Cognition 269 (2026) 106405

Contents lists available at ScienceDirect

Cognition

journal homepage: www.elsevier.com/locate/cognit

# Constructive episodic simulation, self-projection, and scene construction: Investigating the mechanisms of children's episodic thinking

Ege Kamber [a,*], Michael A. Busseri [b], Caitlin E.V. Mahy [b]

[a] Department of Psychology, York University, Toronto, Canada
[b] Department of Psychology, Brock University, St. Catharines, Canada

ARTICLE INFO

*Keywords:*
Middle childhood
Cognitive development
Episodic future thinking
Episodic memory
Constructive episodic simulation
Self-projection
Scene construction

ABSTRACT

Constructive episodic simulation, self-projection, and scene construction are three prominent cognitive mechanisms posited to underpin episodic thinking. This study investigated whether these mechanisms explain individual differences in children's episodic thinking and relations to other related abilities during middle childhood (i.e., imagination, perspective-taking, and spatial navigation). A sample of 150 Canadian children aged 8 to 10 years completed the Autobiographical Interview, in which they described future, past, current, and make-believe events, and several other behavioural tasks measuring their perspective-taking, spatial navigation, narrative ability, and receptive vocabulary. Structural equation modelling revealed significant covariance among episodic thinking for future, past, and current events, imagination, and spatial navigation, but not perspective-taking. When children's verbosity was controlled, these relations were weakened in magnitude and spatial navigation was no longer significantly related to episodic thinking processes. These results support constructive episodic simulation and scene construction accounts, as well as a more general underlying episodic simulation ability, as mechanisms for episodic thinking in middle childhood.

People spend a significant amount of time imagining past events and future possibilities. For example, people think about future events 59 times per day on average, which corresponds to one future-oriented thought every 16 min or so (D'Argembeau et al., 2011). Contemplating future possibilities and remembering past events can benefit individuals, as imagining future events promotes farsighted decisions in adults (e.g., reduced smoking, Rösch et al., 2022) and children (proactive behaviours, Schreiber et al., 2024; saving, Zhang et al., 2024; but see Burns et al., 2021). Remembering positive autobiographical memories also decreases delay discounting (Lempert et al., 2017; but see Duff et al., 2025) and social anxiety (Moscovitch et al., 2024). Several mechanisms have been proposed to explain how people imagine personal events occurring in the past or future (Addis & Tanguay, 2022). However, developmental research has rarely examined these mechanisms in children (Nyhout & Mahy, 2023). The present study addresses this research gap and investigates three prominent accounts of episodic thinking in middle childhood.

## 1. Episodic thinking in childhood

Episodic thinking allows people to mentally time travel and remember personal past events (episodic memory) and pre-experience future alternatives (episodic future thinking; hereafter EFT, Tulving, 1985). EFT is often considered a future counterpart of episodic memory, as both involve mentally simulating the 'what, where, and when' details about specific personal future or past events (Addis, 2020). These abilities also share a similar development across childhood. Children begin to engage in conversations with their parents about past and future events during their toddler years (Fivush & Fromhoff, 1988; Hudson, 2002), and their competency in episodic memory and EFT further rapidly develops during the preschool years (Atance & Sommerville, 2014; Hayne et al., 2011). For example, when preschool children were asked to report something that they had done yesterday and that they were going to do tomorrow, only one-third of 3-year-olds but around two-thirds of 4- and 5-year-olds provided accurate answers for past and future events (Busby & Suddendorf, 2005).

In middle childhood, however, age-related improvements in episodic thinking are inconsistent across studies (e.g., Coughlin et al., 2014, 2019; Gott & Lah, 2013). In one common paradigm, the Autobiographical Interview (Addis et al., 2008), children are asked to narrate personally relevant future and past events. Children's narratives are then transcribed and coded. In the coding process, each piece of

* Corresponding author at: Department of Psychology, York University, 4700 Keele St, North York, ON M3J 1P3, Canada.
*E-mail address:* ekamber@yorku.ca (E. Kamber).

https://doi.org/10.1016/j.cognition.2025.106405
Received 24 April 2025; Received in revised form 8 December 2025; Accepted 10 December 2025
0010-0277/© 2025 The Authors. Published by Elsevier B.V. This is an open access article under the CC BY-NC license (http://creativecommons.org/licenses/by-nc/4.0/).

information that is mentioned in children's narratives (e.g., time, place, perception, or emotion) is categorized as an internal (related to the main event narrated) or external detail (off-topic or not related to the main event, see Addis et al., 2008). Some researchers also score children's narratives in terms of overall episodicity, with higher scores indicating more detailed event descriptions with contextual details (e.g., thoughts and emotions, Coughlin et al., 2014). Using these coding methods, 5- to 11-year-olds were found to report less episodic content for future event narratives than past event narratives (Coughlin et al., 2014, 2019), suggesting that the development of EFT might be protracted compared to episodic memory (Nyhout & Mahy, 2023). Across age-groups, 9-year-olds' event narratives were more episodic than those of 5-year-olds, but there was no difference between 5- and 7-year-olds and between 7- and 9-year-olds (Coughlin et al., 2014). Similarly, 14- to 16-year-olds produced more internal details in their past and future events than 8- to 10-year-olds, but no age differences were reported between 14- and 16-year-olds and between 8- and 10-year-olds (Gott & Lah, 2013). Taken together, episodic memory and EFT show non-linear age-related development throughout childhood, with rapid improvement during the preschool years and slower age-related development during the school years.

There are several possible explanations for the non-linear development of episodic thinking. For example, neurocognitive mechanisms of episodic thinking (e.g., Schacter & Addis, 2007) might explain the overall age-related improvement during childhood, as neural structures that are responsible for episodic thinking continue to develop throughout childhood (e.g., the default mode network, Sato et al., 2014; Sherman et al., 2014). The rapid development of executive function and language in early childhood could explain the age-related improvements in episodic thinking during preschool years (Kamber et al., 2023; Suddendorf & Corballis, 2007; Ünal & Hohenberger, 2017; but see Hanson et al., 2014).

Developmental research has predominantly focused on two episodic thinking processes: EFT and episodic memory (Nyhout & Mahy, 2023), with a recent growing interest in episodic counterfactual thinking (contemplating negated versions of past events; Gautam et al., 2019). However, people engage in various types of episodic thought in their everyday lives. One is thinking about current possibilities. In addition to past and future events, individuals often contemplate possible present events that might occur right now, such as imagining doing homework or playing video games. These episodic thoughts for current events can be self-generated and goal-directed, similar to episodic thoughts for past and future events (e.g., Andrews-Hanna et al., 2014; Christoff et al., 2016). In contrast, episodic thinking for past and future events might allow individuals to retrieve past experiences to inform future decisions (e.g., Szpunar et al., 2014), while episodic thinking for current events might serve to inform current decisions. Episodic thinking for current events is also different from episodic counterfactual thinking in terms of temporal orientation. Episodic counterfactual thoughts are directed to past events and about what could have happened in the past yet did not occur (Gautam et al., 2019). Developmental research has rarely examined children's episodic thinking for current events in relation to other episodic thinking processes, so the current study also aims to measure episodic current thinking and examine its cognitive underpinning during childhood.

## 2. Cognitive underpinnings of episodic thinking

The adult literature contains rich theoretical discussions on how people engage in episodic thinking (Addis, 2020). Some of these accounts focus on episodic memory and suggest that it plays a critical role in EFT (e.g., *constructive episodic simulation,* Schacter & Addis, 2007; Tulving, 1985). For example, Tulving (1985) argued that the core feature of episodic memory is *autonoetic consciousness* (an aspect of self-awareness), which enables people to recollect a past episode and pre-experience a future episode. Other accounts argue for a separate neurocognitive mechanism that underpins not only episodic memory and EFT but also other cognitive skills, such as spatial navigation and perspective-taking (Buckner & Carroll, 2007) or spatial navigation and imagination (Hassabis & Maguire, 2007). The current study focuses on three such prominent accounts: constructive episodic simulation (Schacter & Addis, 2007), self-projection (Buckner & Carroll, 2007), and scene construction (Hassabis & Maguire, 2007).

### 2.1. Constructive episodic simulation

Episodic memory is a constructive process that allows people to (a) re-experience personal memories and (b) pre-experience personal future events (Schacter & Addis, 2007). Episodic memory uses past details from our memory as building blocks to recreate past events for episodic remembering. Similarly, episodic memory flexibly recombines past details to create novel future scenarios for episodic pre-experiencing.

In support of this approach, neuroimaging studies show that episodic memory and EFT recruit similar neural regions called the default mode network (Addis & Schacter, 2012). Episodic memory and EFT also exhibit similar developmental trajectories with aging: Older adults produce fewer episodic details for past and future events than younger adults (Addis, 2020; Addis et al., 2008). Childhood research also shows a positive relation between episodic memory and EFT (e.g., Coughlin et al., 2019; Hayne et al., 2011; but see Cuevas et al., 2015 and Immel et al., 2022). In 5- to 11-year-olds, the level of detail for past events is positively related to the level of detail for future events (Coughlin et al., 2014, 2019). Importantly, these findings did not establish a causal link between episodic memory and EFT but showed a correlation between them across lifespan.

### 2.2. Self-projection

Future and past event simulations require projecting the self into the future or the past. Thus, self-projection, *the ability to detach from the present and shift one's perspective across different temporal (*e.g.*, past or future), mental (*e.g.*, self or others), and spatial contexts (*e.g.*, here or elsewhere;* Buckner & Carroll, 2007*),* might underpin episodic memory, EFT, and also other projection abilities, such as perspective-taking, and spatial navigation (Buckner & Carroll, 2007). Adult neuroimaging studies show similar brain activation patterns when adults engage in episodic memory, EFT, perspective-taking, and spatial navigation (Spreng et al., 2008 for a meta-analysis).

Developmentally, perspective-taking (Perner et al., 2007; Schidelko et al., 2025) and spatial navigation (Pullano & Foti, 2022) show parallel age-related improvements to episodic thinking during the preschool years. However, when age and language were controlled, perspective-taking was not significantly related to preschool children's EFT (Hanson et al., 2014). Moreover, recently Immel et al. (2022) examined the assumptions of self-projection in 4-year-old children who completed a battery of tasks for EFT, episodic memory, perspective-taking, and spatial navigation. Weak relations were observed between the tasks within each battery, suggesting that the tasks might have poor reliability or validity. Also, the batteries were not significantly related, providing no evidence for self-projection during preschool years. In middle childhood, however, perspective-taking and EFT show a positive relation, even after accounting for age, IQ, and executive function (Adornetti et al., 2021). Additionally, children and adolescents with autism spectrum disorder simulate past and future events with limited details and struggle to take another person's perspective relative to their typically developing peers, suggesting that children with autism spectrum disorder might have poor self-projection skills (Ciaramelli et al., 2018; Terrett et al., 2013, but see Lind et al., 2014). Overall, self-projection skills might start to relate to each other during middle childhood. Notably, except for Immel et al. (2022), none of these developmental studies examined the interrelations between all self-projection skills.

