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Review

Episodic thought in development: On the relation between memory and future thinking

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ABSTRACT

Extensive research from cognitive neuroscience has shown that episodic memory and future thinking are related processes and has given rise to theories attempting to explain these similarities, but developmental research has only minimally been considered. We argue that developmental research is fundamental to understanding the association between episodic memory and future thinking and that existing neurocognitive theories do not fully accommodate developmental findings. We review evidence from studies investigating children's episodic memory, future thinking, and comparing across the two, as well as studies on the developing brain, and research with patients with brain lesions and individuals with autism spectrum disorder. These data provide an emerging but incomplete picture of the relation between memory and future thinking, and therefore we present a framework that deconstructs episodic thought into its separate components – who an episode is about, what happens in it, and when and where it occurs. We argue that episodic memory and future thinking place different demands on these subcomponents but are bound together by a shared episodic simulator that plays episodes to conscious awareness. We then provide a roadmap for future research that will clarify how memory and future thinking are related in development.

Introduction

Episodic thinking consumes much of our everyday thought. We often spend time escaping the present by remembering events from the past (*episodic memory*), imagining how those past events might have turned out differently (*episodic counterfactual thinking*), thinking about how the future will unfold (*episodic future thinking*), or daydreaming about events that we know will never transpire (*fictional thinking*). Clearly, there is much that unites these types of thought. All involve imagining an agent – most often the self – in another time and place. Given the similar features of episodic memory, counterfactual thinking, future thinking, and fictional thinking, an extensive amount of research in cognitive neuroscience has focused on investigating their common neurophysiological underpinnings. This research generally finds that a common set of brain networks are engaged during different types of episodic thought, with a particular focus on the commonalities between episodic memory and episodic future thinking (e.g., Schacter & Addis, 2007). Theoretical work in this area has also focused on the underlying nature of these abilities, with some theorists proposing a common basis for a broad swath of episodic thinking abilities, and a minority proposing that these abilities are relatively distinct.

In contrast, research in developmental psychology has generally focused on these abilities in isolation. Extensive developmental

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research on episodic memory was carried out (e.g., Bauer & Dow, 1994; Fivush et al., 1984; Hudson, 1990; Perner & Ruffman, 1995) before other types of episodic thought were studied developmentally (e.g., counterfactual thinking: Harris et al., 1996; episodic future thinking: Atance & O'Neill, 2001; imagination: Taylor & Carlson, 1997). Although several developmental researchers have acknowledged the similarity between these episodic abilities (e.g., Atance & O'Neill, 2001; Coughlin et al., 2014; Suddendorf and Corballis, 2007), few have investigated the precise mechanisms connecting these abilities.

The goals of the present paper are to bridge disparate lines of investigation to (1) bring the debate about the relation between different types of episodic thought to developmental psychology and (2) use developmental findings to make sense to the relation between different forms of episodic thought to advance relevant theoretical work. Our focus is mainly on two types of episodic thought: episodic memory and episodic future thinking (henceforth, memory and future thinking). Theoretical and empirical work in cognitive psychology and cognitive neuroscience has made significant progress towards the understanding of these abilities, and a lively debate currently exists about the precise nature of the relation between memory and imagination (e.g., see 2020 special issue of *Review of Philosophy and Psychology* on "*Memory as Mental Time Travel*"). These debates concern whether and how memory and future thinking are related. Are they the same kind or qualitatively different capacities? If they are related, what is the nature of their relation? Do they draw on similar cognitive processes, or are they the *same* ability projected in different temporal directions?

Along with neuroscientific data, developmental data are highly relevant to these debates. Yet, the existing developmental evidence that could inform these debates is generally not considered or has been somewhat misconstrued by cognitive neuroscientists. Moreover, developmentalists often do not enter these debates, despite cognitive developmentalists' interests in modularity, the mechanisms underlying cognitive abilities, and understanding the nature of the difficulties children face with certain cognitive tasks (cf. Immel et al., 2022). Previous theoretical and empirical work by cognitive psychologists and neuroscientists lays the groundwork for developmental investigations of memory and future thinking. At the same time, existing theories may need to be modified in light of developmental evidence.

In the following sections, we first review the major theoretical perspectives from the neurocognitive literature on the relation between memory and future thinking before describing relevant evidence, mostly from behavioural and neurocognitive developmental research, and research with patients with brain lesions and individuals with autism spectrum disorder. These data provide an emerging but incomplete picture of the relation between memory and future thinking, and therefore we present a framework that deconstructs episodic thought into its separate components – *who* an episode is about, *what* happens in it, and *when* and *where* it occurs. We consider these as *subcomponents* of episodic thought that are called upon to varying degrees depending on the task at hand. We argue that the output of these subcomponents is integrated by a central episodic simulator that plays episodes to conscious awareness. We then outline directions for future research that will clarify how memory and future thinking are related in development.

Theoretical perspectives on the relation between memory and future thinking

Developmentalists often study memory and future thinking as if they are different kinds. Most research on episodic thinking abilities in development is siloed, and relatively few developmental studies have investigated the relation between memory and future thinking or between subtypes of imagination (see the section *Comparing Episodic Thinking Abilities in Development*). Although these questions have largely been overlooked by developmentalists, extensive theoretical and empirical work in cognitive psychology and neuroscience has interrogated the relation between memory and future thinking.

Theories differ in the nature and degree of relation they propose between memory and future thinking. According to Addis (2020), "[w]ithin modern psychology and cognitive neuroscience, the intertwinement of past and future thinking has been emphasized, most influentially by Tulving (1985), but nevertheless are usually conceived of as distinct capacities.“ (p. 234). Although many contemporary theories argue for *some* relation between memory and future thinking, they differ in the exact nature of the relation they propose. We first review the predominant theories in cognitive psychology and neuroscience that propose a degree of continuism, including self-projection (Buckner & Carroll, 2007), constructive episodic simulation (Schacter & Addis, 2007), scene construction (Hassabis & Maguire, 2007), contextual associations (McDermott et al., 2011), and, most recently, what we will call the single system hypothesis (Addis, 2020). We then briefly review discontinuist theories that propose memory and imagination are distinct abilities (Debus, 2014; Robins, 2020). Discontinuism is a view mostly held by philosophers but is not strongly supported by empirical research findings in adulthood or childhood. We do not attempt to provide an exhaustive list, but instead cover major theories that inform the current debate.

In reviewing the theoretical debate, two distinct considerations emerge over whether memory and future thinking are the same kind. The first concerns the nature and root of any similarities and differences one assigns. For instance, some theories propose that the phenomenological experiences of remembering and imagining are different (e.g., Debus, 2014; Robins, 2020). Others argue that imaginative simulations are built off episodic memories, and thus propose a unidirectional relation (e.g., Buckner & Carroll, 2007; Schacter & Addis, 2007). The second consideration concerns whether the similarities or differences one proposes constitute distinct cognitive capacities. Two individuals may agree that memory and future thinking involve different phenomenological experiences but may disagree over whether this necessitates classifying them as the same or different kinds. Indeed, a single cognitive system can produce a diversity of outputs so differences in phenomenology on their own do not provide sufficient evidence for the existence of distinct systems.

Several theories, starting with Tulving's (1985) notion of **mental time travel** have proposed that future thinking is supported and enabled by episodic memory. According to Tulving (1985), the human capacity for autonoetic (or self-knowing) consciousness characterizes episodic thought, including both episodic memory and future thinking, and distinguishes it from semantic thought. This capacity for autonoetic thought allows us to project ourselves into the past or future (and have a sense of self that is continuous in time), imagining events that have already occurred or events that will (or might) occur in the future. Tulving (1985) first observed that an amnesic patient who was unable to recall personal events in the past was also unable to answer questions about what he will do in the future. Subsequent patient studies, reviewed in the section *Patient populations/ brain lesion studies*, have mostly confirmed these findings.

Reminiscent of Tulving's (1985) theory of autonoetic consciousness, Buckner and Carroll (2007) propose that memory and future thinking share a need for **self-projection**. Summarizing evidence that overlapping brain networks support a broad range of abilities, including remembering, episodic future thinking, theory of mind, and navigation through space, Buckner and Carroll argue that these abilities share a need to step outside the here-and-now to mentally transport oneself to another time, place, and/or perspective. These abilities are argued to be constructive, such that autobiographical experiences are used to build simulations of novel events and perspectives on events. According to this view, episodic memory is a necessary precursor to other types of episodic simulation.

