. Thus, by age 4, children's PM performance should be better predicted by their executive ability. Research showing that 2- and 3-year-olds struggle to remember the content of their intention, leading to PM failures (Kliegel & Jäger, 2007), supports this prediction. Indeed, only 33% of 2-year-olds could accurately report the PM intention at the end of the PM task, compared to 78% of 3-year-olds and 95% of 4-year-olds (Kliegel & Jäger, 2007).

However, once retrospective memory is sufficient to support memory for the content of the intention, children still often perform poorly on PM tasks. For instance, despite the majority of 4-year-olds being able to remember the intention, there is still great variance in their ability to carry it out at the appropriate time. One study by Mahy and Moses (2011) found that, on average, 4-year-olds who could correctly report what the PM intention was still failed to fulfill it approximately 50% of the time. Thus, it seems that another ability is contributing to young children's challenges with executing their intentions at the appropriate time.

The Executive Framework of PM Development predicts that executive functioning is a critical ability involved in children's PM, and it is this ability that drives PM development in childhood. Accordingly, one's ability to keep the intention active in their mind (working memory), inhibit the tendency to treat the PM cue as an ongoing task item (inhibition), switch back and forth between ongoing task items and PM cues (shifting), and pay attention to the environment to monitor for the PM cues (monitoring) seems crucial for successful PM performance. It may be that executive functions are particularly important for detecting the PM cue because it is embedded in a demanding ongoing task that requires inhibition and shifting in order to refrain from treating the cue like an ongoing task item and shift to execute the novel PM intention. Indeed, these proposals are in line with the predictions of the Multiprocess Framework (McDaniel & Einstein, 2000), which states that when demands are high (e.g., a difficult ongoing task, a non-focal PM cue, or low cue salience), PM relies on strategic monitoring; however, when demands are low, PM can be supported by spontaneous retrieval.

In line with the predictions of the Executive Framework of PM Development, it might be the case that 4-year-old children's poor PM performance can be accounted for by failures in executive ability (and more specifically, failing to detect the cue), whereas 3-year-old children's poor performance might be accounted for by failures in retrospective memory ability (i.e., failing to remember what they had to do). The current study attempted to test these predictions, as well as examine how children's responses to questions designed to capture retrospective memory and cue detection are related to independent measures of retrospective memory and selective and sustained attention. Importantly, no study has examined the extent to which young children's PM task performance is due to success (or failure) in detecting the PM cue (or at least reporting that they detected it).

Further, one important limitation of previous research is that the memory control question is typically asked at the very end of the PM task, which usually occurs well after the appearance of the PM targets (see Kvavilashvili et al., 2001). Thus, it is possible that children remember the content of the PM intention in the moment but then forget what they were supposed to do by the very end of the task. To address this potential limitation, we asked children the retrospective memory and PM cue detection questions almost immediately after the PM cue appeared. This approach allowed us to examine children's retrospective memory for the intention as well as whether they detected the cue as close to when the cue appeared as possible.

1. Current study

In the current study, children were given a difficult, non-focal PM task that involved detecting a single PM cue in a stack of cards. Almost immediately after the PM cue appeared, children were asked about their retrospective memory for the PM task and whether they saw the PM cue (in a counterbalanced order). Given the predictions of the Executive Framework of PM Development (Mahy et al., 2014b), we predicted that: (1) 3-year-olds would fail the PM task mainly due to failures in retrospective memory compared to 4-year-olds, (2) 4-year-olds would fail the PM task mainly due to failures in PM cue detection compared to 3-year-olds, (3) children's performance on the retrospective memory and selective and sustained attention tasks would both be positively related to age, (4) our independent measure of retrospective memory (Episodic Recall task) would be positively related to children's ability to answer the retrospective memory question, and (5) our measure of selective and sustained attention (Track-It task) would be positively related to children's ability to answer the PM cue detection question.

2. Method

2.1. Participants

One hundred and three 3- and 4-year-old children participated in this study. Data from seven children were excluded from the analysis due to: uncooperativeness ($n = 1$), English language comprehension difficulty ($n = 2$), choosing not to participate ($n = 1$), being distracted ($n = 2$), and being very shy ($n = 1$). The final sample consisted of 96 children (52 girls): 46 3-year-olds (26 girls; $M_{Age} =$ 41 months, $SD = 3.63$) and 50 4-year-olds (26 girls; $M_{Age} = 54$ months, $SD = 3.34$). This sample size was chosen a priori based on other studies on young children's PM that used a similar sample size (Mahy & Moses, 2011; Mahy et al., 2014, 2016). Participants represented a range of ethnic backgrounds (57% Caucasian, 11% Asian, 5% Asian Indian, 2% Middle Eastern, 1% African American, and 24% mixed ethnicity) and were primarily of middle-class backgrounds (66% had a family income over $75,000).