### 2.3. Scene construction

Hassabis and colleagues (Hassabis et al., 2007; Hassabis & Maguire, 2007) noted that imagination ability, defined as *the skill of visualizing new experiences that do not involve a subjective sense of time and are not necessarily self-relevant or possible* (e.g., "standing in the main hall of a museum containing many exhibits"; Hassabis et al., 2007. p. 1727), shares similar brain activation in the hippocampal region with episodic thinking. Thus, they introduced the concept of scene construction, *the ability to construct and maintain complex scenes* that underpin abilities requiring a spatiotemporal context: episodic memory, EFT, spatial navigation, and imagination (Hassabis & Maguire, 2007).

Scene construction and self-projection might appear to be similar accounts because both predict interrelations between episodic memory, EFT, and spatial navigation. Yet, these accounts have different assumptions. The self-projection account centers the "self" at the core of its approach, positing that projecting the self across different temporal, mental, and spatial contexts is the shared cognitive mechanism among episodic memory, EFT, perspective-taking, and spatial navigation (Buckner & Carroll, 2007). However, Hassabis and colleagues (Hassabis et al., 2007; Hassabis & Maguire, 2007) argued that projecting the self across different temporal contexts might be uniquely critical for episodic thinking only, but it does not explain the commonalities between episodic thinking and other abilities, such as spatial navigation, and imagination. According to their approach, what these other abilities share in common is the mental process of scene construction. Further, Hassabis and Maguire (2007) noted that perspective-taking does not necessitate scene construction unless the perspective-taking task involves an imagination of a scene.

In line with this account, as hippocampal neural activity decreases with aging (argued to support scene construction), older adults (65 years and older) perform worse than younger adults on scene construction skills (i.e., episodic memory, EFT, spatial navigation, and imagination; Rendell et al., 2012; Romero & Moscovitch, 2012). Also, patients with hippocampal damage show worse performance on episodic memory, EFT, spatial navigation, and imagination than healthy adults (Maguire et al., 2010), suggesting that hippocampal function might be critical for scene construction.

In children, little is known about scene construction. In one study of 8- to 13-year-olds, spatial navigation and episodic memory loaded on the same latent cognitive processes after accounting for age and IQ (Nguyen et al., 2025). However, this study did not include assessments of other scene construction skills, such as EFT and imagination. Despite comprehensive predictions of scene construction about episodic thinking, developmental work has yet to examine such skills together in a single study to understand whether scene construction supports episodic thinking in children.

## 3. Current study

The current study investigated the predictions of three prominent cognitive accounts of episodic thinking in 8- to 10-year-olds: constructive episodic simulation, self-projection, and scene construction (Table 1). Most developmental works have so far tested some, but not all, of the key predictions of these mechanisms in children (e.g., Adornetti et al., 2021). Thus, we aimed to comprehensively examine all predictions of each account to allow for the assessment of developmental continuity in the mechanisms underlying episodic thinking.

We examined these mechanisms in 8- to 10-year-olds because much of the existing literature on the Autobiographical Interview (Addis et al., 2008) focuses on middle childhood, when children's verbal and cognitive abilities allow them to describe their narratives verbally (e.g., Gott & Lah, 2013). This age range is, we believe, the earliest at which children can provide a coherent narrative about their episodic experiences.

Also, there is a lack of theoretical discussion and experimental work on how these cognitive mechanisms explain other types of episodic thinking processes (in addition to episodic memory and EFT, see De Brigard et al., 2013; Schacter et al., 2015), including with respect to current events. In this study, we measured children's episodic thinking for current events. Similar to episodic memory and EFT, we expected episodic thinking for current events to require a projection of the self, scene construction, and the use of past memory details. Thus, each of the cognitive mechanisms should underpin episodic thinking for current events (Table 1).

**Table 1**
Relations among Cognitive Abilities According to Three Prominent Accounts.

| | Constructive Episodic Simulation (Schacter & Addis, 2007) | Self-Projection ( Buckner & Carroll, 2007) | Scene Construction (Hassabis & Maguire, 2007) |
|---|---|---|---|
| Episodic Memory | + | + | + |
| Episodic Future Thinking | + | + | + |
| Spatial Navigation | not discussed | + | + |
| Perspective-Taking | not discussed | + | should not be related*** |
| Imagination | not discussed | should not be related** | + |
| Episodic Thinking for Current Events | not discussed* | not discussed* | not discussed* |

*Note.* + indicates that the cognitive mechanism underpins the ability. – indicates that the cognitive mechanism does not underpin the ability.

* Episodic Thinking for Current Events has not been discussed/examined in the literature. However, it is expected to be underpinned by each account, similar to episodic future thinking and episodic memory.

** Imagining fictitious scenes should not require self-projection because these scenes do not require a projection of self across different temporal situations (Hassabis & Maguire, 2007).

*** Although perspective-taking is not classified under scene construction, Hassabis and Maguire (2007) stated that under some circumstance, perspective-taking may require scene construction, especially when the perspective-taking task requires individuals to create scenes to account for others' mental states.

Finally, the current study aimed to simultaneously test these cognitive mechanisms in the same structural model to compare which of account better explains children's episodic thinking. So far, developmental research has mostly examined the relation between episodic memory and EFT (see Nyhout & Mahy, 2023 for a review), which is common to all three cognitive accounts (Table 1), or tested a single cognitive mechanism. For example, Immel et al. (2022) examined only the predictions of self-projection using structural equation modelling in 4-year-olds. However, this single account approach limited the ability to assess which mechanisms best explain the development of episodic thinking. Therefore, the current study adopted Immel et al.'s approach but tested the assumptions of three cognitive accounts with an expanded structural equation model. Examining alternative mechanisms together is critical to evaluating which mechanisms may play a stronger role during childhood.

## 4. Method

### 4.1. Participants

A sample of at least 130 children was indicated in a power analysis based on our pre-registered analysis with a medium effect size (power = 0.80, $d = 0.30$, alpha level = 0.05, Muthén & Muthén, 2002; Westland, 2010). Thus, we planned to collect data from 150 children (see Immel et al., 2022 for a similar research design with a similar sample size). One hundred and sixty 8- to 10-year-old children participated in the study. Ten children were excluded from the study for the following reasons: the

child was not typically developing ($n = 4$); the child did not want to participate ($n = 3$); or parents interfered with the protocol ($n = 3$). The final sample size comprised 150 children (78 males, 64 females, one other, and seven unreported; $M_{age} = 113.66$ months, $SD_{age} = 11.17$ months): 54 were 8-year-olds, 47 were 9-year-olds, and 49 were 10-year-olds. Children were mostly White (54 %) and from middle- to high-socioeconomic backgrounds (54 % of families earned more than 75,000 CAD annually, and 82.4 % of parents had at least a bachelor's degree, see Table S1 for demographics).

### 4.2. Measures

#### 4.2.1. The Autobiographical Interview (adapted from Addis et al., 2008)

The interview measured children's episodic thinking by examining their narratives for personal future, past, current, and make-believe events. During the interview, children were asked to narrate four personal events in a random order that happened or would happen at a specific place and time: a future event (e.g., "*an upcoming birthday party*"), a past event (e.g., "*a recent visit to their grandparents*"), a current event (e.g., "*preparing for a family trip*"), and a make-believe event (e.g., "*a make-believe trip to Tokyo*"). For each event, children were first asked to generate a personal event (e.g., "*Think of a real event that may happen to you in the next few months.*"). Then, they were asked to narrate the event in detail. One generic and four specific prompts (e.g., "*Do you imagine what you see, hear, smell, taste, or touch?*") were asked in a set order to enrich children's narratives (see Table S2 for all instructions).

Children's initial narratives and responses to prompts were transcribed. Then, the initial narrative and responses to prompts were combined for each child and scored as a single event. A standardized scoring manual (Levine et al., 2002) was used to score children's narratives by three raters (intra-class correlations >0.84): First, each narrative was divided into the smallest informational segments. Then, these segments were coded into different detail categories: Event (e.g., "*I had breakfast.*"), place (e.g., "*Grandma's cottage*"), time (e.g., "*last week*"), perceptual (e.g., "*I touched the dog's fur.*"), emotion/thought (e.g., "*I think he did not like it.*"), semantic (e.g., "*Her puppy's name is Willow.*"), repetitions, and other (e.g., metacognitive statements such as "*I do not remember it well.*"). These details were also coded as either internal or external. Internal details directly pertained to the main event, and external details did not pertain to the main event (e.g., off-topic details or extended event details). Event, place, time, perceptual, and emotion/thought details could be internal or external. However, semantic, repetitions, and other details were classified as external. Finally, the raters provided an episodicity rating for each event narrative, which assessed the overall richness of the event on a scale of 0 to 6. Higher scores indicated narratives that were richer in detail and evoked an impression of true re-experiencing. For each of the four events (past, current, future, make-believe), each child received three scores: internal details, external details, and episodicity rating.

#### 4.2.2. Silent film (Devine & Hughes, 2016)

The task measured children's perspective-taking. Children watched five short clips from a classic silent film. Each clip depicted a humorous scene that could be explained by an agent's false belief. Children watched each clip once and were asked to verbally explain the character's intention (six questions in total). Children's answers were scored (0 to 2) by two raters ($\kappa = 0.86$): A score of 2 was awarded if children accurately explained the character's mental state (e.g., "*He thought the cat was the woman's scarf.*"). A score of 1 was awarded if children showed a partial understanding (e.g., "*The cat looked like the scarf.*"). A score of 0 was given if children showed no mentalization (e.g., "*The lady dropped her cat.*"). Also, a code of 99 was assigned when children's responses were missing, uninterpretable, or insufficient. These missing responses were excluded from the calculation of the overall score. Children's scores were summed and averaged, with higher scores indicating better perspective-taking skills.