In their **constructive episodic simulation hypothesis**, Schacter and Addis (2007) similarly argue that memory and future thinking are constructive processes, but do not place the shared emphasis specifically on self-projection or mental time travel. A starting point for this hypothesis comes from the everyday observation that memory is not a faithful rendition of past experience but is often fuzzy and error prone (e.g., Brainerd & Reyna, 2001). This feature of memory allows it to be flexibly recombined both to reconstruct representations of the past and to construct novel episodic simulations. Cheng, Werning, and Suddendorf (2016) also argue that imagination – or mental time travel, according to how they conceptualize the ability – is built from traces from episodic memory. However, Cheng et al. (2016) more explicitly describe what is difficult about mental time travel compared to episodic memory: whereas episodic memory requires encoding and storing a personal event, upheld by sequential mnemonic representations of experienced episodes, mental time travel requires the more challenging task of constructing novel scenarios into coherent narratives. These higher-level mental time travel abilities are argued to involve construction, phenomenological insight, and the ability to compare between different hypothetical possibilities.

Like the other theories covered thus far, Hassabis, Maguire, and colleagues (Hassabis & Maguire, 2007; Hassabis et al., 2007; Maguire & Mullally, 2013) argue that much is shared between memory and future thinking but argue that the commonalities are due to **scene construction**. Scene construction involves mentally constructing the location where an episode takes place. Because episodic representations are situated in specific spatiotemporal contexts, it makes sense that they should call on the ability to represent such contexts. It is this ability for scene construction that is argued to be impaired in certain patients and populations, and particularly patients with hippocampal amnesia (Hassabis et al., 2007).

In the **contextual association hypothesis**, McDermott et al. (2011) argue that the critical shared feature of memory and future thinking is the fact that they often take place in familiar contexts. This theory is reminiscent of the scene construction hypothesis but argues for a central role of a broader set of features involving associations between entities and events in a simulation. In support of this argument, imagined events that take place in familiar locations (e.g., one's home) tend to be more vivid (and memory-like) than events imagined in unfamiliar locations (Szpunar & McDermott, 2008).

Although the theories we have reviewed thus far all propose that memory and future thinking are closely related, a more extreme continuist proposal comes from Addis (2020) who argues that memory and future thinking are in fact one neurocognitive system to simulate events. On this **single system hypothesis**, memory and future thinking differ in the associative strength between constituents of the simulation. In the case of episodic memory, a stronger associative history between constituents makes the simulation easier to construct than novel simulations. Addis (2020) also argues for a central role of schema knowledge in episodic simulation, especially when one is imagining novel future events. Addis proposes that schema reliance is stronger in future thinking than in memory due to the need to construct novel events within a framework of existing knowledge and experiences. We will return to the role of schema knowledge in laying out our framework for the development of episodic simulation.

Finally, although few, if any, cognitive psychological theories argue that memory and future thinking are entirely distinct, philosophical theories more often argue for some degree of discontinuism between the two processes mostly based on differences in phenomenology. For instance, Debus (2014) argues that memory and future thinking are fundamentally different kinds because they involve different *mental attitudes* – in the case of remembering, the individual is aware of having experienced the event, but this is not the case with forms of imagining including future thinking (see Robins, 2020 for a similar philosophical argument). Specifically, she states that "[memories] of past events and [imaginations] of future events are ultimately mental occurrences of two different kinds… because there is an important *metaphysical difference* between the two kinds of 'mental time travel' under consideration here" (p. 337). Others, while agreeing that memory may have a distinctive experiential element that future thinking lacks, contend that this difference does not constitute different kinds (Sant'Anna & Michaelian, 2019).

Based on empirical evidence, many psychologists – ourselves included – would similarly challenge the assertion that differences in the subjective experience of types of episodic cognition necessarily render them different kinds. However, discontinuism seems to be at least implicitly endorsed by some developmental psychologists, in keeping with a long tradition of theories of domain-specificity and modularity (e.g., Barrett & Kurzban, 2006; Fodor, 1983). Given the fact that the study of memory and future thinking in development is often siloed, few researchers have studied their relation (but see studies reviewed in the section *Comparing Episodic Thinking Abilities in Development*). Despite its relevance, developmental research has generally not entered theoretical debates about the relation between memory and future thinking. Still, researchers in other areas have argued that developmental evidence supports a common basis for memory and future thinking. Several theories specifically claim that memory and future thinking emerge at the *same time* in development (e.g., Addis, 2020; Buckner & Carroll, 2007; Schacter et al., 2012), but as we discuss below, the available developmental data do not always support these claims, which seem to be made based on the assumption that abilities that emerge within a year of one another constitute emerging at the same time. A year is of course a long time in early development.

Although the theories we have reviewed provide a useful framework for considering the relation between memory and future thinking (and other episodic abilities), as we will see, none of them provide a completely satisfactory explanation for the developmental evidence. In the following section, we review empirical evidence from a variety of fields on the relation between memory and future thinking. We do not intend for this review to be exhaustive, but rather to represent some of the major findings and trends in different areas. We first provide a brief overview of the development of two core episodic abilities: episodic memory and episodic future thinking. We then review findings from a limited but growing set of studies that have compared between these abilities in development. Next, we discuss results of neuroimaging studies that have compared brain activity in the developing brain when remembering and thinking about the future, with a focus on activity in the default mode network. Finally, we review findings from special populations that provide insight into this relation, including patients with brain lesions and individuals with autism spectrum disorder.

Empirical evidence from developmental and clinical research

The development of episodic memory

The first signs of episodic memory appear in infancy when babies as young as 10 weeks of age can remember certain motor repertoires minutes later (Rovee & Rovee, 1969), but these memories may lack a subjective sense of having previously experienced the events, given that infants' self-awareness emerges only around 18 months (Anderson, 1983). These earliest memories that lack autonoetic consciousness may not be classified as true episodic memories according to some conceptualizations of the ability (Buckner & Carroll, 2007; Tulving, 1985).

Episodic memory continues to develop during the toddler and preschool years and is often measured using tasks that require verbal reports of past events (i.e., list recall or description of events). Toddlers and young preschoolers can engage in conversations with their parents about past events (e.g., Fivush & Fromhoff, 1988; Reese et al., 1993). In early childhood, children's episodic memory has been measured in various ways including recall of a small number of items or pictures previously presented (e.g., Naito, 2003), discussing past events on a timeline (e.g., Hayne et al., 2011), and showing deferred imitation of actions on an object (e.g., Burns et al., 2015).

Most studies that measure episodic memory by verbal report require that details being reported are not just semantic in nature or based on script knowledge, but rather refer to the personal recollection of the event (Tulving, 2001). Perner (2001) suggested three important criteria for episodic memory: (1) the remembered events need to be a particular event that occurred in the past, (2) the memory of the event must originate from one's direct experience, and (3) the memory must be available for re-experiencing.

During middle childhood, the Episodic Thinking Interview has been used to capture episodic memory by asking children to provide details on past events (e.g., Coughlin et al., 2014; Ghetti, 2014; Coughlin et al., 2019). Children's responses are then coded for episodic and semantic details. Findings suggest that as children get older, the amount of episodic detail they provide increases. For instance, Coughlin et al. (2014) found that 9-year-olds' and adults' narratives contained more episodic details than 5-year-olds' event narratives.

Neuroimaging work also supports the idea that episodic memory increases in detail during childhood as the hippocampal and prefrontal areas of the brain mature (Coughlin et al., 2018). Specifically, increases in hippocampal volume from middle childhood to adolescence correlate with improvements in episodic memory (e.g., Lee et al., 2014), suggesting episodic memory undergoes protracted development. The upshot is that most research seems to suggest that episodic memory develops between the age of 3 and 4 (Perner & Ruffman, 1995) in a form that would satisfy Perner's (2001) criteria[1] but continues to show protracted development through late childhood and adolescence as the level of detail in children's episodic memories increases.

The development of future thinking

The first signs of future thinking appear in the toddler years when children begin to talk about the future with their parents (Hudson, 2006). During the preschool period, this ability undergoes rapid development (e.g., Atance, 2008; 2015). Future thinking is measured with tasks that require children to project themselves into the future to imagine a need, desire, or preference. While many different tasks have been used to capture future thinking in preschoolers (e.g., Atance & Jackson, 2009; Atance & Meltzoff, 2005; Bélanger et al., 2014; Russell et al., 2010), one of the more common tasks has been the two-room tasks (e.g., Tulving, 2005; Suddendorf et al., 2011). In this task, children are introduced to two separate rooms: in the first room, there is an item that requires a specific object to be functional (an empty puzzle board, a locked box without a key, etc.). Children then spend time in a second room, where a critical object to complete the activity in the first room is located. They are then told that they will return to the first room and are typically given a choice of which object out of an array to bring with them to the first room. If children select the object that can be used with the original item in the first room, it is argued to be evidence of episodic foresight.