2.2. Procedure

Children were recruited to participate at the [blinded for review] Science Centre and daycares in the [blinded for review] region. Tasks were presented in the following fixed order: the Prospective Memory task, Prospective Memory Cue Identification task, Episodic Recall task, and Track-It task. The tasks took approximately 15 min to complete in total. All procedures were granted clearance by the Research Ethics Board at [blinded for review] University.

2.3. Measures

2.3.1. Prospective memory task

Children were introduced to "Joe the Zookeeper," who needed help organizing zoo animals into blue or yellow cages. They were told that it was their job to sort cards with pictures of animals on them into a blue or yellow box, based on the colour of a dot on the bottom of each card (the ongoing task). Children were also asked to name the colour of the dot on the card before sorting it into the appropriate box. Then, children were told that the elephant cage had been left open and that all the elephants had escaped, so if they saw an elephant (the PM cue) in the stack of cards, they should put it in the box that was approximately one metre behind them (the PM intention). To ensure children understood the task, they were asked to name and sort three cards into the boxes. All children sorted these cards correctly.

Next, children were asked to draw pictures during a 3-minute delay period. After the delay period, children began the ongoing task in which they named the colour of the dot (yellow or blue) on 19 cards and sorted them into the corresponding coloured box. The PM cue (the elephant) was always the 17th card in the stack and had a yellow dot on the bottom of it (Fig. 1). Once the PM task was completed, children were immediately asked the retrospective memory control question, "*What were you supposed to do when you saw an elephant*?" to determine if their retrospective memory for the content of the intention was intact. Children were also asked the PM cue detection question, "*Did you see an elephant*?" The order of these questions was counterbalanced across participants.

Children received a PM score out of one and an ongoing task score out of 18 based on whether they sorted the cards into the correct box according to the dot colour.

2.3.2. Prospective cue identification task

In order to control for the possibility that children failed the PM task because they did not know what an elephant was, children were shown 10 different cards with pictures of animals on them and were asked to identify them. At the start, children were told that they were going to be shown some pictures and were asked if they could name them for the experimenter. For each card, children were asked, "*What is this*?" The 4th image was the elephant that served as the PM cue in the PM task, and the 8th card was a picture of another elephant that they had not seen in the PM task. Children were given a score out of two based on whether they correctly labelled each elephant. All children correctly identified the image of an elephant that was presented as the PM cue, and 95% of children could identify both elephants as such.

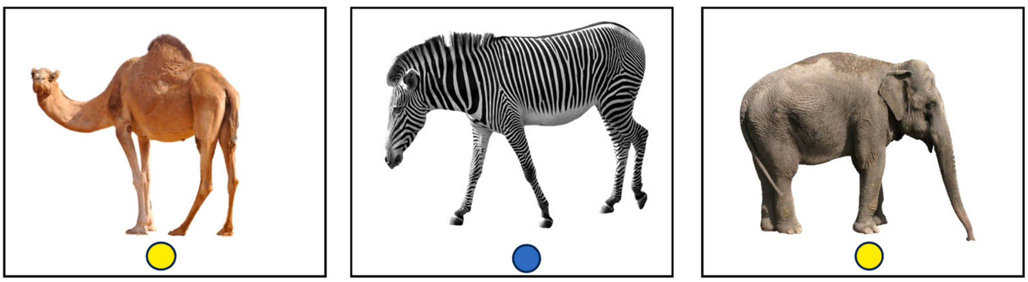

Fig. 1. Example ongoing task and prospective memory cards.

2.3.3. Episodic recall task (Naito, 2003)

In order to independently measure children's episodic retrospective memory, children were shown 12 drawings of objects (e.g., a tree, bus, castle, carrot) and asked to name each object as it was laid in front of them on a table. Children were then told to look at the pictures carefully because the pictures would be taken away, and they would be asked later what was on the cards. Children were given 20 s to look at the cards. Then, children were given a simple maze to complete for one minute as a brief delay period. Finally, children were asked to verbally recall as many objects as they could that they had been shown earlier. Children were given a score out of 12 based on how many objects they independently recalled. Two children did not complete this task due to disinterest (resulting in a final sample of $n = 84$).