**Fig. 1.** Navigation Board Game Task.
The stick figure indicated the spot children started their route planning.

#### 4.2.3. Navigation board Game (adapted from Rusconi et al., 2015).

This computerized board game measured children's spatial navigation. First, children were introduced to a pretend neighbourhood on a computer screen. The neighbourhood had six streets and eleven landmarks such as a pet shop, bank, and pharmacy (Fig. 1). The experimenter introduced each landmark and its street. Then, children were told they would need to plan their route to visit certain places, so it was very important for them to know the neighbourhood well. Children were given 30 s to study the layout of the neighbourhood. Further, children completed two exercises to help them memorize the neighbourhood: (a) landmark replacement trials and (b) landmark recognition trials. In the landmark replacement trials, children were shown a partially missing neighbourhood and needed to place missing landmarks (e.g., the school) in the correct locations. In the landmark recognition trials, children were shown several landmarks: Some of them were taken from the neighbourhood, but others were new landmarks children had never seen before. Children needed to distinguish which landmarks were from the neighbourhood and which were new.

After these practice trials, the experimenter administered the spatial navigation questions. Children were told that they would plan their route to visit four different landmarks: the bank, the bookstore, the toy shop, and the park. While children were planning their routes, their starting point was always the same (Fig. 1). But the landmarks were removed so children could only see the street names. So, children needed to remember the location of the landmarks and verbally provide the correct directions to visit the landmarks. Each route required a three-step plan: (a) walk down or up to Pie Street (i.e., the starting point), (b) turn left on any one of the horizontal streets, and (c) indicate the exact location of the landmark. At each step, children received a score of 1 for the correct direction or a score of 0 for the wrong direction. Each route plan had a maximum score of 3. Children's route plans were scored by two raters ($\kappa = 0.89$). Children's scores were summed and averaged, with higher scores indicating better spatial navigation skills.

#### 4.2.4. Narration task (adapted from Crosson & Geers, 2001).

The task assessed children's narrative ability. Children were shown a cartoon with six panels that told a story about a child whose balloon was popped by a bully. Children were asked to create a story based on what the pictures showed. Children's responses were coded by two raters ($r = 0.93$) based on Gardner-Neblett and Iruka's (2015) six-point scoring scale ranging from 0 (no response) to 5 (articulate, detailed sentences, vivid vocabulary, and complex constructions). Lower scores reflected a short, disconnected storyline with limited details. Higher scores indicated an articulate, recognizable storyline with rich details.

#### 4.2.5. National Institutes of Health Toolbox Picture Vocabulary (Gershon et al., 2013)

Children's receptive vocabulary was measured using the National Institutes of Health (NIH) Toolbox. In the task, children saw four pictures on the screen and heard a word read aloud. Children chose which picture matched the word read aloud by indicating the number next to the picture. Children's raw scale scores were used as a measure of their receptive vocabulary.

### 4.3. Procedure

Children participated in the study online via Microsoft Teams between July 2022 and July 2024. The tasks were completed on Qualtrics except for the NIH Toolbox Picture Vocabulary, which was administered using the NIH toolbox application on an iPad. Parents provided their written consent and completed a brief demographic form before the session. At the beginning of each session, parental and child verbal assent was obtained, and the experimenter administered the tasks in the following fixed order: the Autobiographical Interview, the Silent Film, the Navigation Board Game, the Narration task, and the NIH Toolbox Picture Vocabulary task. At the end, parents were asked to confirm the accuracy of children's reported events. The children received a $20 Amazon gift card and a Junior Scientist certificate, which were emailed to their parents. Each session took approximately one hour to complete. All procedures were granted clearance by the Research Ethics Board at Brock University.

### 4.4. Transparency and openness

The design and analyses were pre-registered (https://aspredicted.org/7fvv-33s2.pdf). Deviations from the pre-registered analyses are noted below. We performed the analyses in AMOS 29.0 (Arbuckle, 2023) and R using the *ggplot2* package (Wickham, 2016). In analyses with multiple comparisons (e.g., Pearson's correlations), Benjamini and Hochberg's (1995) false discovery rate (FDR) correction was used to adjust *p*-values. Data, code, protocol, and materials are available at osf.io/tqvmd.

### 4.5. Analysis plan

#### 4.5.1. Preliminary analysis

The frequency of missing data was examined, and Pearson's correlations were estimated between the amount of missing data per child and study variables to assess potential bias in the missing data. We did not impute missing data in our analysis. Rather, in the main analyses we used Full Information Maximum Likelihood (FIML) to estimate the SEMs based on all available data. Children's age, narrative ability, receptive vocabulary, sex, socio-economic status, and event order in the Autobiographical Interview were examined in relation to children's performance on the behavioural tasks using Pearson's correlations, independent samples *t*-tests, and analysis of variance tests. Variables found to be related to children's performance were included in the main analysis.

#### 4.5.2. Main analysis

We first tested whether children's episodic thinking, imagination, perspective-taking, and spatial navigation were interrelated, consistent with the cognitive mechanisms (Table 1). Pearson's correlations among these skills were estimated (Fig. 2). Second, we aimed to simultaneously test the cognitive mechanisms (i.e., constructive episodic simulation, self-projection, and scene construction) to examine (a) whether children's skills loaded onto the same cognitive mechanisms and (b) which of the cognitive mechanisms better explained children's episodic thinking. Measurement and structural models were estimated to test these goals.

We first ran a measurement model to examine whether Autobiographical Interview variables (i.e., total internal details, total external details, and episodicity ratings) loaded onto a latent factor for each event condition (i.e., future, past, current, and make-believe events; Fig. 4). Then, we examined our pre-registered structural model for the cognitive mechanisms involving latent factors for all four of these tasks along with spatial navigation and perspective-taking (Fig. 3 and Fig. S1 for our pre-registered model). However, our pre-registered model showed poor fit. Thus, we deviated from our pre-registration plan and created a new structural model (Figs. S2, S3, and Fig. 5) comprising one underlying latent factor indicated by the internal details for the past, current, future, and imagination tasks, along with spatial navigation and perspective-taking.

## 5. Results

### 5.1. Preliminary analysis

In the Autobiographical Interview, four future, two past, seven current, and eight make-believe events were missing because children did not want to narrate ($n = 7$); parents interrupted children's narration ($n = 3$); children narrated the event, but parents indicated the event was not accurate or possible ($n = 9$); and the recording was not audible ($n = 2$). One Silent Film, one Navigation Board Game, one Narration task, and three NIH toolbox receptive vocabulary scores were also missing due to technical problems. The amount of missing data per child was significantly correlated with their age ($r[148] = -0.17$, $p = .042$). Children's sex, socio-economic status, and event order in the Autobiographical Interview were not significantly related to children's performance. Children's age, narrative ability, and receptive vocabulary were related to their performance in the behavioural tasks (see Supplemental Information file for detailed reporting). Descriptive statistics are presented in Table 2.

### 5.2. Main analysis

#### 5.2.1. Cognitive mechanisms underlying episodic thinking

Across events (i.e., past, future, current, and make-believe events), positive relations were observed among internal details, among external details, and among episodicity ratings (Fig. 2). Also, children's spatial navigation was positively related to internal details for future, past, current, and make-believe events, external details for current events, and episodicity ratings of all events. These positive, statistically significant correlations between episodic thinking, imagination, and spatial navigation were in line with the predictions of the constructive episodic simulation, self-projection, and scene construction accounts. However, perspective-taking was only significantly related to episodicity ratings of past, future, and current events but not internal and external details. These non-significant correlations involving perspective-taking were contrary to the predictions of the self-projection account (Table 1).

#### 5.2.2. Structural equation modelling based on the pre-registration

A pre-registered Structural Equation Modelling (SEM) was planned to examine self-projection, scene construction, and constructive episodic simulation mechanisms. We planned to estimate separate first-order

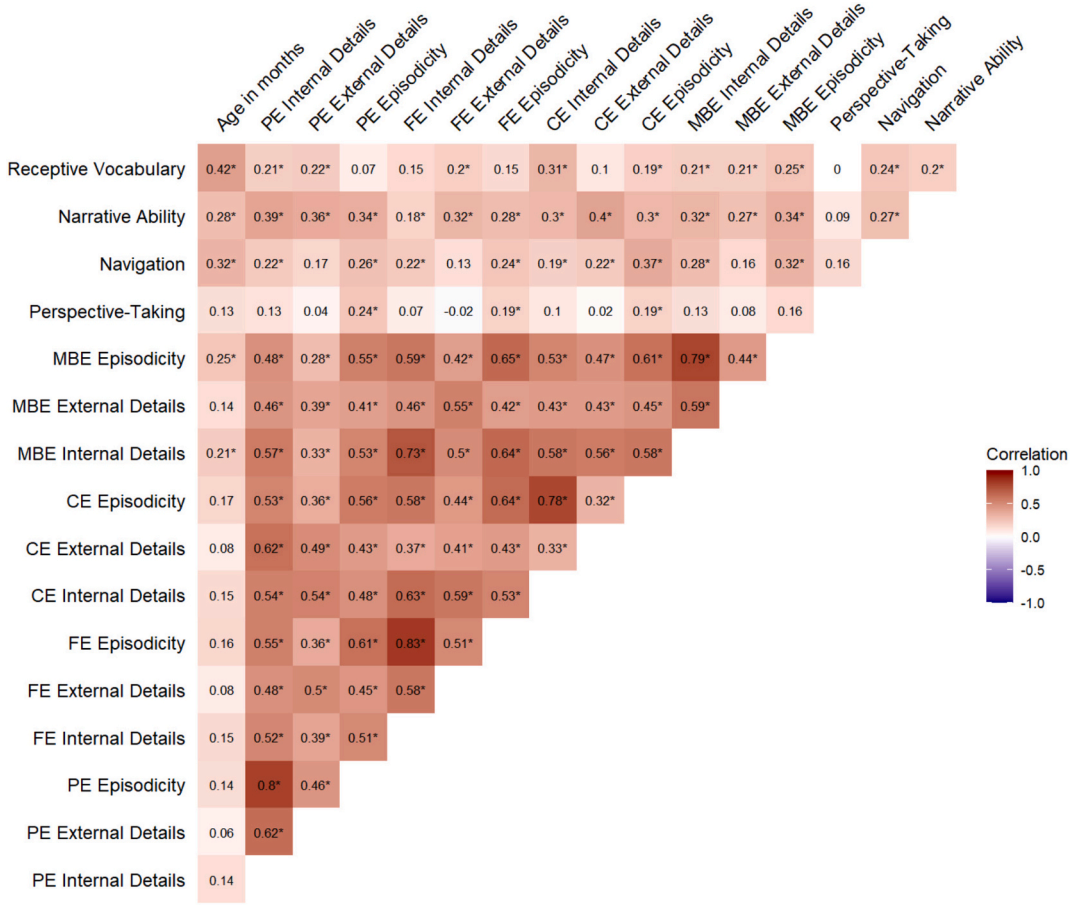


**Fig. 2.** Heatmap Correlation Matrix for Children's Performance in the Measures.
Note. FE: Future Event; PE: Past Event; CE: Current Event; MBE: Make-Believe Event; *$p_{adj} < 0.05$.

latent factors for each event: future, past, current, and make-believe events (Fig. 3). Internal details, external details, and episodicity ratings for each event were treated as indicators of the corresponding latent factor. The full model would then estimate three (correlated) second-order latent factors, each representing one of the three underlying cognitive processes: The self-projection second-order latent factor would be indicated by loadings from the first-order latent factors for future, past, and current event narratives, perspective-taking, and spatial navigation abilities. The scene construction second-order latent factor would be indicated by loadings from the first-order latent factors from future, past, current, and make-believe event narratives, and spatial navigation. The constructive episodic simulation second-order latent factor would be indicated by loadings from the first-order latent factors future, past, and current event narratives. Finally, other predictors (i.e., children's age, narration ability, and receptive vocabulary) would be added to the model to predict each second-order latent factor (Fig. 3).