Suddendorf et al. (2011) proposed the two-rooms task to fit a set of stringent criteria for the measurement of future thinking, including the use of: (1) single trials, (2) novel problems, (3) different temporal/spatial contexts for the future-directed action, and (4) problems from different domains (Suddendorf et al., 2011). The logic behind this set of criteria is to avoid reliance on memory for

[1] Note that vivid gist-consistent false memories also meet the three criteria outlined by Perner given that the false memory involves the subjective recollection of a personal past event, albeit one that did not occur. With false event memories, one recalls a particular event that one *thinks* occurred in the past, the memory seems to originate from one's direct experience, and the false memory is available for re-experiencing. Phantom recollection of false memories involves a phenomenological experience of recalling a past personal episode.

specific events, relevant past learning, cuing, and specific behavioural predispositions. However, children may be able to solve this task based on memory processes alone and need not project themselves into the future room to select the correct solution. For instance, children could solve the two-room task by remembering what item was in the first room (e.g., empty puzzle board) and associating it with the items in the second room (e.g., puzzle pieces) rather than engaging in any sort of future simulation process. In fact, Atance and Sommerville (2014) found that memory abilities accounted for more variance than age in future thinking measured by the two-rooms task. In sum, although Suddendorf and colleagues' suggested criteria rule out some reliance on memory and linguistic abilities, the two-rooms task might not escape heavy reliance on episodic memory and associative memory processes as well as other future-oriented abilities such as planning.

Other future thinking tasks used with children rely on semantic knowledge in addition to memory processes. For example, Atance and Meltzoff's (2005) Picture-book task requires young children to select an appropriate item (e.g., water bottle, warm coat, raincoat) to take with them on a trip to various locations (e.g., the desert, a snowy mountain, a waterfall). Although this is a commonly used task to measure future thinking, children might simply rely on semantic knowledge to complete it. For instance, a child might understand that the script for going out into the snow includes putting on a winter coat or their semantic knowledge of the desert being a dry, hot place might allow them to select the water bottle as a suitable item to take to the desert without engaging in episodic simulation processes. Interestingly, children perform better for certain locations in the Picture-book task than others, suggesting that differences in semantic knowledge of the location, or direct experience, might influence their performance on this task (Mazachowsky, Atance, Mitchinson, & Mahy, 2020).

Another core feature of future thinking is uncertainty. Behavioural tasks measuring future thinking are often designed to account for uncertainty, but this uncertainty has also been captured in the delay discounting literature. In delay discounting tasks, an individual is asked to make a choice between a smaller, immediate gain or a larger, later gain. Typically, individuals discount the larger, later rewards due to the delay in time and the fact that the future gains are uncertain, often giving up larger sums of money or rewards in favour of a more certain, immediate reward. A large body of work on children's delay of gratification exists, a similar construct to delay discounting. In the classic marshmallow task, for instance, children are offered one marshmallow immediately or asked to wait 15 min for two marshmallows (Mischel et al., 1989). Recent evidence shows that children are less likely to delay gratification in circumstances where the later rewards seem uncertain such as in the case of an unreliable experimenter (Kidd et al., 2013). Thus, other literatures suggest that children are sensitive to uncertainty and it likely impacts their future reasoning and decision making.

As we will see in the following section, developmental studies generally find that future thinking is more difficult for children than episodic memory, though the locus of this difficulty – for instance, different cognitive processes versus different task demands – needs to be carefully interrogated.

Comparing episodic thinking abilities in development

Although extensive work with adults has compared episodic memory and future thinking, relatively little empirical work has looked at this relation in childhood. We review studies that have looked at the relation between episodic memory and future thinking next.

Several studies have used variations on the episodic or autobiographical interview (Addis et al., 2007) where participants are asked to report personally relevant past or future events given a cue or prompt. Most studies have been conducted with participants in middle childhood, finding that participants provide greater episodic detail about past compared to future events (Coughlin et al., 2014; 2019; Gott & Lah, 2014; Richmond & Pan, 2013).

In one early study, Busby and Suddendorf (2005) asked 3- to 5-year-old participants to report events that happened yesterday, will happen tomorrow, and events that *did not* happen yesterday and will not happen tomorrow. Children were required to provide only a minimal verbal response (e.g., "painting") and their responses were verified for accuracy by their parents. More than half of 4- and 5-year-olds accurately reported on all event types. The same was not true of 3-year-olds, who accurately reported past or future events only about 30 % of the time. There was a significant improvement from age 3 to 5 in children's ability to report future events, but the same was not found for past events, suggesting that future thinking shows later development than episodic memory. Busby and Suddendorf (2005) argued, however, that the two abilities emerge in tandem, sometime around the age of 4.

Hayne et al. (2011) used a similar task but provided participants with a visual timeline to help reinforce the concept of linear time. Five-year-olds provided more detailed accounts than 3-year-olds, although the two age groups did not differ in the *accuracy* of details provided. With the support of the visual timeline, 3-year-olds' accounts were richer than those found by Busby and Suddendorf (2005). Children's past and future descriptions did not differ in level of detail or accuracy. Hayne et al. (2011) argued that "the seeds of episodic memory and episodic foresight have been firmly planted by a child's third birthday" (p. 353). However, subsequent research on the relation between memory and future thinking suggests that they emerge on slightly different timelines.

Coughlin et al. (2014) investigated 5-, 7-, and 9-year-old children's and adults' past and future event *narratives*, and the phenomenological experiences associated with generating these narratives. Using a cue word paradigm (e.g., "Think of an event related to cake."), participants were asked to describe four types of events that varied in temporal direction (past vs. future) and temporal distance (one week vs. one year). All age groups provided fewer details for future compared to past events. The level of detail provided for past events predicted detail for future ones. Participants also rated their visual experience of temporally near events as clearer than distant events, but no such difference was found for past versus future events. Children rated future events as more difficult to think about than past ones, but the same was not true of adults. Because past and future narratives were probed in the same manner, differences in results cannot be attributed to task demand differences.

Another study by Coughlin et al. (2019) examined the ability of 5- to 11-year-old children and adults to generate personal past, personal future, and *fictional* events. Fictional events provide a useful comparison to determine whether children have a general difficulty with generating novel events, or whether difficulties are specific to generating *future* events. Participants' narratives were scored for episodicity according to the level of specificity provided (e.g., specific time and place) and contextual detail (e.g., imagery, emotions, thoughts). Children's future event narratives were lower in episodicity than their past and fictional narratives, which did not differ from one another. Children also required more prompts to help them generate future events compared to other types of narratives. These results suggest that children have particular difficulty generating *future* events. Children seem to struggle with the temporal component of generating future events, rather than the process of generating a novel event.

Two further studies found a relation between past and future event narratives. Richmond and Pan (2013) asked 3- to 5-year-old children to describe past and likely future events endorsed by their parents. Children provided more specific episodic detail for past than future episodes, and the amount of episodic detail was correlated for past and future events. Children's performance on the future event task also correlated with performance on a relational memory task (remembering associations between animals and locations), which the authors argued supports the constructive episodic simulation hypothesis, because relational memory allows the individual to recombine elements of past events to create a coherent future event representation.

In the second study, Gott and Lah (2014) also found a relation between performance on the episodic interview and relational memory. They measured both episodic and *semantic* details in past and future narratives generated by 8-, 10-, 14-, and 16-year-olds. The richness of future events increased with age and tracked with the richness of past events, indicating that these abilities continue to develop into adolescence. The researchers found a correlation between episodic interview scores and performance on a relational memory task that required participants to remember word pairs, arguing, like Richmond and Pan (2013), that these findings supported the constructive episodic simulation hypothesis (Schacter & Addis, 2007).

Several studies using the episodic/autobiographical interview have found a correlation between children's past and future event descriptions in terms of the level of detail they provide. This relation could be attributed to different factors (e.g., attention, verbal abilities) and does not necessarily indicate that past experience contributes directly to future thinking, as implied by the constructive episodic simulation hypothesis. Other studies have taken different approaches to looking at the relation between thinking about past and future events.