2.3.4. Track-it task (Fisher et al., 2013)

In order to measure children's selective and sustained attention, they completed the Track-It task, which was available via open-source software (https://sites.google.com/andrew.cmu.edu/trackit/home) and presented to children on a 13-inch laptop. In this task, children were asked to help Pete the Pirate find his treasure by tracking a specific treasure shape and indicating where it disappeared on a gray three-by-three matrix (Fig. 2). Two other distractor shapes also moved around the matrix simultaneously in a random fashion. Each trial was 10,000 ms in length. At the start of each trial, children were shown the shape they would need to track, which was surrounded by a red circle. The experimenter pointed this shape out to the children to ensure they understood which shape they needed to track. After the shape vanished from the screen, children were asked to point to where it disappeared (monitoring accuracy). Then, children were presented with four shapes and asked to indicate which shape they were supposed to be tracking as a memory control question. Children first completed a practice trial where the experimenter followed the shape with their finger to help guide the child's attention and to ensure they understood the rules. The movement of the shapes was randomized, occurring at 30 frames per second, with the shapes moving at 800 pixels per second. Children completed four trials and were given an accuracy score out of four. They also received a memory control score out of four based on whether they selected the correct shape they should have been tracking for each trial. Only trials where children answered the memory control question correctly were included to calculate monitoring accuracy. Data from 19 children were excluded due to failure to complete the task due to disinterest ($n = 2$), technical difficulties ($n = 4$), and failure to identify the correct shape that they were tracking on any of the trials ($n = 13$), resulting in a final sample of 67 children for this task.

3. Results

3.1. Part I: whole sample analysis

As a first step, we compared the children who failed ($n = 86$) and passed ($n = 10$) the PM task regarding their performance on all tasks and questions using Pearson's chi-square analyses. Children who passed the PM task performed significantly better than children who failed the PM task on: the retrospective question ($M = .90$, $SD = .32$ vs. $M = .49$, $SD = .50$; χ^2 (1) = 6.10, $p = .014$), the PM cue detection question ($M = .90$, $SD = .32$ vs. $M = .37$, $SD = .49$; χ^2 (1) = 10.20, $p = .001$), and the Episodic Recall task ($M = 3.60$, $SD = 1.51$ vs. $M = 2.04$, $SD = 2.05$; t (92) = 2.33, $p = .02$, 95% CI [-2.90, −.23], $d = .78$). Notably, out of the 10 children who succeeded in the PM task, one child could not recall their intention (failed the retrospective question) and another child reported that they did not see the elephant. Children who passed and failed the PM task did not differ in their ongoing task performance or Track-It task performance, $ts < .38$, $ps > .70$, $ds > .12$. Thus, children who passed the PM task were better at answering the retrospective memory and PM cue detection questions and, additionally, performed better on the Episodic Recall task compared to children who failed the PM task.

Our first analysis focused on what predicted children's success vs. failure in the PM task. In order to do this, we used a binary

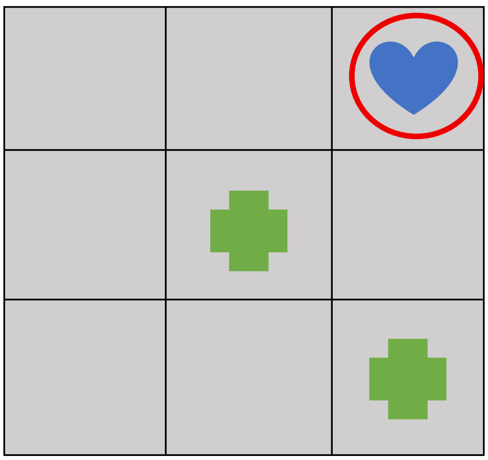

Fig. 2. Sample track it task 3 by 3 matrix.

logistic regression. Preliminary analyses revealed that sex and counterbalancing order had no effect on PM performance, so these factors were excluded from subsequent analyses. On the first step, age, PM cue detection accuracy, retrospective memory question accuracy, Episodic Recall, and Track It task accuracy were entered as predictors, and the outcome measure was PM task accuracy (failure vs. success). The analysis showed that only PM cue detection accuracy significantly predicted success on the PM task, $B = 5.01$, *Wald* χ^2 (1) = 10.83, $p < .001$. Thus, children who were able to answer "yes" to seeing an elephant were more likely to pass the PM task. No other predictors were statistically significant.