Before testing the full model, we tested a measurement model for each of the first-order latent factors (i.e., future, past, current, and make-believe events). Children's internal and external details and the raters' episodicity ratings were specified as indicators of each first-order latent factor. The latent factors were then simultaneously correlated with each other. All factor loadings were freely estimated and the variance of each latent factor was fixed to 1 for model identification (Fig. 4). This measurement model showed poor fit, $\chi^2(49) = 283.434$, $p < .001$, Bentler's comparative fit index (CFI) = 0.815, root mean square error of approximation (RMSEA) and its 90 % confidence interval = 0.179 [0.159, 0.200], $p < .001$. The standardized loadings of internal details and episodicity ratings on each latent factor were large and positive. The standardized loadings of external details were the weakest, although they were also statistically significant. Notably, several of the latent factor correlations were very large (Fig. 4), suggesting that episodic thinking for these four events might not be distinct.

Given that the internal details had the largest factor loadings in each latent factor (Fig. 4), we removed the first-order latent factors for each type of event and instead used the internal details score as the sole indicator of past, future, current, and make-believe events; correlated latent factors were estimated for constructive episodic simulation, scene construction, and self-projection (Fig. S1).[1] All loadings were freely estimated, and the latent factor variances were fixed to 1 for model identification purposes. This modified model showed poor fit, $\chi^2(4) = 37.016$, $p < .001$, CFI = 0.870, RMSEA =0.235 [0.170, 0.307], $p < .001$. Further, contrary to our expectations, there was a negative standardized factor loading for future event internal details on the latent scene construction factor ($\lambda = -0.20$), and a standardized factor loading greater than 1 ($\lambda = 2.24$) for perspective-taking on the latent self-projection factor. The rest of the standardized loadings were weak ($\lambda$s = 0.05 to 0.26, see Fig. S1).

To address these issues, we replaced the latent factors for constructive episodic simulation, scene construction, and self-projection with one latent factor indicated by the internal details score for each of the

[1] We re-estimated the measurement model using only participants with complete data ($N = 135$) to examine modification indices and residual covariances. There were a few positive residual correlations between event indicators (mostly between episodicity and external details), such as the residual correlation between future event external details and make-believe external details (modification indices = 14.84). We did not modify the model based on these suggestions. Instead, we focused on internal details.

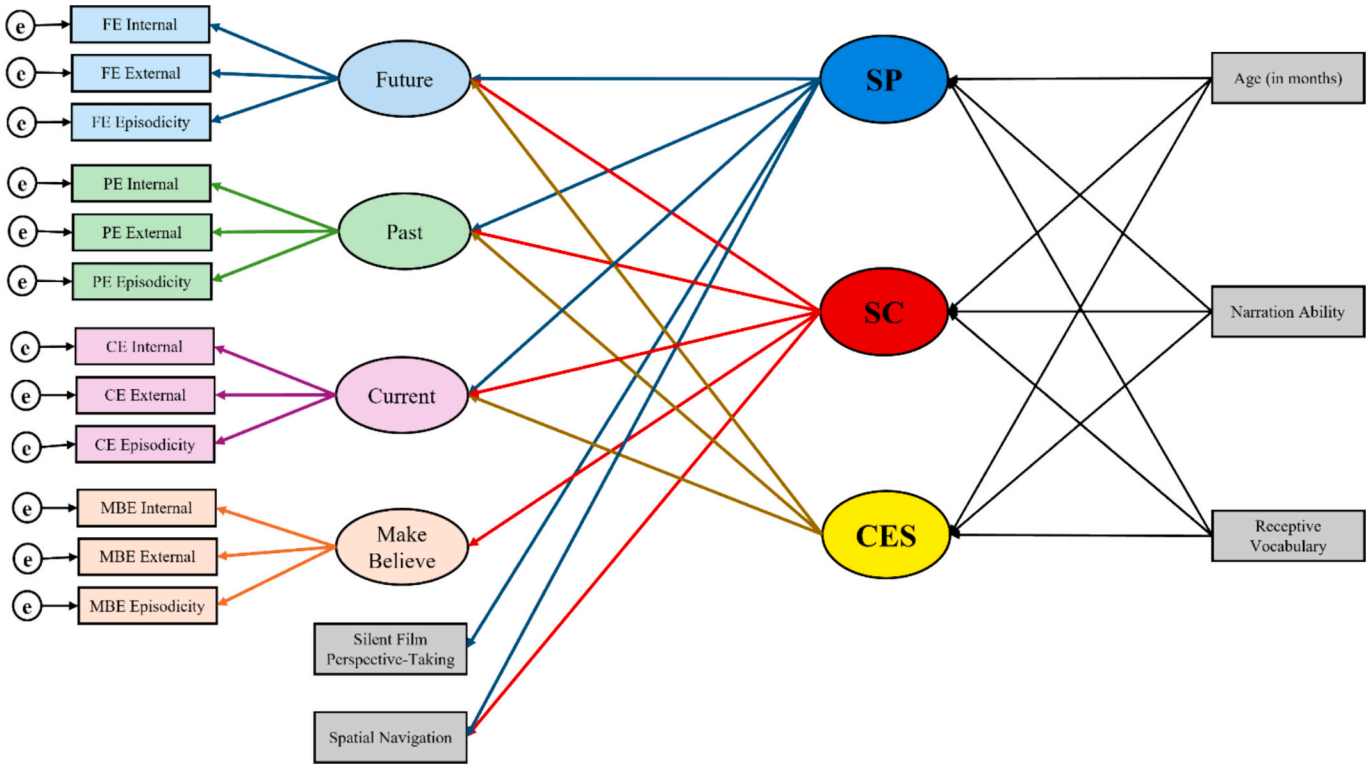


**Fig. 3.** *Pre-Registered Model. Note.* FE: Future Event; PE: Past Event; CE: Current Event; MBE: Make-Believe. SP: Self-Projection. SC: Scene Construction. CES: Constructive Episodic Simulation.
The correlations between second-order latent factors and between age, narration ability, and receptive vocabulary would also be estimated in this model.

four event types (Fig. S2). All loadings were freely estimated and the variance of the latent factor was fixed to 1 for model identification. This model showed excellent fit, $\chi^2(2) = 5.50$, $p = .064$, CFI = 0.986, (RMSEA) =0.108 [0.000, 0.221], $p = .134$. Standardized loadings were positive and large ($\lambda s = 0.66–0.85$, $ps < 0.001$), suggesting that internal details for each event were strongly associated with the underlying latent factor. Perspective-taking and spatial navigation were then specified as loading on the same latent factor (Fig. S3). The model again showed excellent fit, $\chi^2(9) = 10.324$, $p = .325$, CFI = 0.995, RMSEA =0.031 [0.000, 0.101], $p = .592$. The standardized factor loadings of internal details for future, past, current, and make-believe events and spatial navigation were positive and statistically significant ($\lambda s = 0.30–0.84$, $ps < 0.001$). However, the loading for perspective-taking was not statistically significant ($\lambda = 0.13$, $p = .158$).

Then, children's age, narrative ability, and receptive vocabulary were included in the model as correlated predictors of the single latent factor (Fig. 5). This model showed good fit, $\chi^2(24) = 48.281$, $p = .002$, CFI = 0.927, RMSEA =0.082 [0.048, 0.116], $p = .059$. The standardized factor loadings of internal details for future, past, current, and make-believe events ($\lambda s$ =0.68–0.85, $ps < 0.001$) and spatial navigation ($\lambda = 0.32$, $p < .001$) were positive and statistically significant. The standardized factor loading of perspective-taking was not statistically significant ($\lambda = 0.13$, $p = .141$). These findings fully support the constructive episodic simulation account and partially support the scene construction and self-projection accounts, as episodic thinking, imagination (i.e., make-believe events) and spatial navigation shared significant variance with the underlying latent factor. However, the factor loading of perspective-taking was not statistically significant, contrary to the self-projection account (Table 1).

### 5.2.3. *Additional model testing*

The analyses reported above used the internal details counts as indicators of children's performance in all four event conditions. However, this approach does not account for individual differences in verbosity (i.e., total number of words spoken), which may be relevant to understanding the associations observed among task scores based on children's verbal reports during the Autobiographical Interview (Lockrow et al., 2024; Spreng et al., 2018). To explore this issue, we re-estimated the structural model using an alternative approach recommended during the peer review process in which we controlled for verbosity. More specifically, we calculated the total number of words spoken by each child in the narratives for future, current, past, and make-believe events (see Supplemental Information file for descriptive statistics). These total word count variables were included in the model as predictors of the internal details for the corresponding event. The total word count variables were also specified as loading on a latent 'verbosity' factor (loadings for which were freely estimated, and the latent factor variance was fixed to 1). This latent verbosity factor was specified as a predictor perspective-taking and spatial navigation to control for the potential role of verbosity in these scores, and was correlated with child's age, receptive vocabulary, and narration ability (Fig. S4).