For instance, Prabhakar & Hudson (2019) developed a task to ask whether 3- and 4-year-olds use past information to guide choices in the future. Children learned a sequence of tapping three animals in a specific order to play a song. After a 10-minute delay, children were then asked to *remember* how they played the music game or *imagine* playing the game tomorrow. The animals either remained in their original locations (termed 'reinstatement' by the authors) or were presented in new locations (termed 'reconstruction'). Unlike past studies which had children select a single object for future use (e.g., Russell et al., 2010; Suddendorf et al., 2011), this task required them to bind together several elements (i.e., three animals, their locations and temporal sequence). Children performed better in the past than future condition, with four-year-olds outperforming three-year-olds. Performance was also better in the *reinstatement* condition, where the animals remained in their original locations. Because the past versus future versions of this task were effectively *identical*, differences in performance cannot be attributed to differing task demands, but instead suggest that different processes might be recruited when thinking about the past versus future.

Prabhakar and Ghetti (2020) used a similar task in where children were taught that placing three animals in a specific location and in a specific order would trigger a fun video. They were then asked to *remember* how they played before (past version) and *show* how they will play it tomorrow (future version).[2] Children performed worse in the future phase than in the past phase, but there was a significant correlation between the two. The design also allowed the researchers to look at whether children preserve spatial details and the temporal order in the two versions of the task. Children retained more spatial than temporal details overall. Notably, they provided more accurate *temporal* details for the past compared to the future. *Spatial* details did not differ between the two. In a follow-up study, additional contextual cues were introduced to help children connect past and future, which boosted 3-year-olds' performance. Based on these results, Prabhakar and Ghetti (2020) concluded that challenges with future thinking stem from difficulties retrieving temporal information from past experience. It is again notable that task demands were comparable between the past and future versions, suggesting that differences in performance might arise from differences in the (sub)processes that children engaged when reinstating the game in the past versus re-constructing for the future. There were clear differences in how well children preserved temporal (but not spatial) details between past and future events, highlighting that young children have particular difficulty with *temporal* understanding of the future.

In contrast to most other results, three recent studies did not find a relation between performance on memory and future thinking tasks. Cuevas et al. (2015) measured whether 3- and 4-year-olds could *recall* where a series of four objects were hidden, and the order in which they were hidden (a measure of memory). Children were given a version of the two-rooms task as a measure of future thinking. There was no significant association between performance on the memory and future thinking measures. On the memory task, children were better able to recall where specific objects were hidden than the temporal order in which they were hidden. The lack of relation between the recall and two-rooms tasks might have been driven by their individual task demands.

In another study, Cheke and Clayton (2019) examined the relation between episodic memory and future thinking in children aged 3

[2] An important caveat is that both Prabhakar and Hudson's (2019) and Prabhakar and Ghetti's (2020) studies would not meet Suddendorf et al. (2011) criteria for episodic future thinking (outlined above in "The Development of Future Thinking") because of their requirement for children to reinstate a repeated event as a future representation. However, as we will describe in Deconstructing episodic thought in development, these criteria may be too stringent and overlook many instances of future thinking. More significantly, perhaps, the events used in these studies lacked elements of scene construction and self-projection.

to 6. To measure future thinking, the researchers used a task in which children must override a current physiological bias (e.g., thirst) to select a refreshment in the future (e.g., salty crackers or water). Previous research has shown that children in this age range have difficulty overcoming the current bias to select what would normally be the more preferred option (Atance & Meltzoff, 2005; Mahy, 2016). Episodic memory was measured using a task in which children were shown pictures and scenes and were later asked various unexpected questions about them (e.g., "Which animal stole the treasure?"). There was no relation between performance on the future thinking tasks that required one to escape a current state to consider a future state and performance on episodic memory tasks. However, children performed so poorly on the future thinking tasks that floor effects may have limited the likelihood of finding a significant relation.

Most recently, Immel et al. (2022) administered various measures of episodic memory (Treasure box, Yesterday, and Cartoon recognition) and future thinking (Picture-book, Tomorrow, and Item selection) to four-year-olds. Correlations among the measures were weak with the exception of a significant positive correlation between the Yesterday and Tomorrow tasks, which both required children to name three specific activities they had completed at school the day before or expected to do the next day, and a negative correlation between the Cartoon recognition and Picture-book tasks. This study highlights measurement challenges within the domains of episodic memory and future thinking, suggesting that different tasks may not be measuring the same underlying ability or may be psychometrically weak.

It is likely that Cuevas et al. (2015) and Cheke and Clayton (2019) did not find a significant association between performance on memory and future thinking tasks because of differences in the way the two types of episodic thought were measured. Immel and colleagues' findings highlight the importance of considering task similarities and demands. Tasks that have similar demands are likely to be correlated as in the case of the Yesterday and Tomorrow tasks. To compare memory and future thinking, it will be important to carefully match tasks so that they only differ on the temporal direction (see the section *A Roadmap for Future Research*).

Together, studies comparing children's memory and future thinking reveal two main findings: earlier strengths on past than future versions of the task, and (generally) some association between the two. Developmentalists have acknowledged the intricate relation between episodic memory and future thinking (Atance & O'Neill, 2001; Suddendorf and Corballis, 2007), and as we have reviewed, a growing set of studies have looked at this relation in development. Although these results imply some relation between memory and future thinking, little work has probed the mechanisms that connect the two. Where theoretical accounts are considered, most researchers argue their results align with the constructive episodic simulation hypothesis whereby there is a unidirectional contribution of episodic memory to future imagination. These conclusions are likely premature. More work is needed to consider other theoretical proposals in light of developmental performance (e.g., scene construction; Hassabis et al., 2007).

For instance, theories arguing that simulation involves recombining elements from memory would argue that *recalling* past events is an easier process than *recombining* elements to construct novel simulations (Buckner & Carroll, 2007; Cheng et al., 2016; Schacter & Addis, 2007). Addis (2020) would likely argue that the stronger associative connections uniting elements of memories of past experiences makes them easier to represent than the relatively weaker associations between elements of imagined events, especially when we do not allow children to integrate schema knowledge. Others may argue that imagined events are more likely to happen in unfamiliar settings or contexts, and therefore may be harder to simulate than memories that have by their nature taken place in at least moderately familiar (experienced) contexts (Hassabis et al., 2007; McDermott et al., 2011). On these latter views, there is nothing inherently easier about simulating the future than the past. Atance and O'Neill (2005) argue that future thinking is more demanding because it involves more uncertainty and hypotheticality than memory. However, we would expect children to show earlier success at recalling past events than simulating *any* type of event that has not happened, including novel atemporal ones. All the explanations covered fail to account for the fact that simulating atemporal fictional events appears to be relatively simpler for children compared to simulating future ones (Coughlin et al., 2019). As we will discuss in subsequent sections, more research is needed to understand the mechanisms connecting memory and future thinking, and why future thinking is relatively more difficult.

In the following section, we review research from the developmental neuroscience literature that contributes to our understanding of the relation between memory and future thinking.

Default mode network activation when remembering vs. imagining in the developing brain

Many researchers have found that both episodic remembering and future thinking activate parts of the Default Mode Network (DMN; Addis, 2020; Addis et al., 2007; Spreng et al., 2009). The DMN comprises the medial prefrontal cortex, posterior cingulate cortex/precuneus, inferior parietal lobe, lateral temporal cortex, and hippocampal formation (Spreng et al., 2010). The DMN undergoes significant changes in functional and structural connectivity during development (Supekar et al., 2010) but developmental changes are not uniform across areas. Connectivity between the posterior cingulate cortex and medial prefrontal cortex was the most immature connection and structural connectivity between posterior cingulate cortex and left medial temporal lobes was weak to nonexistent in 7- to 9-year-old children's DMN despite adult-like functional connectivity (Supekar et al., 2010). Addis (2020) argues that the DMN underpins both memory and future thinking processes, but some of the evidence surrounding DMN functioning during development suggests that memory and future thinking processes recruit this system to different extents.

Even though children can engage in remembering and future thinking early in development (e.g., Atance, 2015; Atance & O'Neill, 2001; Ghetti & Lee, 2011; Hayne et al., 2011; Russell et al., 2010; Scarf et al., 2013), the developing DMN functionally shows a stronger relation to past remembering than to future thinking. For example, Østby et al. (2012) found that in 9- to 21-year-olds, functional connectivity of the DMN was related to the quality of past remembering but only marginally related to future thinking. Although the authors concluded that their results support the suggestion of a common neural substrate for memory and future thinking given that past remembering and future thinking (at least marginally) was related to the functional connectivity of the default mode network, these findings are somewhat problematic for theories proposing a high degree of overlap between memory and future thinking as one would expect that functional connectivity would be *significantly* and similarly related both to past remembering *and* future imagination. If memory and future thinking are indeed the same process with the same underlying components, as in Addis' (2020) single system view, then we would not expect differential relations between DMN functional connectivity and quality of past remembering and quality of future thinking.