3.2. Part II: analysis of children who forgot to carry out the intention

Given our interest in why children forget to carry out their intentions, this second part of the analyses examined predictors of PM failure and so only includes the 86 children who failed to place the elephant card in the box behind them. Descriptive statistics for performance on the retrospective memory and PM cue detection questions by age are shown in Table 1.

We used a one-sample *t*-test (two-tailed) to examine whether children's performance on each of the questions differed from chance levels. Three year olds performed below chance on the retrospective memory question, t (44) = -2.35, $p = .02$, whereas 4-year-olds performed significantly above chance, t (40) = 2.11, $p = .04$. Three year olds were at chance on the PM cue detection question, t (44) = 1.05, $p = .30$, but 4-year-olds were significantly below chance, t (40) = -6.33, $p < .001$.

A Pearson's chi-square analysis showed that the percentage of children who correctly answered the retrospective memory question significantly differed between 3- and 4-year-olds (33% vs. 66%, respectively), χ^2 (1) = 9.08, $p = .003$. Similarly, a Pearson's chi-square analysis showed that the percentage of children who answered the PM cue detection question correctly significantly differed between 3- and 4-year-olds (58% v. 15%, respectively), χ^2 (1) = 17.09, $p < .001$.

3.3. Retrospective memory question

Preliminary analyses revealed that child sex and counterbalancing order had a significant effect on retrospective memory question responses; thus, these factors were included in subsequent analyses. In order to examine the effects of child age in years (3 or 4), sex, and counterbalancing order, these variables were entered into Step 1, and all interactions (all 2-way and one 3-way) were entered into Step 2 of a binary logistic regression predicting performance on the retrospective memory question. Since the two-way and three-way interactions were non-significant, we reported the findings from Step 1 only. In line with our prediction, more 4-year-olds were accurate in answering the retrospective memory question (M =.67, SD =.48) than 3-year-olds (M =.33, SD =.48), *Wald* χ^2 (1) = 10.02, $p = .002$, Exp (B) = 4.99. Girls were also more accurate in answering the retrospective memory question (M =.59, SD =.50) compared to boys (M =.37, SD =.49), *Wald* χ^2 (1) = 6.08, $p = .014$, Exp (B) = 3.56. Finally, children who received the retrospective memory question prior to the PM cue detection question (M =.60, SD =.50) were more accurate than children who answered the retrospective memory question after the PM cue detection question (M =.39, SD =.49), *Wald* χ^2 (1) = 5.47, $p = .019$, Exp (B) = .31.

When Episodic Recall and Track-It task scores were added as predictors of retrospective memory question performance in a binary logistic regression, child age in years, sex, and counterbalancing order remained significant predictors ($ps < .05$). In addition, Episodic Recall score predicted children's performance on the retrospective memory question, *Wald* χ^2 (1) = 3.73, $p = .05$, Exp (B) = 1.35. Children who performed better on the Episodic Recall task were more accurate in answering the retrospective memory question. Track-It task score was not a significant predictor of retrospective memory question performance ($p = .73$).

3.4. PM cue detection question

Preliminary analyses revealed that child sex and counterbalancing order had no effect on PM cue detection question responses, so these factors were excluded from subsequent analyses. Child age in years was entered into a binary logistic regression predicting performance on the PM cue detection question. Age in years had a significant effect on children's responses to the PM cue detection question. Three-year-olds were more accurate on the PM cue detection question (M =.58, SD =.50) than 4-year-olds (M =.15, SD =.36), *Wald* χ^2 (1) = 15.07, $p < .001$, Exp (B) = .13, although 3-year-olds' performance did not differ from chance, t (44) = 1.05, $p = .30$. Four-year-olds performed significantly worse than chance on the PM cue detection question, t (40) = -6.33, $p < .001$, stating that they had not seen an elephant the vast majority of the time. Importantly, poor PM cue detection could not be attributed to children's inability to identify the PM cue as an elephant, as all children were able to do so in the Prospective Cue Identification task immediately after the PM task was completed.