The model showed good fit, $\chi^2(53) = 109.054$, $p < .001$, CFI = 0.953, RMSEA =0.084 [0.062, 0.107], $p = .008$. The standardized factor loadings of internal details for future, past, current, and make-believe

**Table 2**
Descriptive Statistics of the Variables.

| | 8-Year-Olds | 9-Year-Olds | 10-Year-Olds | Total |
|---|---|---|---|---|
| | *M (SD)* | *M (SD)* | *M (SD)* | *M (SD)* |
| Age (in months) | 101.28 (3.72) | 114.24 (3.16) | 126.76 (3.84) | 113.66 (11.17) |
| PE Internal Details (range 5–70) | 17.60 (9.22) | 17.39 (9.60) | 21.00 (14.34) | 18.66 (11.32) |
| FE Internal Details (range 3–67) | 14.74 (9.37) | 14.66 (9.47) | 17.63 (13.03) | 15.69 (10.78) |
| CE Internal Details (range 0–58) | 12.50 (8.58) | 11.54 (5.21) | 15.30 (10.45) | 13.11 (8.48) |
| MBE Internal Details (range 2–76) | 13.37 (7.28) | 13.22 (7.69) | 17.90 (13.85) | 14.85 (10.26) |
| PE External Details (range 0–42) | 4.75 (6.39) | 3.85 (4.97) | 6.47 (6.02) | 5.04 (5.91) |
| FE External Details (range 0–26) | 3.68 (3.34) | 2.94 (2.92) | 4.47 (5.02) | 3.71 (3.90) |
| CE External Details (range 0–40) | 3.40 (3.96) | 2.85 (2.82) | 4.85 (6.89) | 3.70 (4.90) |
| MBE External Details (range 0–39) | 3.59 (3.28) | 3.76 (3.63) | 5.69 (7.84) | 4.35 (5.40) |
| PE Episodicity Ratings (range 1–6) | 3.04 (1.48) | 2.89 (1.23) | 3.45 (1.34) | 3.13 (1.37) |
| FE Episodicity Ratings (range 1–6) | 2.48 (1.11) | 2.40 (1.26) | 2.82 (1.40) | 2.57 (1.26) |
| CE Episodicity Ratings (range 0–6) | 2.28 (1.09) | 2.13 (0.98) | 2.64 (1.22) | 2.35 (1.12) |
| MBE Episodicity Ratings (range 0–6) | 2.20 (0.94) | 2.24 (0.98) | 2.75 (1.30) | 2.40 (1.11) |
| SF Perspective-Taking Score (range 0–2) | 0.77 (0.50) | 0.76 (0.40) | 0.92 (0.42) | 0.82 (0.45) |
| Spatial Navigation Score (range 0–3) | 1.68 (0.67) | 1.91 (0.55) | 2.15 (0.51) | 1.91 (0.61) |
| Narrative Ability Score (range 1–5) | 3.09 (1.04) | 2.98 (1.07) | 3.86 (0.94) | 3.31 (1.08) |
| Receptive Vocabulary Score (range 64–122) | 80.38 (8.27) | 84.83 (7.39) | 88.9 (9.57) | 84.59 (9.11) |

Note. FE: Future Event; PE: Past Event; CE: Current Event; MBE: Make-Believe Event; SF: Silent Film.

events were positive and statistically significant ($\lambda$s = 0.12–0.46, $p$s < 0.05). The standardized factor loading of perspective-taking was not statistically significant ($\lambda = 0.01$, $p = .939$). In addition, the standardized factor loading of spatial navigation was not statistically significant ($\lambda = -0.001$, $p = .983$). Also, child's age, receptive vocabulary, and narration ability were not significantly related to the underlying latent factor.

Overall, controlling for verbosity reduced the magnitudes of the factor loadings compared to the model based on the internal detail scores without controlling for verbosity (Fig. 5). Nevertheless, even after controlling for verbosity, internal details for future, current, past, and imaginary events each loaded positively on the latent factor, suggesting some underlying commonality among the episodic thinking and imagination tasks independent of verbosity.

## 6. Discussion

The present study demonstrated that children's episodic thinking for future, current, past, and make-believe events, as well as spatial navigation, were interrelated, providing evidence for the constructive episodic simulation (Schacter & Addis, 2007), scene construction (Hassabis & Maguire, 2007), and self-projection accounts (Buckner & Carroll, 2007). Further, internal details for the various episodic thinking tasks, including imagination (i.e., make-believe events), had positive and significant loadings on a single underlying latent factor, as did spatial navigation (but note that this latter loading was not significant after controlling for verbosity). Although perspective-taking was positively correlated with episodicity ratings for past, future, and current events, it did not have a significant loading on the latent factor, which is inconsistent with the self-projection account (Buckner & Carroll, 2007). As we discuss below, findings from the present study provide valuable new insights concerning episodic thinking, including with respect to prominent accounts of the underlying cognitive mechanisms.

### 6.1. Cognitive mechanisms underlying episodic thinking

The present study tested constructive episodic simulation, self-projection, and scene construction accounts using correlations and structural models. There were positive correlations between episodic thinking for past, future, current, and make-believe events, spatial navigation, and perspective-taking (Fig. 2). Further, although the pre-registered structural model showed a poor fit, our modified model comprising a single latent factor indicated by internal details for the episodic thinking tasks, showed excellent fit and revealed significant positive loadings from episodic thinking processes and spatial navigation, but not from perspective-taking.

These findings support the constructive episodic simulation account (Schacter & Addis, 2007, Table 1). That is, there were strong positive relations between episodic memory and EFT in the study, aligning with past research with children (Nyhout & Mahy, 2023) and adults (Addis & Schacter, 2012; Table 1 and Fig. 4). Constructive episodic simulation might be underlying the association between re-experiencing past events and pre-experiencing future happenings during middle childhood. This account, however, pertains only to episodic memory and EFT, rather than the various other forms of episodic thinking and related abilities, including thinking about current events, imagination, perspective-taking, and spatial navigation.

With respect to this broader array of cognitive abilities, our results also partially supported the scene construction account (Hassabis & Maguire, 2007). That is, children's spatial navigation and imagination were related to their episodic thinking for future, past, and current events. Also, the factor loading for spatial navigation on the single underlying latent factor was positive and statistically significant; however, this loading was moderate in magnitude, indicating that spatial navigation did not share substantial variance with the other episodic thinking abilities. Additionally, when we controlled for verbosity, spatial navigation was no longer significantly related to the underlying latent factor, which implies that the association between episodic thinking and spatial navigation might be driven by the amount that children say. That is, children who produce higher number of words in their narratives were likely to report more internal details in the Autobiographical Interview and get higher scores in the Navigation Board Game. Thus, spatial navigation might not rely on the same mechanism as episodic thinking processes in middle childhood, or at least not to the same degree.

Additionally, the scene construction account proposed that imagination (the ability to visualize imaginary events that are not temporal and self-relevant) requires scene construction like EFT and episodic memory (Hassabis et al., 2007). In our study, the make-believe event condition was aimed to measure children's imagination ability. We found significant covariance between children's performance in the future, past, and make-believe event narratives (Fig. 4). However, the make-believe events might not have fully captured the definition of imagination with respect to its proposed atemporality (Hassabis & Maguire, 2007). Indeed, although almost all children produced events that were subsequently confirmed to be imaginary by parents, post hoc coding of children's make-believe narratives showed that many of their events were temporal (44.8 % happened in the future; 22.8 % happened

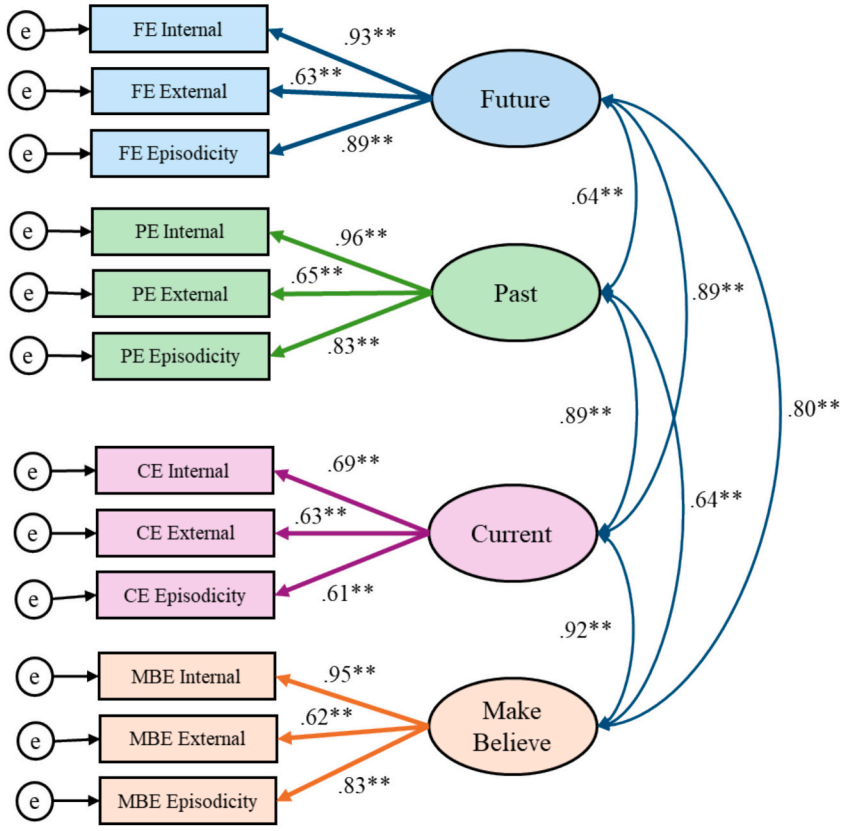


**Fig. 4.** Measurement Model.
Note. FE: Future Event; PE: Past Event; CE: Current Event; MBE: Make-Believe. Standardized parameter estimates are shown.
* $p < .05$, ** $p < .001$.

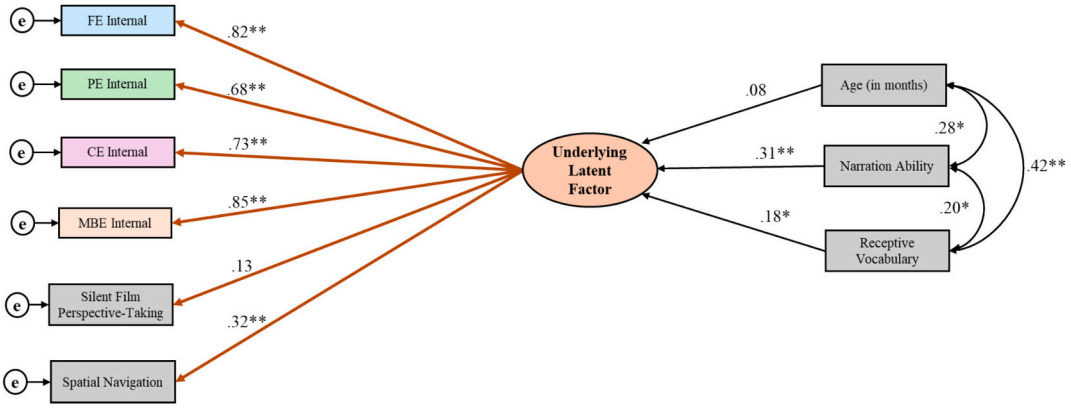


**Fig. 5.** Single Latent Factor Model.
*Note*. Future Event; PE: Past Event; CE: Current Event; MBE: Make-Believe. Standardized parameter estimates are shown.
* $p < .05$, ** $p < .001$

in the present; 13.1 % happened in the past), whereas only a minority of the events were atemporal (19.3 %). Accordingly, the commonality among the past, future, and make-believe events we observed might not have been a reflection of atemporal scene construction per se, but rather other skills, such as children's temporal reasoning (Hoerl & McCormack, 2019).