Although many parts of the hippocampus are recruited during remembering and future thinking, the anterior hippocampus has been found to be more active when imagining the future compared with remembering the past (Addis & Schacter, 2012; Xu et al., 2016; but see Miloyan et al., 2019), particularly when future stimulations are specific and novel (e.g., unlikely future events). This provides some evidence for the idea that future thinking might rely on distinct processes (and neural substrates) especially in cases where future events are especially novel or uncertain. Research has also suggested that hippocampal damage in children does not equally impact past remembering and future simulation. Notably, although 9- to 18-year-old children with bilateral hippocampal damage struggled with episodic recall, they were able to construct fictious future scenarios suggesting that this process and its neural underpinnings might be distinct from those that support the retrieval of episodic details from the past (Cooper et al., 2011). Further, these results might suggest that future thinking is less impacted by hippocampal damage perhaps due to lower reliance on episodic recall and perhaps higher recruitment of scripts or semantic knowledge. These findings contrast with some adult research on hippocampal damage which has been associated with deficits in both autobiographical memory and construction of fictious or future scenarios (e.g., Klein et al., 2002; Tulving, 1985). However, more recent research suggests that hippocampal damage does not uniformly limit adults' future simulation (e.g., Addis & Schacter, 2012; Martin et al., 2011; Kwan et al., 2012; 2013).

Additionally, recent research has failed to find a relation between hippocampal volume in children and adolescents and the subjective quality of their remembering or future thinking (Østby et al., 2012) but the authors suggest that hippocampal function might not be essential for constructing coherent future scenarios but instead may play an important role in encoding future simulations into memory (Martin et al., 2011). Thus, hippocampal damage might be less detrimental to future thinking than to memory, and children might be able to compensate for hippocampal damage by recruiting scripts or using semantic knowledge.

At minimum, this body of research suggests that the developing DMN - specifically its functional connectivity and hippocampal function - might not equally support past remembering and future thinking during childhood and development (or at least not support them in an identical manner), which is what one might expect according to a single system account. However, the neuroimaging literature may better support theories that propose similar processes (and yet allow for distinct processes as well) involved in memory and future thinking including self-projection, scene construction, contextual associations, and constructive episodic simulation accounts.

Patient populations/ brain lesion studies

Studies examining individuals with brain lesions suggest that memory and future thinking are related. For example, the amnesic patient K.C. could not engage in mental time travel into the past *or* future, leading Tulving to propose a common capacity underlying both abilities (Tulving, 1985). In fact, K.C. could invent a story that he did not experience but was only able to do so after a prompt and an introductory sentence was provided to him (Rosenbaum et al., 2009). It seems that K.C.'s deficit laid in constructing *personal* episodes rather than a misunderstanding about times beyond the present. Similarly, other amnesic patients such as D.B. struggled with remembering past episodes and envisioning personal episodes in the future (Klein et al., 2002a, 2002b). Interestingly, D.B. understood the concept of time and could consider general societal problems that would be faced in the future.

Another patient, H.C., with bilateral hippocampal damage due to premature birth, produced fewer internal, central details of both past and future episodes. However, both H.C. and another bilateral hippocampal damage patient, Jon, showed competence in envisioning hypothetical and future episodes using the scene construction task by Hassabis and colleagues (2007) rather than the standard autobiographical interview (Schacter & Addis, 2007). In line with Tulving's early insights about K.C., this finding could be explained by an impairment in constructing personally relevant episodes (as measured by the autobiographical interview) or in self-projection, rather than difficulties with the more general simulation of episodes (as measured by the scene construction task).

Individuals with autism spectrum disorder

While most of the literature on memory and future thinking supports that both processes are impaired in children and adults with autism spectrum disorder (ASD; e.g., Lind et al., 2014; Terrett et al., 2013), there is some evidence to suggest that they might be distinct processes. For instance, Lind, Williams, Raber, Peel, & Bowler (2013) found in a group of adults with ASD that episodic memory was related to spatial navigation, but there was no relation between spatial navigation and episodic future thinking. If memory and future thinking were in fact one and the same or even relied on very similar component processes, then we would expect them to relate to other abilities in more or less the same way. The authors argued that navigation and episodic memory share cognitive underpinnings, which are different than the common cognitive underpinnings shared by episodic memory and future simulation (although they did not speculate about which specific cognitive abilities underlie each).

Lind and Bowler (2010) also found differences in perspective taking by individuals with ASD when remembering versus imagining. Participants reported primarily taking a first-person perspective when remembering past events but reported no difference in first- and third-person perspective in simulating future events. These differences in subjective experiences might hint at some differences in the processes or subprocesses underlying memory and future thinking, but do not allow us to pinpoint the mechanisms connecting these processes.

However, more recent studies with individuals with ASD seem to lend support to the scene construction hypothesis. Lind et al. (2014) collected three types of episodic descriptions from adults with ASD and typically developing controls: atemporal fictious episodes not involving the self, self-relevant future episodes, and personal past episodes. They also measured general narrative ability. This set of tasks allowed them to test the predictions of the scene construction (Hassabis & Maguire, 2007) and self-projection hypothesis (Buckner & Carroll, 2007). The scene construction hypothesis would predict relatively equivalent performance across all three tasks, whereas the self-projection hypothesis would predict difficulty on *self-relevant* tasks (memory and future thinking), but not the atemporal fictitious scenario. Consistent with the scene construction hypothesis, participants with ASD showed diminished performance across all three episodic tasks relative to controls, and performance did not relate to general narrative ability.

Summary

In this section, we reviewed behavioural and neurocognitive developmental findings, as well as findings from clinical populations including patients with brain lesions and individuals with ASD. Overall, developmental studies indicate that episodic memory is developmentally primary, emerging somewhat earlier in development than episodic future thinking. At the same time, most research examining the relation between memory and future thinking suggests that the two are not completely distinct. Children's abilities to recall past episodes and imagine future ones share much in common (e.g., Prabhakar & Ghetti, 2020; Prabhakar & Hudson, 2019).

Causal links between the two have yet to be established. Research looking at typical development has been fairly limited in scope and has not generally interrogated the mechanisms connecting memory and future thinking. Most developmental findings do not, therefore, speak to the theoretical debate about the underlying nature of different types of episodic thought. At present, most developmental research could be consistent with suggestions that episodic memory contributes to episodic future thinking, as in Schacter and Addis's (2007) influential constructive episodic simulation hypothesis, and with arguments that the two abilities share common underlying processes (e.g., scene construction; Hassabis et al., 2007; self-projection; Buckner & Carroll, 2007).

Moreover, neurological evidence suggests that memory and future thinking may be subserved by overlapping but distinct networks in the developing DMN. The developing DMN seems to support both memory and future thinking but its function is not identically related to memory and future thinking processes. Further, evidence from patient populations suggests impairments in both memory and future thinking, but this seems to depend on the task that is used to capture these abilities (e.g., scene construction versus autobiographical interview tasks). Finally, work with individuals with ASD indicates that while memory and future thinking processes are both impacted, they relate differently to other abilities such as spatial navigation and perspective-taking (as measured using a first- or third-person perspective), suggesting reliance on different subprocesses.

In sum, a complicated picture exists of the relation between episodic memory and future thinking. It is not clear that one factor alone (e.g., self-projection, scene construction, schema reliance) can explain or account for the differences between episodic memory and future thinking. Rather, evidence supports the idea that different subprocesses might support memory and future thinking or that they rely on the same subprocesses to varying degrees. In the following section, we analyze the separate components of episodic thought to provide a framework for understanding how different types of episodic thought emerge in development. Informed by theoretical work on the relation between memory and future thinking, we shift the focus from the question of what unites the two abilities to what sets them apart. What features of future thinking are challenging for children? We suggest that children's difficulty may not sit with future thinking *per se* but with some of the challenges unique to this type of thought – in particular, temporal understanding of the future. This framework helps to clarify discrepant findings in the different literatures and provides several directions for future research.