When Episodic Recall and Track-It task scores were added as predictors of PM cue detection question performance in a binary logistic regression, child age in years remained a significant predictor ($p = .003$). Neither Episodic Recall nor Track-It task score was a significant predictor of performance on the PM cue detection question ($ps > .31$).

Table 1
Descriptive statistics for question performance by age group.

	3-year-olds n = 45		4-year-olds n = 41	
	Correct	Incorrect	Correct	Incorrect
Retrospective Memory Question	15 (33%)	30 (67%)	27 (66%)	14 (34%)
PM cue detection Question	26 (58%)	19 (42%)	6 (15%)	35 (85%)

3.5. Relations among performance on questions

For children who forgot to carry out the PM intention, we examined Pearson's correlations (two-tailed) between their performance on our two questions. There was a strong negative relation between children's accuracy on the retrospective memory question and the PM cue detection question overall, r (84) = -.42, $p < .001$. Interestingly, however, the negative correlation represented two distinct patterns for 3-year-olds and 4-year-olds. For 3-year-olds, children had lower accuracy on the retrospective memory question (33%) and higher accuracy on the PM cue detection question (58%), r (43) = -.26, $p = .09$ (see Fig. 3). In contrast, 4-year-olds had higher accuracy on the retrospective memory question (68%) and very low accuracy on the PM cue detection question (15%), r (39) = -.43, $p = .005$.

3.6. Age effects in episodic recall and track-it task performance

As expected, there were age effects in both our independent measures of episodic retrospective memory and selective and sustained attention. Using an independent samples t-test (two-tailed), 4-year-olds ($M = 2.60$, $SD = 2.05$) outperformed 3-year-olds ($M = 1.52$, $SD = 1.93$) on the Episodic Recall task, t (82) = 2.48, $p = .02$. Similarly, using an independent samples t-test (two-tailed), 4-year-olds ($M = .60$, $SD = .36$) outperformed 3-year-olds ($M = .27$, $SD = .34$) on the Track-It task, t (65) = 3.86, $p < .001$. Using a Pearson's correlation (two-tailed), children's performance on the Episodic Recall and Track-It tasks was positively correlated, r (65) = .26, $p = .03$.

3.7. Correlations between question performance and independent measures

Finally, we examined Pearson's correlations between responses to the follow-up questions and performance on the independent measures of episodic retrospective memory and selective and sustained attention. As predicted, children's performance on the retrospective memory control question was positively correlated with Episodic Recall task performance, r (82) = .33, $p = .002$. However, PM cue detection question accuracy was unrelated to Track-It task performance, r (65) = -.19, $p = .12$.

4. Discussion

In line with predictions of the Executive Framework of PM Development and past research (e.g., Kliegel & Jäger, 2007), 4-year-olds were much better at recalling the PM intention than 3-year-olds. Notably, 4-year-olds were above chance in their accuracy in recalling their intention, whereas 3 year olds were below chance. Additionally, girls and children who received the retrospective memory question first were more accurate in recalling the content of the PM intention. In contrast, while 3-year-olds reported detecting the PM cue at chance levels, 4-year-olds performed very poorly (below chance) and rarely reported detecting the PM cue. All children successfully identified the target PM cue as an elephant in the Prospective Cue Identification task, which allowed us to rule out the possibility that children were not able to identify what an elephant was. Performance on the retrospective memory and PM cue detection questions was negatively related across 3- and 4-year-olds, but the pattern of results was distinct between the age groups. Three-year-olds did poorly on the retrospective memory question but did relatively well on the PM cue detection question, whereas 4-year-olds did well on the retrospective memory question but poorly on the PM cue detection question. As expected, 4-year-olds performed better than 3-year-olds on the independent measures of episodic retrospective memory and selective and sustained attention. Episodic Recall performance was positively related to children's responses to the retrospective memory question, but