Further, in contrast to the assumptions of the self-projection account (Buckner & Carroll, 2007), perspective-taking did not load significantly on the underlying latent factor, despite showing positive correlations with episodicity ratings of past, future, and current events (Figs. 2 and 5). The literature also shows mixed results concerning associations between perspective-taking and the other abilities we examined: Studies with preschool children have found non-significant relations (e.g. EFT, Hanson et al., 2014; episodic memory, Naito, 2003), but studies with school-aged children have shown significant relations between perspective-taking and episodic thinking (e.g., Schidelko et al., 2025). Although our sample comprised school-aged children, we did not find a significant relation between episodic thinking and perspective-taking. Our perspective-taking task may have failed to capture the self-projection required in perspective-taking but instead assessed children's ability to anticipate others' mental states. Thus, we might have failed to capture the relation. It is also possible that during childhood,

perspective-taking may have minimal underlying commonality with episodic thinking. Rather, children's episodic thinking might share greater commonality with the ability to flexibly re-construct past details (constructive episodic simulation) and create scenes in a spatial context (scene construction) than with the ability to project the self.

Overall, the present study revealed that the skills (episodic thinking for past, future, current, and make-believe events, spatial navigation, and perspective-taking) proposed by three prominent cognitive accounts of episodic thinking showed considerable shared variance in children. These cognitive mechanisms may be functionally interrelated and support episodic thinking in children to some degree, as early as age 8 years. However, episodic thinking processes showed greater associations between each other than to spatial navigation, and perspective-taking was not significantly related to episodic thinking and spatial navigation (Figs. 2, S4 and 5), which implies that mechanisms like self-projection and scene construction might not account for individual differences in children's episodic thinking, perspective-taking, and spatial navigation. It is possible that the neurocognitive mechanisms that support self-projection and scene construction are not yet fully mature in middle childhood (Buckner & Carroll, 2007; Hassabis & Maguire, 2007). During middle childhood, mechanisms specific to episodic thinking, such as constructive episodic simulation (Schacter & Addis, 2007) and episodic simulator (Nyhout & Mahy, 2023), may more strongly support episodic thinking processes.

### 6.2. *Episodic simulation as the underlying commonality between skills*

Children's performance in episodic thinking for past, future, and current events showed strong interrelations and shared significant covariance (Figs. 2 and 5). When verbosity was controlled, the loadings on the single underlying latent factor remained significant, although weakened in magnitude (see Fig. S4). These findings go beyond the assumptions of constructive episodic simulation, which focuses only on EFT and episodic memory, and beyond scene construction, which focuses on EFT, episodic memory, imagination, and spatial navigation. Notably, in a recent review of episodic memory and future thinking in children, Nyhout and Mahy (2023) proposed that episodic thinking processes, including episodic memory, EFT, imagination, or episodic counterfactual thinking, are integrated by a "central episodic simulator" (p. 2) that brings episodes to conscious awareness.

In support of this notion, previous studies have found that children's and adults' performance in different episodic thinking processes shows close resemblance in terms of neural activation and phenomenological characteristics (e.g., vividness, Addis, 2020). Extending previous research, in the present work all of the episodic thinking processes loaded positively and significantly onto a single latent factor. Such findings provide initial evidence that a single underlying 'episodic simulator' ability might account for the relations among episodic thinking about various types of events in children (including past, future, current, and make-believe episodes). Nyhout and Mahy (2023) proposed that the episodic simulator also underpins atemporal and counterfactual episodes, which were not examined in the present study. Future work is needed to test these other episodic thinking processes in relation to the tasks and abilities examined in the present work, including whether all of these abilities load positively onto a single underlying latent factor.

Also noteworthy, the single latent factor was related to children's narrative ability and receptive vocabulary, suggesting significant links between narrative ability, receptive vocabulary, and the proposed episodic simulation ability. Children who created detailed narratives and had better language skills might have also produced personal events rich with internal details (see Coughlin et al., 2019 for a similar relation in children). Note, however, that when children's verbosity was controlled, these relations were no longer significant. Interestingly, age was not significantly related to episodic thinking, imagination, and perspective-taking in the pairwise correlations (Fig. 2). Age-related improvement in episodic thinking may slow down during middle childhood, resulting in weaker correlations with age. The lack of significant correlations may also be attributed to the narrower age range in our current sample. Previous studies with a broader age range showed statistically significant correlations between age and several of the specific skills and task-related abilities examined in the present work (e.g., Coughlin et al., 2014, 2019). Future research could include a wider age range to better examine age-related differences. Further, in the present study, the number of participants in each age group was too small to test the structural model separately by age group. However, in future studies based on substantially larger sample sizes, the structural model (Fig. 5) could be tested separately in different age groups (e.g., preschool-aged children, school-aged children, and adolescents) to explore how the mechanisms underlying episodic thinking change across development.

## 7. Limitations and future directions

The study administered a single task to capture children's related cognitive abilities (i.e., the Autobiographical Interview), instead of using a battery of tasks. Given children's limited attention span, we decided to use a single task to measure each ability. Second, we employed the Autobiographical Interview to measure children's episodic thinking. Although the interview and scoring protocol are standardized and have been shown to capture robust effects (e.g., Open Science Collaboration, 2015), it is possible that the strong correlations we observed between episodic thinking processes were inflated because we used the same task to measure each ability.[2] Nonetheless, future work should employ different measures for each episodic thinking process to avoid potential correlation inflation.

We did not strictly control the temporal distance of the episodic simulations. That is, we asked children to generate events that happened in the last few months or may happen in the next few months without constraining such events to a specific temporal anchor or specific date. Temporal distance may influence the phenomenal characteristics of simulation in adults. For example, events in the distant future or past comprise fewer sensorial details and have lower clarity than near future or past events (e.g., D'Argembeau & Van der Linden, 2004, 2006). Although such factors may also influence children's simulations of the past and/or future, we note that recently, O'Brien et al. (2024) failed to find consistent effects of temporal distance on 5- to 9-year-old children's event descriptions. Also, we did not control for children's visual perspective in the imagined events (e.g., first vs. third-person perspectives). Visual perspective may influence children's episodic experience, as first-person events include more visual information than third-person events in adults (e.g., Butler et al., 2016). Future studies could expand on the present work by examining children's simulations and episodic thinking based on systematically varying the temporal distance and visual perspective of past and future events.

In addition, in the Autobiographical Interview we did not limit the number of words children produced in their narratives, but in an exploratory analysis we included verbosity as a covariate (Fig. S4). Although our results controlling for verbosity were similar with respect to the pattern of loadings for the episodic thinking tasks on the single latent factor, the strength of the loadings was attenuated; further, the loading for spatial navigation was no longer statistically significant.

[2] In a post-hoc (exploratory) analysis, we re-estimated the single latent factor model (Figure 5) after including correlations among the residual variances in the past, current, future, and imagination scores to account for common method variance arising from the use of the Autobiographical Interview to assess all four abilities. In this model, the loadings for each of the tasks on the single latent factor remained positive and statistically significant, along with the loading for spatial navigation; in contrast, the loading for perspective-taking was still not statistically significant (see Figure S5 for details).

Such findings are consistent with the proposal from Lockrow et al. (2024) that verbosity might account for part of the relations among episodic thinking processes. Past studies examining episodic thinking in children based on the Autobiographical Interview typically have not controlled for verbosity (e.g., Gott & Lah, 2013; Terrett et al., 2013). Notably, such findings may be confounded, at least in part, by individual differences in verbosity – an issue that merits further consideration with respect to interpreting previous results and evaluating future findings based on the Autobiographic Interview.

However, we may lose meaningful individual differences in children's episodic thinking by controlling the number of words that children produce. For example, producing more details is likely to be an important way that children demonstrate a rich imagination (or a sophisticated cognitive representation of future, current, or past events), and thus, children with vivid imaginations would be expected to have higher word counts than others with poorer imaginations. If so, statistically controlling for verbosity may change the meaning of the residual variation in episodic thinking abilities particularly in those with rich imaginations. In our view, therefore, more work is needed to better understand the role of verbosity in episodic thinking and to examine alternative ways to measure children's performance based on the Autobiographical Interview (e.g., Levine et al., 2002; Lockrow et al., 2024) and other methodologies.

Additionally, we used the Silent Film task (Devine & Hughes, 2016) to measure children's perspective-taking. In the task, children were required to anticipate *others'* mental states. However, employing a task in which children need to take *their own* point of view at different time points may better capture self-projection. For example, the future-preferences task (Bélanger et al., 2014) assesses children's anticipations about their future preferences (e.g., coffee vs. juice). Also, the Director Task (Epley et al., 2004) measures children's ability to take another person's point of view. During pilot testing, we administered both the Director and Silent Film tasks to measure children's perspective-taking (see the pre-registration form for more details). The Silent Film task produced fewer technical errors during the online testing than the Director Task, so we chose to use the Silent Film task. Future studies might seek to use tasks that capture self-projection more specifically, to see if the present results hold.

Finally, the current sample size provided sufficient statistical power to detect moderate but not small associations. Studies based on much larger sample sizes may be needed to identify statistically significant but small associations between perspective-taking and the other tasks and abilities examined in the present study. At present, therefore, it may be premature to conclude that perspective-taking is entirely unrelated to episodic thinking and spatial navigation. Further, the pre-registered SEM comprising first-order latent factors for each of the four event types, along with separate second-order latent factors each of the three explanatory accounts, did not provide good fit. Although a modified model comprising one latent factor provided excellent fit and is consistent with the recently proposed notion of a central episodic simulator (Nyhout & Mahy, 2023), further pre-registered research is needed to determine the replicability of our findings, as well as generalizability to other samples and age groups.