Deconstructing episodic thought in development

If we assume that memory and imagination are the same ability, we can ask why children generally show earlier success on tasks involving *past* compared to *future* episodic thinking. Is it because the future has not yet been experienced and is therefore uncertain, because of its inherently temporal component, or some combination? Or is it due to task differences? Some evidence also suggests that children are better able to simulate novel episodes that are *atemporal* compared to those that situated in the future (Coughlin et al., 2019). Understanding these differences requires deconstructing episodic thought into its separate components. A developmental approach allows us to piece apart these abilities, asking not what unites them, as has been the dominant approach in cognitive neuroscience, but what sets them apart. In this section, we consider a variety of components that contribute to episodic thinking, including self-awareness/self-projection, generic script, schema, and semantic knowledge, representations of space and setting, and temporal reasoning. These abilities may scaffold or constrain children's episodic thinking.

Episodic cognition is often characterized by its inclusion of a *what*, a *where*, and a *when* (Tulving, 1972; 2002; Russell et al., 2011). Given the central role of the self in episodic thought (Tulving, 2002), we suggest adding *who* as a property. In this sense, the dimensions of episodic memories or future simulations are like those included in models of episodic cognition in the language comprehension literature – termed situation models (van Dijk & Kintsch, 1983). Situation models are multidimensional representations of events that individuals build, typically when reading or listening to narratives, and include the dimensions of characters, objects, space, time, causation, and characters' goals (Zwaan & Radvansky, 1998). Research suggests that adults track and represent these dimensions to different degrees, but all are typically integrated in a coherent situation model. Although this work has made significant progress towards identifying how episodes are processed and updated, the approach of unpacking episodes into their separate dimensions to examine how they are represented has not been a major focus of research on episodic memory and future thinking. Most theoretical and empirical work has focused on single dimensions (e.g., space: Hassabis & Maguire, 2007; perspective: Buckner & Carroll, 2007) or whole episodes (e.g., Schacter & Addis, 2007).

Zwaan and Radvansky's (1998) framework may be useful for understanding the dimensions in children's episodic thought. We consider next how developments in different areas corresponding to these dimensions may constrain and enable different types of episodic thought. Although the various theories of the relation between memory and future thinking do not fall neatly into the categories of who, what, where, and when, they do offer insight into different component processes. For example, self-projection emphasizes the *who* aspect whereas scene construction emphasizes the *where* component.

In this section, we discuss the dimensions of who, what, where, and when in relation to existing evidence and prominent theories laid out in the first section. We argue that each dimension presents unique challenges, but children struggle particularly with the *when* dimension (temporal reasoning) as they attempt to project novel events into the future.

The "Who?" dimension: Self-awareness and self-projection

Episodic thought is most often focused on the self as we remember personal events from the past or imagine ourselves in future situations. Some of the leading theories described in the first section highlights the integral role of the self. For instance, Tulving's (1985) notion of autonoetic consciousness describes an awareness of the self mentally traveling through time to past or future episodes. Similarly, Buckner and Carroll (2007) assign a critical role to the experience of projecting the self to different times, places, and perspectives.

Developmentally, self-awareness has been identified as a precursor to episodic memory (Howe & Courage, 1993). A popular litmus test of self-awareness is the mirror self-recognition test. In this task, an experimenter surreptitiously puts paint on a child's face before the child is placed in front of a mirror. Children who reach for the paint on their face when they see their reflection are judged to have a sense of self – something children begin doing around 18 months of age.

Although mirror self-recognition is typically achieved around 18 months (Anderson, 1983; Courage et al., 2004), children do not show *delayed* self-recognition until much later. In a series of studies, Povinelli and colleagues filmed or photographed as an experimenter covertly placed a large sticker on children's heads (Povinelli et al., 1996; Povinelli & Simon, 1998). Children were then shown the video or photograph after a delay of three minutes or one week. Although most 4- and 5-year-olds reached for the sticker on their head, most 3-year-olds did not. These results suggest that children do not show awareness of the *temporally extended* self until age 4, which is an essential component of self-relevant future thinking. (It is not yet clear when children achieve an understanding of others as temporally extended beings.) However, children show evidence of episodic memory much earlier , and as we will review in the subsection, *The "When?" dimension*, temporal reasoning begins to develop around 4 years of age. Temporal reasoning may therefore be a rate-limiting factor when it comes to episodic thought, rather than self-awareness per se.

The "What?" dimension: Scripts, schemas, novelty, and the contents of episodes

We take a broad conceptualization of the "*What?*" dimension to consider the ability of episodic simulation independent of dimensions such as *who* the episode is about and *when* it occurs in time. How do children simulate *what happens* in episodes?

Children begin simulating novel episodes from early in development in the (externalized) form of pretend play, and these episodes often follow familiar scripts (Bretherton, 1984). In research on episodic cognition, cases where children could rely (partly or entirely) on familiar scripts and schemas are often excluded. For instance, according to Suddendorf et al. (2011) criteria, children cannot rely on scripts, schemas, or semantic knowledge, and must demonstrate future thinking on *novel* problems. However, in setting the bar here, researchers may create situations that are highly demanding and not an accurate reflection of everyday episodic thought even in adulthood.

In fact, Addis's (2020) single system theory includes a central role of schema knowledge in episodic cognition. On Addis's view, simulating events that are higher in novelty (e.g., novel future events) involves a greater reliance on schema knowledge than remembering events that occurred in the past. According to Addis, schema reliance operates on an opposite continuum to *associative strength*. Constituents of event simulations from *remembered* events have stronger associative histories, making schemas less necessary. In contrast, *imagined* novel future events include constituents with weak associative histories, implicating schema knowledge. These opposing roles of associative history and schema knowledge proposed by Addis could explain why remembering past events is easier (and earlier developing) than imagining future events but does not explain why imagining atemporal fictional events (that should similarly rely on schemas and have a weak association) is easier than future ones (Coughlin et al., 2019). Although more empirical work in support of Addis's account is needed, her work suggests that it may be both premature and overly stringent to argue that children should not be credited with future thinking in cases where they can integrate script or schema knowledge. Many cases of adult event cognition rely on schemas. For instance, research with adults suggests that activation of event schemas is part of *processing* novel event narratives (Baldassano et al., 2018).

More work is also needed in development to understand children's episodic simulation. What role do script and schema knowledge play when children imagine novel events? Early research on children's episodic memory focused on the integral role of scripts. For instance, children infer that future episodes will follow a routine script after only a few exposures to invariant episodes (Hudson et al., 1992), and children may in some cases abstract away a script after a single occurrence (Fivush et al., 1984). This work highlights the close connection between episodic memory and script knowledge and suggests that by excluding cases in which script or schema reliance is possible, we may be overlooking many instances of episodic thought in development.

The "Where?" dimension: Scene construction and the space and setting of episodes

Leading theories of episodic cognition assign a central role to the space or setting in which an episode occurs. For instance, Hassabis and colleagues' (2007) scene construction theory argues that memory and imagination are connected by a mutual need to mentally construct a scene in which events take place. McDermott and colleagues' (2011) contextual association hypothesis purports that events are more easily imagined in familiar settings. Consistent with the predictions of these theories, a series of studies by de Vito et al. (2012) revealed that scene imagery was more integral to adults' episodic thinking than either self-relevance (*who*) or self-projection in time (*when*).

The role of scene imagery or construction has received little attention in research on children's memory and future thinking. Research on children's narrative comprehension suggests that the ability to construct detailed spatial representations of *novel* story settings emerges in middle childhood between the ages of 7 and 9 (Barnes et al., 2014; Nyhout & O'Neill, 2017). Consistent with the contextual association theory (McDermott et al., 2011), we might predict that children will more readily imagine novel episodes in *familiar* compared to unfamiliar settings. Considering that many studies of future thinking involve children having to imagine an event in the lab that will occur the following day (e.g., two-rooms task), providing children with different levels of exposure to and experience with the lab setting could lead to meaningful changes in performance.

The "When?" dimension: Temporal reasoning and episodic thought

Children's understanding of the nature of time by definition constrains their episodic future thinking, as implicit in questions of "what will happen…?" is an understanding that events extend along a timeline into a future that has not yet occurred. Zhang and Hudson (2018) found that preschool aged children understand the term "yesterday" better than the term "tomorrow", presumably due to the cognitive demands of thinking about an uncertain future. Hoerl and McCormack (2019) propose that temporal understanding undergoes significant qualitative changes in the first five years of life, progressing from a simple *temporal updating system* that allows infants to update their representations of the environment to a full *temporal reasoning system* around four to five years that allows children to think and reason about time (e.g., to represent particular times and temporal order and use tense in language). Around two to three years, children are argued to be in an intermediate phase where they are beginning to represent situations outside of the present but may fall back on the temporal updating system and may be unable to consider the temporal order between episodes. Children may show earlier success on episodic memory tasks if thinking about time is not an essential component. In contrast, thinking about the future may inherently recruit their nascent temporal concepts and reasoning abilities.