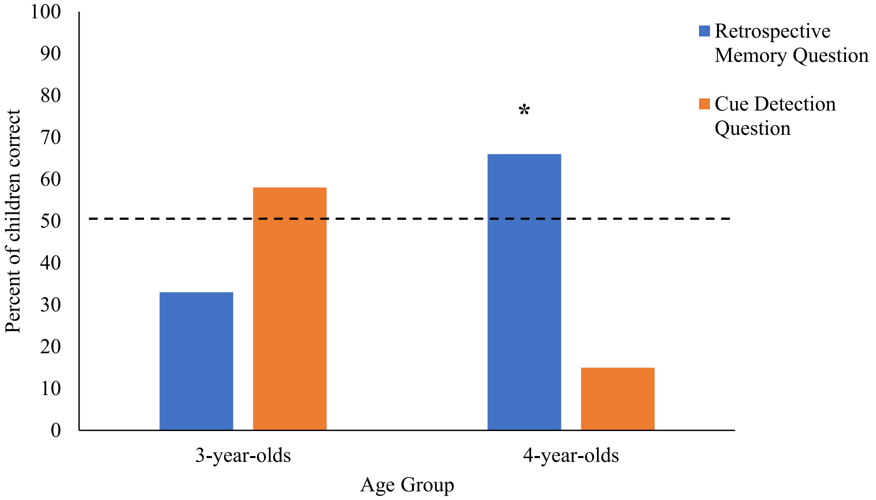

Fig. 3. Percentage of children correct on questions by age group. Note. The dotted line indicates chance-level performance. The asterisks indicates when performance was greater than chance.

Track-It task performance was unrelated to the PM cue detection question responses.

Our results indicate that 3-year-olds' difficulty in answering memory control questions at the end of PM tasks is not due to a time delay between the PM cue and the control question, but rather from being truly unable to remember what they were supposed to do. In fact, two-thirds of 3-year-olds in our study had difficulty recalling what the PM intention was. In contrast, two-thirds of 4-year-olds successfully recalled the PM intention. Thus, this suggests a shift in retrospective memory ability between 3 and 4 that results in better encoding, storage, and retention of the content of a PM intention. This finding supports previous research (e.g., Kliegel & Jäger, 2007; Ślusarczyk et al., 2018 suggesting that between 2 and 4 years of age, children make great improvements in their retrospective memory for PM intentions. Interestingly, girls were better than boys in verbally recalling their PM intention, perhaps due to superior language comprehension or production abilities (e.g., Kaiser et al., 2002). Further, the order in which children were asked the retrospective memory question affected their performance, as children who were asked this question first did better than children who were asked it after the PM cue detection question. This order effect could have been due to the PM cue detection question interfering with children's memory for the PM intention. Possibly, being asked about seeing an elephant (and most of them reporting they didn't see one) negatively affected children's recall of what they had to do in the PM task or confused them about the PM intention.

A novel contribution of the current study was the examination of whether children could report detecting the PM cue. Results showed that slightly over half of the 3-year-olds reported seeing the PM cue, which did not differ from chance. Perhaps given that the majority of these 3-year-olds could not even remember what they were supposed to do, they were guessing "yes" or "no" as to whether they had seen a PM cue. This explanation seems reasonable, as some 3-year-olds may have responded that they saw an elephant since they had just seen many animal cards (and it would make sense that an elephant was on one of these cards, even if they forgot why the elephant was relevant). If 3-year-olds were indeed guessing, this would result in the chance levels of performance that we observed.

In contrast to 3-year-olds, 4-year-olds' responses showed a very different pattern. The majority of 4-year-olds indicated that they did not see the PM cue (at below chance levels), even though most of them could remember their PM intention. There are several potential reasons for this pattern of performance.

One potential reason is that 4-year-olds simply didn't detect the cue when it appeared and answered accordingly (representing a genuine online monitoring failure). This interpretation provides support for the idea that executive function and attention might be driving PM performance when children develop sufficient retrospective memory (by 4 years of age). Perhaps the monitoring demands on this task were quite high, given that the PM cue (the elephant) was a non-focal cue and children were absorbed in an ongoing task that captured much of their attention (sorting the cards into boxes based on the coloured dot on the bottom of each card). Still, there are other abilities that might also limit 4-year-olds' ability to detect the PM cue. One candidate is children's metacognitive ability (children's understanding of their cognitive processes), which is still developing and might be critical for children to perform well on PM tasks. For example, if children realized that this is a difficult task and they must regularly monitor the animal on each card to look out for the elephant, they would likely do much better than a child who is less aware of appropriate strategies. Importantly, metacognitive abilities are still developing at age 3 and 4 so it is unlikely that children in our sample were aware of the difficulty of the task and what strategies to use to improve performance. Thus, perhaps executive function is not the sole bottleneck in children's PM performance, and factors such as metacognitive awareness also play an important role in PM development (e.g., Cottini et al., 2021; Schneider, 2008).