## 8. Conclusion

The current study examined episodic thinking during middle childhood in relation to imagination, spatial navigation, and perspective-taking based on three prominent cognitive accounts: constructive episodic simulation (Schacter & Addis, 2007), scene construction (Hassabis & Maguire, 2007), and self-projection (Buckner & Carroll, 2007). Episodic thinking (internal details for future, current, and past events), imagination, and spatial navigation shared significant variance, and these abilities loaded positively onto a single underlying latent factor. These results align with the adult literature (Addis, 2020), supporting the roles of constructive episodic simulation and scene construction mechanisms in middle childhood. In contrast, perspective-taking was not significantly related to episodic thinking and spatial navigation and did not load significantly onto the latent factor. Such results do not support the self-projection mechanism, consistent with other emerging evidence (Immel et al., 2022). Extending these three accounts, the strong relations between episodic thinking, imagination, and spatial navigation, along with their significant and positive loadings onto a single latent factor, suggest a general underlying episodic simulation ability (Nyhout & Mahy, 2023) that contributes to episodic thinking by creating a conscious awareness in the episodes. Thus, the present work provides important new insights concerning episodic thinking during middle childhood and informs our understanding of the cognitive mechanisms that support episodic thinking more broadly.

## CRediT authorship contribution statement

**Ege Kamber:** Writing – original draft, Visualization, Project administration, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Michael A. Busseri:** Writing – review & editing, Supervision, Methodology, Formal analysis. **Caitlin E.V. Mahy:** Writing – review & editing, Supervision, Resources, Project administration, Methodology, Funding acquisition, Formal analysis, Conceptualization.

## Acknowledgements

CEVM would like to acknowledge funding from a Discovery Grant from the Natural Sciences and Engineering Research Council of Canada (RGPIN-2023-03712) and from an Early Researcher Award from the Ontario Ministry of Innovation, Research, and Science (ER-17-13-118).

## Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.cognition.2025.106405.

## Data availability

osf.io/tqvmd

## References

Addis, D., & Tanguay, A. (2022, July 19). *Prospective cognition and its links with memory*. https://doi.org/10.31234/osf.io/w69nd

Addis, D. R. (2020). Mental time travel? A neurocognitive model of event simulation. *Review of Philosophy and Psychology, 11*(2), 233–259. https://doi.org/10.1007/s13164-020-00470-0

Addis, D. R., & Schacter, D. L. (2012). The hippocampus and imagining the future: Where do we stand? *Frontiers in Human Neuroscience, 5*, 173. https://doi.org/10.3389/fnhum.2011.00173

Addis, D. R., Wong, A. T., & Schacter, D. L. (2008). Age-related changes in the episodic simulation of future events. *Psychological Science, 19*(1), 33–41. https://doi.org/10.1111/j.1467-9280.2008.02043.x

Adornetti, I., Chiera, A., Altavilla, D., Deriu, V., Marini, A., Valeri, G., & Ferretti, F. (2021). Self-projection in middle childhood: A study on the relationship between theory of mind and episodic future thinking. *Cognitive Processing, 22*, 321–332. https://doi.org/10.1007/s10339-021-01013-w

Andrews-Hanna, J. R., Smallwood, J., & Spreng, R. N. (2014). The default network and self-generated thought: Component processes, dynamic control, and clinical relevance. *Annals of the New York Academy of Sciences, 1316*(1), 29–52. https://doi.org/10.1111/nyas.12360

Arbuckle, J. L. (2023). *Amos (version 29.0) [computer program]*. Chicago: IBM SPSS.

Atance, C. M., & Sommerville, J. A. (2014). Assessing the role of memory in preschoolers' performance on episodic foresight tasks. *Memory, 22*(1), 118–128.

Bélanger, M. J., Atance, C. M., Varghese, A. L., Nguyen, V., & Vendetti, C. (2014). What will I like best when I'm all grown up? Preschoolers' understanding of future preferences. *Child Development, 85*(6), 2419–2431. https://doi.org/10.1111/cdev.12282

Benjamini, Y., & Hochberg, Y. (1995). Controlling the false discovery rate: A practical and powerful approach to multiple testing. *Journal of the Royal Statistical Society: Series B: Methodological, 57*(1), 289–300. https://doi.org/10.1111/j.2517-6161.1995.tb02031.x