Young children have difficulty reasoning about the past when asked to make temporal judgments about order. Tillman et al. (2017) found that 3-year-olds had difficulty with making judgments about the relative order of several past and future events. Young children seem to have difficulty ordering events, even if those events are widely separated in time (e.g., Busby Grant & Suddendorf, 2009). The ability to order events shows substantial improvement over the later preschool years (e.g., Hudson & Mayhew, 2011; Tillman et al., 2017). In sum, children's temporal reasoning improves across the preschool years, which directly supports their ability to engage in future simulation.

Recent studies reviewed under *Comparing Episodic Thinking Abilities in Development* suggest that children have difficulty with the notion of the future generally, as they can simulate atemporal/fictional events more easily and at a younger age than future events. Thus, difficulty with future thinking seems to stem from a difficulty with situating events on a timeline in the future relative to the present rather than with simulating events that have not happened. Similarly, Beck and colleagues (2006) have argued that children have more difficulty reasoning about *counterfactual* episodes when the temporal component is made salient. They argue that children can engage in atemporal counterfactual thinking earlier "by thinking about the counterfactual event in isolation, without recognizing its temporal relationship to the actual event." (Beck, Robinson, Carroll, & Apperly, 2006; p. 423). It may be that children succeed earlier at episodic memory tasks because the temporal dimension is less integral.

Research on more basic conceptualizations of what, where and when involving remembering *what* objects were hidden *where* and in what order (*when*) reinforces the point that the temporal (*when*) dimension presents a particular challenge for children. For instance, children recall the *what* and *where* dimensions of events earlier than the *when* (Cuevas et al., 2015), and preserve more details about *where* objects were located than the relative order of *when* they were presented, especially for future episodes (Prabhakar & Ghetti, 2020). However, these tasks required children to remember temporal *order*, rather than exclusively temporal direction (past and future), which likely places different types of demands on children's temporal reasoning and executive abilities.

Theories of the relation between memory and future thinking are mixed in the role they attribute to the temporal dimension of episodic thought. As reviewed by Schacter et al. (2012), some theories argue for an atemporal perspective on episodic thought (i.e., future and atemporal simulations are equal), such as the self-projection and scene construction hypotheses. Others, including theories of mental time travel, argue for a critical role of temporal representations. A recent developmental taxonomy of mental time travel, introduced by Gautam et al. (2019) places an emphasis on temporal representations, arguing that some types of mental time travel are easier than others because they have lower levels of temporal embedding. Overall, much of the difficulty children have with reasoning about and representing events in the future seems to come from the notion of "future" itself, rather than factors such as simulating a novel event, constructing a novel scene, or self-projection. Thus, one of the key abilities that supports as well as constrains children's future thinking appears to be temporal reasoning.

Other factors

Additional features of future thinking distinguish it from other types of episodic thought. For instance, when describing or reasoning about future events, children are often asked about events that *will* happen and thus are asked to reason about a constrained set of possibilities (or often even just one possibility). In contrast, when reasoning about fictional or atemporal events, a wider space of possibilities is available in which to reason about events that *might* or *might not* happen. The distinction between alternatives to reality in terms of their possibility and necessity – events that will, might, or must happen – is referred to as modal cognition. Past research shows that children often conflate what *could not* happen with what *is unlikely to* happen, and what *will* happen with what *should* happen (e.g., Shtulman & Carey, 2007; Shtulman & Phillips, 2018). These patterns reflect difficulties in modal reasoning. Although speculative, it may be the case that asking children to reason about a constrained set of future possibilities – where experimenters are looking for a single correct answer - is more demanding than asking them to think about events with fewer constraints.

However, with fewer constraints comes more uncertainty. As others have highlighted, the future is inherently more uncertain than the past (Atance & O'Neill, 2005). Future thinking tasks with children often feature a highly certain future (e.g., two-rooms task), but this may be at odds with children's experience with the future. Uncertainty and the space of possibilities are two features that have not been well controlled in past studies of future thinking. In the case of delay discounting (reviewed in *The Development of Future Thinking*), the dimensions of certainty and temporality are conflated, with the participant asked to choose between a certain present and an uncertain future. Research is needed to better compare children's memory and future thinking along the dimension of uncertainty, comparing perhaps a highly certain future (e.g., scheduled event) to an uncertain one, and a certain versus uncertain past (e.g., where some detail of a past event is unclear).

Along with differences in modality and uncertainty, memory and future thinking also involve differences in phenomenology. Relatively little research has investigated the subjective experiences of future thinking in development (cf. Coughlin et al., 2014), compared to extensive research on the phenomenology of remembering particularly with respect to phantom recollection (Brainerd et al., 2003).

More research is needed to compare memory and future thinking in terms of modal reasoning, uncertainty, and their phenomenology.

Putting it all together: The episodic simulator

When considering the available evidence that has compared different types of episodic thought, we are left with an incomplete picture. Whereas most theories of their relation argue for more commonalities than differences, and much of the empirical data support the idea that memory and future thinking are related, developmental data suggest that there are at least some differences between these processes. Generally, children show better and earlier success at episodic memory tasks than future thinking tasks. Are these differences artefacts of the tasks used, or do they point to different processes underlying memory and future thinking? And how do we reconcile these findings with the many theories arguing that memory and future thinking are united processes?

We suggest that the answer lies in the level of processing at which we consider episodic thought. What all types of episodic thought *share* is a need to be bound and processed by a single, central *episodic simulator*. We argue that episodic simulation – the playing of an episode to conscious awareness – is a common (and unitary) process involved in memory, future thinking, and other types of episodes. This means that the subjective experiences of remembering and imagining are remarkably similar. On this view, a single episodic simulator[3] takes as input a range of episode types – episodic memories (both real and false), future episodes, counterfactuals, narratives from other perspectives, and atemporal episodes, to name a few.

Where memory and future thinking diverge is in the constellation of subcomponents that underlie them. In the previous section, we unpacked episodic thought in development and discussed four key dimensions– *who, what, where,* and *when*. These different dimensions represent different subcomponents that are called upon to differing degrees depending on the experimental task and type of thought employed. Children struggle with representing events along some of these dimensions, which may present challenges for certain types of thought more than others.

Currently, little is known about how children meet the challenge of integrating across dimensions, as limited work has considered the separate dimensions alongside one another (cf. Cuevas et al., 2015). However, research on children's ability to construct atemporal events (e.g., Coughlin et al., 2019) and tell fictional narratives (e.g., Hudson & Shapiro, 1991) suggests they are adept at integrating across dimensions before they achieve success on a range of *future* thinking measures.

To borrow from Suddendorf and Corballis's (2007) theatre metaphor, we may consider the episodic simulator to be doing the job of a stage director. The episode that is played to conscious awareness is the output, as in the stage production performed for an audience. However, the components that go into different types of productions may be wildly different. Episodic memory may be akin to actors re-enacting a historical event. We might liken future thinking to a range of performance types, depending on their adherence to a schema, degree of familiarity, and certainty, from rehearsed productions that follow a script to improvisation. The entire production will run more seamlessly when one can use existing sets, props, and actors compared to when one must build and recruit new ones.

The ease with which episodes are simulated depends on a variety of factors and constraints including *where* an episode takes place, *when* it takes place, *whose* perspective it happens from, *what* happens, the degree of familiarity, and the degree of certainty. Some of

[3] For related arguments, see the episodic buffer in working memory (Baddeley, 2001) and episodic binding (Olson & Newcombe, 2014; Russell et al., 2011).

these factors present a bottleneck. It is up to future research to provide a fine-grained comparison of memory and future thinking, controlling along these various dimensions to investigate what it is about future thinking that is relatively more challenging for children.

Considering the systems involved in episodic thought

Are memory and future thinking a single system or two distinct systems? The view that we have outlined here, built from the developmental evidence, is that they are integrated by a single system that "plays" episodes, but rely on different subcomponents or underlying processes to a greater or lesser extent.

Based on inconsistencies in tasks used, there may be as much variation within the abilities of memory and future thinking as there is between them. As we have discussed, and in line with past proposals, both memory and future thinking likely call upon a common set of abilities including episodic memory, temporal sequencing, scene construction, and schemas. Future thinking may be more challenging (and later developing) because of the demands it places on temporal reasoning (especially in tasks where the temporal dimension is more integral or salient) and reasoning in the face of uncertainty. The future is replete with possibilities and this might pose a particular challenge for a young child's cognitive capacities.