Alternatively, another possibility is that 4-year-olds may be retrospectively explaining their poor performance by reasoning that if they knew what to do but didn't do it, then they must not have seen a PM cue in the first place (retrospective rationalization). Essentially, 4-year-olds might have more awareness than 3-year-olds and think, "If I didn't put an elephant card in the box, there must not have been an elephant in the stack of cards." This represents an honest, albeit inaccurate, assessment of their PM performance.

A third distinct explanation is that 4-year-olds were aware that they forgot to fulfill the intention but claimed they had not seen the elephant cue in an attempt to "save face" (a deceptive response to realizing they had not fulfilled their intention). This would rely on fairly quick and sophisticated deception, but findings indicate that very young children often tell lies, especially to protect themselves or others (e.g., Evans et al., 2021; Evans & Lee, 2013). A possible way to test this in future work would be to ask children to indicate if they saw an elephant by showing them the PM cue card that was presented in the PM task at a later point in the study. If children indicated "yes" that they had seen the elephant in a seemingly independent task, this would lend support to suggest that children were altering their responses in the main PM task to save face.

A final possibility is that 4-year-olds' poor performance on the PM cue detection question reflects not a broad attentional weakness or simple executive limitation, but a difference in how information was prioritized during the ongoing task. In the adult literature, the "elephant in the room" phenomenon suggests that semantically notable information is not automatically prioritized when it is less relevant to the current task (Spotorno & Tatler, 2017). Here, children sorted cards by the colour of the dot, making animal identity relatively peripheral. Some 4-year-olds may therefore have remembered their intention but failed to prioritize the elephant cue at the appropriate moment in time. This interpretation is consistent with the finding that 4-year-olds outperformed 3-year-olds on the independent measure of selective attention, even though Track-It performance was unrelated to PM cue detection responses.

By any of these accounts, however, it appears that failures in PM cue detection seem to be driving the majority of PM failures in 4-year-olds (rather than being unable to recall the PM intention). It should be noted that 4-year-olds' poor performance on the PM cue detection question was not due to poor attentional skills more generally, as 4-year-olds performed better than 3-year-olds on our measure of selective and sustained attention (Track-It task). Still, it remains unclear whether the 4-year-olds in the current study were aware that they failed to carry out the PM task. One ability that likely plays a role in this is metacognitive monitoring; that is, children's awareness of and accuracy in assessing their own cognitive processes (Nelson & Narens, 1990). Recently, research has begun to examine the relation between metacognitive monitoring and PM in preschool children (Cottini et al., 2021; Lavis & Mahy, 2021). Children's ability to reflect on their PM performance is typically measured via their postdictions of how many PM cues they correctly responded to during the PM task. In a study by Lavis and Mahy (2021), 4- to 6-year-olds' postdictions were significantly associated with their actual performance on the PM task. If 4-year-olds do have an accurate sense of their PM performance but still deny that they saw the PM cue, this might indicate that they are being deceptive.

However, Lavis and Mahy (2021) also found that 4-year-olds' postdictions were less accurate and overly optimistic (i.e., they claimed that they correctly responded to more PM cues than they did in actuality) compared to 6-year-olds. These age findings support the idea that awareness of PM failures increases throughout the preschool years, and consequently, 4-year-olds are not as successful in recognizing them as 5- and 6-year-olds. Thus, in the current study, 4-year-olds may have been truly unaware that they had missed the elephant card and responded as such. This scenario is also plausible, given that children rarely indicated that they knew they had forgotten to execute the PM intention. It would be beneficial for future work to explicitly test these various possibilities to gain further insight into why 4-year-olds do not report detecting the PM cue. Further, future work should seek to replicate these findings, given that this study's power might have been limited in detecting small effect sizes.

In particular, future research could use eye-tracking or reaction-time data to disentangle whether the PM cue was detected in the moment (but just not acted upon) or not detected at all. For instance, children who show longer reaction times or fixation times when presented with the elephant card could be compared to those with shorter reaction or fixation times to deduce whether the children truly detected the PM cue or not. Additionally, the relation between children's reaction or fixation times and their responses on the PM cue detection question could also be examined.