Buckner, R. L., & Carroll, D. C. (2007). Self-projection and the brain. *Trends in Cognitive Sciences, 11*(2), 49–57. https://doi.org/10.1016/j.tics.2006.11.004
Burns, P., Atance, C., O'Connor, A. P., & McCormack, T. (2021). The effects of cueing episodic future thinking on delay discounting in children, adolescents, and adults. *Cognition, 218*, Article 104943. https://doi.org/10.1016/j.cognition.2021.104934
Busby, J., & Suddendorf, T. (2005). Recalling yesterday and predicting tomorrow. *Cognitive Development, 20*(3), 362–372. https://doi.org/10.1016/j.cogdev.2005.05.002
Butler, A. C., Rice, H. J., Wooldridge, C. L., & Rubin, D. C. (2016). Visual imagery in autobiographical memory: The role of repeated retrieval in shifting perspective. *Consciousness and Cognition: An International Journal, 42*, 237–253. https://doi.org/10.1016/j.concog.2016.03.018
Christoff, K., Irving, Z. C., Fox, K. C., Spreng, R. N., & Andrews-Hanna, J. R. (2016). Mind-wandering as spontaneous thought: A dynamic framework. *Nature Reviews. Neuroscience, 17*(11), 718–731. https://doi.org/10.1038/nrn.2016.113
Ciaramelli, E., Spoglianti, S., Bertossi, E., Generali, N., Telarucci, F., Tancredi, R., Muratori, F., & Igliozzi, R. (2018). Construction of past and future events in children and adolescents with ASD: Role of self-relatedness and relevance to decision-making. *Journal of Autism and Developmental Disorders, 48*(9), 2995–3009. https://doi.org/10.1007/s10803-018-3577-y
Coughlin, C., Lyons, K. E., & Ghetti, S. (2014). Remembering the past to envision the future in middle childhood: Investigating the role of memory in the development of episodic foresight. *Cognitive Development, 30*, 96–110. https://doi.org/10.1016/j.cogdev.2014.02.001
Coughlin, C., Robins, R. W., & Ghetti, S. (2019). Development of episodic prospection: Factors underlying improvements in middle and late childhood. *Child Development, 90*, 1109–1122. https://doi.org/10.1111/cdev.13001
Crosson, J., & Geers, A. (2001). Analysis of narrative ability in children with cochlear implants. *Ear and Hearing, 22*, 381–394. https://doi.org/10.1097/00003446-200110000-00003
Cuevas, K., Rajan, V., Morasch, K. C., & Bell, M. A. (2015). Episodic memory and future thinking during early childhood: Linking the past and future. *Developmental Psychobiology, 57*(5), 552–565. https://doi.org/10.1002/dev.2130
D'Argembeau, A., Renaud, O., & Van der Linden, M. (2011). Frequency, characteristics and functions of future-oriented thoughts in daily life. *Applied Cognitive Psychology, 25*(1), 96–103. https://doi.org/10.1002/acp.1647
D'Argembeau, A., & Van der Linden, M. (2004). Phenomenal characteristics associated with projecting oneself back into the past and forward into the future: Influence of valence and temporal distance. *Consciousness and Cognition, 13*(4), 844–858. https://doi.org/10.1016/j.concog.2004.07.007
D'Argembeau, A., & Van der Linden, M. (2006). Individual differences in the phenomenology of mental time travel: The effect of vivid visual imagery and emotion regulation strategies. *Consciousness and Cognition, 15*(2), 342–350. https://doi.org/10.1016/j.concog.2005.09.001
De Brigard, F., Addis, D. R., Ford, J. H., Schacter, D. L., & Giovanello, K. S. (2013). Remembering what could have happened: Neural correlates of episodic counterfactual thinking. *Neuropsychologia, 51*(12), 2401–2414. https://doi.org/10.1016/j.neuropsychologia.2013.01.015
Devine, R. T., & Hughes, C. (2016). Measuring theory of mind across middle childhood: Reliability and validity of the silent films and strange stories tasks. *Journal of Experimental Child Psychology, 149*, 23–40. https://doi.org/10.1016/j.jecp.2015.07.011
Duff, N., Olsen, R., Walsh, Z., Salmon, K., Hunt, M., & Macaskill, A. (2025). A fragile effect: The influence of episodic memory on delay discounting. *The Quarterly Journal of Experimental Psychology, 78*(3), 514–533. https://doi.org/10.1177/17470218241239289
Epley, N., Morewedge, C. K., & Keysar, B. (2004). Perspective taking in children and adults: Equivalent egocentrism but differential correction. *Journal of Experimental Social Psychology, 40*(6), 760–768. https://doi.org/10.1016/j.jesp.2004.02.002
Fivush, R., & Fromhoff, F. A. (1988). Style and structure in mother-child conversations about the past. *Discourse Processes, 11*(3), 337–355. https://doi.org/10.1080/01638538809544707
Gardner-Neblett, N., & Iruka, I. U. (2015). Oral narrative skills: Explaining the language-emergent literacy link by race/ethnicity and SES. *Developmental Psychology, 51*(7), 889. https://doi.org/10.1037/a0039274
Gautam, S., Suddendorf, T., Henry, J. D., & Redshaw, J. (2019). A taxonomy of mental time travel and counterfactual thought: Insights from cognitive development. *Behavioural Brain Research, 374*, Article 112108. https://doi.org/10.1016/j.bbr.2019.112108
Gershon, R. C., Slotkin, J., Manly, J. J., Blitz, D. L., Beaumont, J. L., Schnipke, D., & Weintraub, S. (2013). IV. NIH toolbox cognition battery (CB): Measuring language (vocabulary comprehension and reading decoding). *Monographs of the Society for Research in Child Development, 78*(4), 49–69. https://doi.org/10.1111/mono.12034
Gott, C., & Lah, S. (2013). Episodic future thinking in children compared to adolescents. *Child Neuropsychology, 20*(5), 625–640. https://doi.org/10.1080/09297049.2013.840362
Hanson, L. K., Atance, C. M., & Paluck, S. W. (2014). Is thinking about the future related to theory of mind and executive function? Not in preschoolers. *Journal of Experimental Child Psychology, 128*, 120–137. https://doi.org/10.1016/j.jecp.2014.07.006
Hassabis, D., Kumaran, D., Vann, S. D., & Maguire, E. A. (2007). Patients with hippocampal amnesia cannot imagine new experiences. *Proceedings of the National Academy of Sciences, 104*(5), 1726–1731. https://doi.org/10.1073/pnas.0610561104
Hassabis, D., & Maguire, E. A. (2007). Deconstructing episodic memory with construction. *Trends in Cognitive Sciences, 11*(7), 299–306. https://doi.org/10.1016/j.tics.2007.05.001
Hayne, H., Gross, J., McNamee, S., Fitzgibbon, O., & Tustin, K. (2011). Episodic memory and episodic foresight in 3- and 5-year-old children. *Cognitive Development, 26*(4), 343–355. https://doi.org/10.1016/j.cogdev.2011.09.006
Hoerl, C., & McCormack, T. (2019). Thinking in and about time: A dual systems perspective on temporal cognition. *The Behavioral and Brain Sciences, 42*, Article e244. https://doi.org/10.1017/S0140525X18002157
Hudson, J. A. (2002). "do you know what we're going to do this summer?": Mothers' talk to preschool children about future events. *Journal of Cognition and Development, 3*(1), 49–71. https://doi.org/10.1207/S15327647JCD0301_4
Immel, A.-S., Altgassen, M., Meyer, M., Endedijk, H. M., & Hunnius, S. (2022). Self-projection in early childhood: No evidence for a common underpinning of episodic memory, episodic future thinking, theory of mind, and spatial navigation. *Journal of Experimental Child Psychology, 223*, 1–25. https://doi.org/10.1016/j.jecp.2022.105481
Kamber, E., Mazachowsky, T. R., & Mahy, C. E. (2023). The emergence and development of future-oriented cognition in toddlerhood: The contribution of cognitive and language abilities. *Journal of Cognition and Development, 24*(3), 397–419.
Lempert, K. M., Speer, M. E., Delgado, M. R., & Phelps, E. A. (2017). Positive autobiographical memory retrieval reduces temporal discounting. *Social Cognitive and Affective Neuroscience, 12*(10), 1584–1593. https://doi.org/10.1093/scan/nsx086
Levine, B., Svoboda, E., Hay, J. F., Winocur, G., & Moscovitch, M. (2002). Aging and autobiographical memory: Dissociating episodic from semantic retrieval. *Psychology and Aging, 17*(4), 677–689. https://doi.org/10.1037/0882-7974.17.4.677
Lind, S. E., Bowler, D. M., & Raber, J. (2014). Spatial navigation, episodic memory, episodic future thinking, and theory of mind in children with autism spectrum disorder: Evidence for impairments in mental simulation? *Frontiers in Psychology, 5*, Article 1411. https://doi.org/10.3389/fpsyg.2014.01411
Lockrow, A. W., Setton, R., Spreng, K. A., Sheldon, S., Turner, G. R., & Spreng, R. N. (2024). Taking stock of the past: A psychometric evaluation of the autobiographical interview. *Behavior Research Methods, 56*(2), 1002–1038. https://doi.org/10.3758/s13428-023-02080-x
Maguire, E. A., Vargha-Khadem, F., & Hassabis, D. (2010). Imagining fictitious and future experiences: Evidence from developmental amnesia. *Neuropsychologia, 48*(11), 3187–3192. https://doi.org/10.1016/j.neuropsychologia.2010.06.037
Moscovitch, D. A., White, K., & Hudd, T. (2024). Hooking the self onto the past: How positive autobiographical memory retrieval benefits people with social anxiety. *Clinical Psychological Science: A Journal of the Association for Psychological Science, 12*(5), 882–902. https://doi.org/10.1177/21677026231195792
Muthén, L. K., & Muthén, B. O. (2002). How to use a Monte Carlo study to decide on sample size and determine power. *Structural Equation Modeling: A Multidisciplinary Journal, 9*(4), 599–620.
Naito, M. (2003). The relationship between theory of mind and episodic memory: Evidence for the development of autonoetic consciousness. *Journal of Experimental Child Psychology, 85*(4), 312–336. https://doi.org/10.1016/S0022-0965(03)00075-4
Nguyen, K. V., Olson, I. R., & Newcombe, N. S. (2025). Do spatial navigation and episodic memory rely on the same systems? Evidence from a naturalistic experience with children and adults. *Journal of Experimental Psychology. General*. https://doi.org/10.1037/xge0001805. Advance online publication.
Nyhout, A., & Mahy, C. E. V. (2023). Episodic thought in development: On the relation between memory and future thinking. *Developmental Review, 70*, Article 101103. https://doi.org/10.1016/j.dr.2023.101103
O'Brien, B., Rodriguez, M., Gallitto, E., & Atance, C. M. (2024). Tomorrow versus a year from now: Do children represent the near and distant future differently? *Journal of Experimental Child Psychology, 241*, Article 105878.
Open Science Collaboration. (2015). Estimating the reproducibility of psychological science. *Science, 349*(6251), Article aac4716. https://doi.org/10.1126/science.aac4716
Perner, J., Kloo, D., & Gornik, E. (2007). Episodic memory development: Theory of mind is part of re-experiencing experienced events. *Infant and Child Development, 16*(5), 471–490. https://doi.org/10.1002/icd.517
Pullano, L., & Foti, F. (2022). The development of human navigation in middle childhood: A narrative review through methods, terminology, and fundamental stages. *Brain Sciences, 12*(8), 1097. https://doi.org/10.3390/brainsci12081097
Rendell, P. G., Bailey, P. E., Henry, J. D., Phillips, L. H., Gaskin, S., & Kliegel, M. (2012). Older adults have greater difficulty imagining future rather than atemporal experiences. *Psychology and Aging, 27*(4), 1089–1098. https://doi.org/10.1037/a0029748
Romero, K., & Moscovitch, M. (2012). Episodic memory and event construction in aging and amnesia. *Journal of Memory and Language, 67*(2), 270–284. https://doi.org/10.1016/j.jml.2012.05.002
Rösch, S. A., Stramaccia, D. F., & Benoit, R. G. (2022). Promoting farsighted decisions via episodic future thinking: A meta-analysis. *Journal of Experimental Psychology. General, 151*(7), 1606–1635. https://doi.org/10.1037/xge0001148
Rusconi, M. L., Suardi, A., Zanetti, M., & Rozzini, L. (2015). Spatial navigation in elderly healthy subjects, amnestic and non amnestic MCI patients. *Journal of the Neurological Sciences, 359*, 430–437. https://doi.org/10.1016/j.jns.2015.10.010
Sato, J. R., Salum, G. A., Gadelha, A., Picon, F. A., Pan, P. M., Vieira, G., … Jackowski, A. P. (2014). Age effects on the default mode and control networks in typically developing children. *Journal of Psychiatric Research, 58*, 89–95. https://doi.org/10.1016/j.jpsychires.2014.07.004
Schacter, D. L., & Addis, D. R. (2007). The cognitive neuroscience of constructive memory: Remembering the past and imagining the future. *Philosophical Transactions*

*of the Royal Society, B: Biological Sciences, 362*(1481), 773–786. https://doi.org/10.1098/rstb.2007.2087

Schacter, D. L., Benoit, R. G., De Brigard, F., & Szpunar, K. K. (2015). Episodic future thinking and episodic counterfactual thinking: Intersections between memory and decisions. *Neurobiology of Learning and Memory, 117*, 14–21.

Schidelko, L. P., Baumann, L., Proft, M., & Rakoczy, H. (2025). Do theory of mind and mental time travel abilities build on joint cognitive foundations? *Royal Society Open Science, 12*(6), Article 241960. https://doi.org/10.1098/rsos.241960

Schreiber, F., Schneider, S., Newen, A., & Voigt, B. (2024). Negative (but not positive) affective episodic future thinking enhances proactive behavior in 5-year-old children. *Emotion, 24*(6), 1481. https://doi.org/10.1037/emo0001345

Sherman, L. E., Rudie, J. D., Pfeifer, J. H., Masten, C. L., McNealy, K., & Dapretto, M. (2014). Development of the default mode and central executive networks across early adolescence: A longitudinal study. *Developmental Cognitive Neuroscience, 10*, 148–159. https://doi.org/10.1016/j.dcn.2014.08.002

Spreng, R. N., Mar, R. A., & Kim, A. S. (2008). The common neural basis of autobiographical memory, prospection, navigation, theory of mind, and the default mode: A quantitative meta-analysis. *Journal of Cognitive Neuroscience, 21*(3), 489–510. https://doi.org/10.1162/jocn.2008.21029

Spreng, R. N., Lockrow, A. W., DuPre, E., Setton, R., Spreng, K. A. P., & Turner, G. R. (2018). Semanticized autobiographical memory and the default – executive coupling hypothesis of aging. *Neuropsychologia, 110*, 37–43. https://doi.org/10.1016/j.neuropsych ologia.2017.06.009

Suddendorf, T., & Corballis, M. C. (2007). The evolution of foresight: What is mental time travel, and is it unique to humans? *The Behavioral and Brain Sciences, 30*(3), 299–313. https://doi.org/10.1017/S0140525X07001975

Szpunar, K. K., Spreng, R. N., & Schacter, D. L. (2014). A taxonomy of prospection: Introducing an organizational framework for future-oriented cognition. *Proceedings of the National Academy of Sciences, 111*(52), 18414–18421. https://doi.org/10.1073/pnas.1417144111

Terrett, G., Rendell, P. G., Raponi-Saunders, S., Henry, J. D., Bailey, P. E., & Altgassen, M. (2013). Episodic future thinking in children with autism spectrum disorder. *Journal of Autism and Developmental Disorders, 43*(11), 2558–2568.

Tulving, E. (1985). Memory and consciousness. *Canadian Psychology/Psychologie Canadienne, 26*(1), 1–12. https://doi.org/10.1037/h0080017

Ünal, G., & Hohenberger, A. (2017). The cognitive bases of the development of past and future episodic cognition in preschoolers. *Journal of Experimental Child Psychology, 162*, 242–258. https://doi.org/10.1016/j.jecp.2017.05.014

Westland, J. C. (2010). Lower bounds on sample size in structural equation modeling. *Electronic Commerce Research and Applications, 9*(6), 476–487.

Wickham, H. (2016). Data analysis. In *ggplot2: Elegant graphics for data analysis* (pp. 189–201). Cham: Springer International Publishing.

Zhang, J., Vohs, K. D., & Carlson, S. M. (2024). Imagining the future improves saving in preschoolers. *Journal of Experimental Child Psychology, 246*, Article 105966. https://doi.org/10.1016/j.jecp.2024.105966