Multiple lines of evidence provide insight into these subcomponents of episodic thought including: (1) developmental research suggesting that memory and future thinking emerge on slightly different timelines, possibly driven by limitations in temporal reasoning, (2) neurocognitive work supporting the idea that memory and future thinking rely on distinct but overlapping networks, and (3) behavioural work with individuals with ASD pointing to different correlates of memory and future thinking. The developmental lag between young children's performance on memory and future thinking tasks may be explained by the protracted development of temporal reasoning, and differential demands on factors including schema reliance, scene construction, and reasoning in the face of uncertainty. We suggest that episodic thought should be viewed as one *dynamic* system that integrates several subcomponents that differ in their engagement in memory and future thinking. These subcomponents, represented by the who, what, when, and where framework, are bound together to produce coherent episodic representations. Until children can recruit a robust temporal reasoning system (versus, perhaps, a temporal updating system; Hoerl & McCormack, 2019), their ability to reason about episodes in which the temporal dimension is particularly salient will be limited.

A roadmap for future research

There are many fruitful directions for future work that could shed light on the theoretical debate on the relation between memory and future thinking and could contribute to our knowledge about the mechanisms involved in the development of future simulation.

Developmental research has the potential to contribute to the theoretical debate surrounding which subcomponents are involved in both memory and future thinking. Clearly, these two abilities are related across the lifespan, but studies should attempt to test and tease apart the relative contributions of subcomponent abilities such as self-projection, scene construction, and schema reliance. Features that distinguish memory and future thinking are often confounded in studies comparing the two abilities by factors such as the degree of familiarity with aspects of the event (e.g., the scene, the causal connection) and the degree of certainty about what has or will occur.

A developmental approach will also lead to theoretical precision, as it provides the distinct advantage of being able to examine how various abilities develop over childhood, how the relation between these abilities changes with development, and how they might contribute to children's ability to simulate the future at different points in development. Here we highlight what we consider to be important and promising directions for future research by breaking down episodic thought into various subcomponents. In all cases, researchers could cross the dimension of interest with temporal direction (past vs. future). For each of the following dimensions, multiple different dependent measures could be used, ranging from tasks with limited response options (e.g., two-rooms task) to open-ended tasks (e.g., autobiographical interview-style narrative tasks). The precise task used will depend on the age of interest, with notable challenges associated with each type of measure. Whereas forced-choice tasks may be accessible to preschoolers, they are limited in scope and offer a narrow view of the episodic thinking young children engage in. And while tasks soliciting event narratives offer a more detailed view of children's episodic thinking, they are limited by children's verbal ability and working memory, and are therefore inappropriate for younger children.

Self projection. Something that distinguishes past vs. future episodes in most studies is that participants have experienced the past event but not the future event. To examine the role of self-projection children could be asked to engage in descriptions of past and future events for themselves and for another same-aged peer, looking at differences in the degree of episodic detail in their descriptions and their use of first-person pronouns to examine differences in the role of the self in past and future scenarios.

Familiarity. Similarly, future events are more likely to involve unfamiliar places, events, and people than past events. Studies could control for the degree of familiarity by asking children to imagine past vs. future events in familiar and unfamiliar places.

Uncertainty and modal reasoning. The very notion of the future includes an element of uncertainty, whereas we are (usually) more certain about what happened in the past. Studies could control for uncertainty by comparing an uncertain past to an uncertain future by, for instance, asking children to think about what might have happened at their school last night vs. what will happen tonight when the children go home (e.g., Did/will any animals visit the playground? Did/will anyone clean inside the classrooms?). Closely tied to the notions of uncertainty and modality is the question of *how many* possibilities could occur. Children could be asked to compare a past vs. future for which there is a fixed number of possible outcomes.

Much of the research has focused on how children use information about past events from memory to project and imagine themselves in similar (or identical) situations in the future (e.g., Coughlin et al., 2014; Prabhakar & Ghetti, 2020). In these highly constrained cases, uncertainty in future episodes should be low. Little is known about how children simulate future episodes that are highly novel or unfamiliar. In the absence of direct past experience, it would be interesting to observe how children go about constructing future scenarios and which processes they rely on. Here, we may see greater reliance on schema knowledge, consistent with Addis's (2020) proposal that schema knowledge is more likely to be called upon when simulating highly novel events.

Scripts and schemas. Studies could compare the extent to which past versus future episodes follow a script or rely on semantic knowledge. Although many studies of future thinking have attempted to reduce children's use of semantic knowledge (Atance & O'Neill, 2005), a direct comparison of past versus future episodes in this respect is needed. It would also be valuable to determine whether and when children conceptualize the past and future as specific instantiations rather than generic types of episodes.

Scene construction and spatial reasoning. Extensive work with adults suggests that the ability to represent features of an event's spatial context, captured by the broader notion of scene construction, is shared by different modes of episodic thought (Maguire and Mullally, 2013). Prabhakar and Ghetti (2020) directly compared children's recall of spatial elements of past vs. future scenarios (which animal was located where), finding no significant differences. This work suggests that spatial elements of event simulation may not distinguish memory and future thinking. Rather, it may be that contextual differences – captured in the sections above on uncertainty and familiarity – are factors that separate the two modes of thought (McDermott et al., 2011).

After we strip away all the factors we have just outlined – factors that commonly characterize tasks of future thinking but do not characterize future thinking itself – what are we left with? If studies controlling along the dimensions and factors here find no significant differences between past and future versions of each task, it will suggest that memory and future thinking are indeed united processes. However, there remains the possibility that future thinking is just more difficult, and later developing, because it is about the *future*. Here, we consider a final factor that should be a key focus of future research.

Temporal reasoning. Children have difficulty reasoning about time well into the school years (Hoerl & McCormack, 2019). Current research suggests that children struggle with the notion of the future and may have more difficulty reasoning about temporal sequences projected into the future compared to identical sequences in the past (Prabhakar & Ghetti, 2020). More work is needed to compare children's ability to sequence events and reason about episodes in the past vs. future, holding all other features of the situation constant. Prabhakar and Ghetti's (2020) work comes the closest to achieving a level of control that allows us to compare memory and future thinking, but lacks an experiential (or first-person) element that characterizes much past work on mental time travel with both children and adults. Future studies could use a version of Prabhakar and Ghetti's task that involves the self more directly. Alternately, many future thinking tasks could be easily adapted so that they would have past versions to compare children's performance on the past and future versions of the same task. Studies might also compare temporal distance in the past and future (recent vs. distant events).

Whole episodes: Remembering and forgetting: We also suggest that past versus future versions of tasks could be compared to see what children remember and what they forget over time. For instance, after being told a narrative account of an episode that *has* happened versus one that *will* or *might* happen, what do children remember after a delay? Do episodes become degraded, with certain elements (who, what, where, when) retained more than others? And are future episodes ever falsely recalled as having happened? If not, it could suggest that phenomenological differences in remembering versus imagining are integral to the way episodes are stored.

What is clear to us is that a developmental approach to these unanswered questions will be critical. A key advantage of a developmental orientation is the ability, theoretically and empirically, to pull apart the different demands of these tasks and abilities and to examine their subcomponents as they emerge. Having some knowledge that certain processes emerge earlier than others might be key in testing the underlying processes supporting the early development of memory and future thinking.

Conclusion

Future simulation is a complex process that likely relies on many abilities including recombining elements from episodic memory, scene construction, self-projection, and temporal reasoning. Thus far, most theories have been developed in the adult literature based on research findings with adults, without much consideration of developmental data. The main focus of this work has been on what *unites* memory and future thinking with proposals either pointing to common underlying processes (e.g., scene construction, self-projection) or to a unidirectional contribution of episodic memory to future thinking. Our focus has been instead on what sets these abilities apart. We have argued that developmental research has a critical role to play in these debates, but that much more work is required to delve into the mechanisms underlying memory and future thinking. The available developmental research suggests that future simulation emerges slightly later than and perhaps relies on episodic memory. At minimum, we suggest that memory and future thinking rely on a shared *episodic simulator* that plays episodes to conscious awareness, but the two abilities are subject to different constraints based on the subcomponents that play into them. An open question is whether there is something difficult about future thinking per se, or whether children's difficulty has to do with specific task features. Based on the available data, we argue that temporal reasoning involving projecting events in the future seems to pose a particular challenge for children. Future research should attempt to test the claims of theories that have been put forward to account for the development of episodic foresight and future simulation. The field of episodic cognition has much to benefit from the integration of adult findings with research on its development in early life.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to

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