Overall, our results lend support for some of the predictions of the Executive Framework of PM development. First, they provide evidence for the idea that most 3-year-olds do not have sufficient retrospective memory in order to maintain a PM intention for a sufficient amount of time. Second, they suggest that by 4 years old, children are not failing PM tasks due to poor retrospective memory but rather due to being unable to detect the PM cue, which we consider a failure of attentional monitoring (i.e., executive function). An open question that remains is at what age children are able to reliably detect a PM cue and report having seen it, even after failing a PM task. Past literature demonstrates that by the early school years, children's executive functioning and PM are much improved (e.g., Carlson, 2005; Cheie et al., 2021; Kerns, 2000; Zuber et al., 2019). If executive function does truly underlie children's PM abilities, this would suggest that as executive functioning increases over time, so should children's ability to detect and report seeing a cue.

In addition to the Executive Framework, the findings of the current study speak more broadly to other theories of PM, such as the Multiprocess Framework (McDaniel & Einstein, 2000). Our results show that under demanding circumstances with a non-focal PM cue, strategic monitoring is necessary to detect the PM cue, as children very rarely remembered to carry out their intention in our paradigm (which would be the expected pattern if their PM performance was supported by spontaneous retrieval). However, even spontaneous retrieval relies on processing and detecting the PM cue in the first place, which seems to have been a challenge for the young children in our sample.

Importantly, our findings also have practical implications for supporting children's PM in everyday life. First, they suggest that parents, caregivers, and practitioners working with young children continue to play an active role in promoting their PM successes. For instance, young children might need PM cues pointed out to them in their environment, especially when an ongoing task is particularly challenging or distracting. Indeed, 3-year-olds might even need reminders about what it is they were supposed to do in the first place, whereas 4-year-olds might just need the cue pointed out to act on their intention. In any case, it cannot be assumed that preschool-age children have the attentional capacity to detect a PM cue when it is not in the center of their attention; thus, scaffolding from adults remains crucial for children to demonstrate successful PM in the early childhood years (Mazachowsky et al., 2021).

A notable limitation of the current study was that we asked children directly whether they saw a PM cue in the form of a yes-or-no question. Thus, future work might seek to find more subtle ways to probe whether children detected the PM cue. For instance, showing children stimuli directly (including the PM cue) and having them make judgments whether they saw them before may be a more effective way to examine PM cue detection. In addition, even though our PM cue detection question was designed to assess children's detection of the PM cue, it still relied on their retrospective memory since children had to consider whether they saw the PM cue during the ongoing task (even though the PM cue was presented just a few seconds earlier). Finally, children's Track-It task performance was unrelated to their responses on the PM cue detection question, suggesting that monitoring processes required for PM cue detection might differ from processes needed to selectively sustain attention (despite our intention for the Track-It task to independently capture an ability similar to cue detection in the current study). For instance, the Track-It task involved children tracking a shape as it moved around a matrix, whereas the PM task required children to recognize an elephant that was presented amongst a number of animals while focusing on sorting the animals based on the coloured dot. Thus, this non-focal PM task would have required children to process the elephant by dividing their attention away from the ongoing sorting. Possibly, a divided attention task or even an N-back task might have correlated more strongly with PM cue detection than the Track-It task.

In conclusion, our findings suggest that 3- and 4-year-olds fail PM tasks for different reasons. Younger children tend to struggle with remembering what they have to do, whereas older children seem to fail to carry out their intention due to their inability to detect the PM cue when it appears. Although these results support the predictions of the Executive Framework of PM Development (Mahy et al., 2014b), the question of when children become aware that they saw a PM cue but failed to act on it remains unanswered. Considering that metacognitive monitoring increases across the preschool years, future work may benefit from examining this question in older preschoolers (i.e., 5- and 6-year-olds). Ultimately, given the prevalence of young children's forgetfulness in daily life, understanding the factors that drive and contribute to PM failures is an important endeavour that we hope will gain more attention in future research.

CRediT authorship contribution statement

Conversano Maria C: Writing – review & editing, Methodology. **Lydia Lavis:** Writing – review & editing, Methodology,

Investigation. **Yesim Yavaslar Dogru:** Writing – review & editing, Formal analysis. **Maguire Madeline K:** Writing – review & editing, Writing – original draft. **Mahy Caitlin Emma Victoria:** Writing – review & editing, Writing – original draft, Supervision, Project administration, Methodology, Funding acquisition, Formal analysis, Conceptualization.

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Data availability

Data will be made available on request.

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