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Emergence of Human Episodic Memory and Future Thinking

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Abstract

Episodic memory and future thinking are crucial capacities that emerge and undergo substantial development during the preschool years. However, their relationship has rarely been examined in tandem within development. Narratives were elicited from 3-, 4-, and 5-year-old children \((n = 36)\) to assess episodic memory and future thinking. The richness of children’s memory and imagined future episodes was measured by the number of episodic details in their narratives. Non-narrative measures of episodic memory and future thinking were also administered. As hypothesized, children’s ability to recall personal events and generate possible future events underwent substantial development during the preschool years on three of the four memory and future thinking tasks, with the exception of narrative future thinking. Nevertheless, narrative memory and narrative future thinking remained correlated even after controlling for working memory, inhibition, verbal ability and narrative fluency. These results suggest the possibility of a common neurocognitive basis underlying narrative memory and narrative future thinking in preschool development. Mental time travel and scene construction are identified as possible common mechanisms underlying this relationship.

*Keywords*: episodic memory, future thinking, preschoolers, development, executive function, narrative, scene construction, mental time travel
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Episodic memory is inherently reconstructive. As no brain region stores memories in their entirety, details of personal episodes such as a past birthday—the candles on the tiramisu cake, the weather in the backyard, the faces of family members present—are stored in widely distributed brain areas and are recombined at each recall to create a relatively coherent scene (Hassabis, Kumaran, Vann, & Maguire, 2007; Schacter & Addis, 2007). Consisting of rich spatiotemporal detail, these episodic or autobiographical memories are not veridical copies of an original experience but rather imperfect regenerations, pieced together from subsets of the scene’s perceived and interpreted features. Although the exact process by which elements are recalled and indexed together is not well understood, perceptual details are often stored near their site of processing (e.g., visual cortex, auditory cortex) while more complex details and inferences may traverse higher order regions (e.g., association cortices). Episodic remembering thus recruits multiple brain areas, often the prefrontal cortex, medial temporal structures (e.g., hippocampus, parahippocampal gyrus), and certain posterior brain regions (e.g., retrosplenial cortex) (Buckner & Carroll, 2007).

The reconstructive nature of episodic memory is now considered an essential feature of a system adapted for prediction, recombination, and generation of novel possibilities, contributing to a larger reconceptualization of the brain as potentially adapted for “prospective” thinking (Schacter, Addis, & Buckner, 2007). Episodic future thinking—the ability to project oneself to the future to pre-experience an event—heavily engages spatiotemporal context and visual imagery, though not as extensively as memory recall for concrete events (Viard et al., 2011). Strikingly, much of the neural network...
supporting episodic memory (e.g., prefrontal cortex, hippocampus, parahippocampus gyrus, posterior regions) is also engaged during future thinking (Hassabis et al., 2007; Schacter & Addis, 2007). Functional neuroimaging reveals considerable overlap of activated regions when adults separately imagine a plausible future event and elaborate on a past autobiographical event (Addis, Wong, & Schacter, 2007). By representing events across common activation patterns in the brain, memory traces support prospective thinking by providing the raw materials from one’s reservoir of personal experiences to be recombined into new simulations of the future (Addis et al., 2007; Suddendorf, 2010a).

The medial temporal lobe (MTL) appears to be a major brain region involved in reconstruction during episodic memory and future thinking. The hippocampus, a core MTL structure long established to be integral to episodic memory, has been proposed to be a key region involved in binding disparate elements together during mental construction of past and future scenarios (Hassabis & Maguire, 2007). In a demonstrative study, amnesic adults with severe bilateral hippocampal damage and deficient episodic memory were also significantly impaired at imagining new experiences (e.g., “a day at the beach”), despite spared general world knowledge (Hassabis et al., 2007). Amnesic individuals reported imagined scenarios that were fragmented and markedly impoverished in spatial coherence. These individuals not only lose access to certain life experiences in their past, but also have marked difficulty at projecting themselves in future time-space.

In the strongest evidence yet of the MTL’s role in episodic memory and future thinking, the extent of episodic memory and future thinking impairment in adult
individuals has been shown to be highly and positively correlated (Race, Keane & Verfaellie, 2011). In Race et al. (2011), eight amnesic adults with MTL damage were asked to provide narratives about several specific possible future events and personal past events (e.g., graduation ceremony, winning the lottery). The richness of their episodic memory and future narratives, as measured by the total number of episodic details (i.e., specific details of events, places, times, perceptions, and thoughts/emotions), was significantly impoverished compared to that of healthy controls. These deficits in memory and future thinking were not explained by working memory and narrative construction demands of the tasks as amnesic individuals demonstrated normal performance when asked to tell stories about random detailed pictures. Furthermore, memory and future thinking impairments were highly correlated ($r = 0.75$). Additionally, one patient with purely hippocampal lesions demonstrated memory and future thinking deficits that resembled those with more extensive MTL damage, suggesting that hippocampal damage alone may be enough to impair both abilities. The claim that memory for the past may contribute to imagination for the future has also been supported by demonstrations of parallel and potentially correlated deficits in episodic remembering and future thinking in older adults, in schizophrenic individuals, and in clinically depressed adults (Addis, Wong & Schacter, 2008; Buckner, 2010; Sumner, Griffith, & Mineka, 2011).

**Typical Development of Episodic Memory and Future Thinking**

Another approach to examining whether episodic memory and future thinking share some fundamental underpinnings is to study these abilities in development. The possible relationship between memory and future thinking has been a source of explosive
interest in the cognitive psychology and neuroscience field in recent years. However, few studies have examined memory and future thinking in tandem in children. Children represent a population in which episodic memory and future thinking naturally vary and improve, particularly between the ages of three and five. Episodic memory and future thinking may develop similarly if they also rely on the same neurocognitive resources. An attempt to test this claim requires further examination of both capacities in typically developing children. Developmental research can offer crucial and influential contributions to the study of the future thinking and its link to memory, especially as the majority of studies have been mainly limited to healthy adult or clinical populations.

As mentioned previously, episodic memory appears to emerge and undergo substantial development between the ages of three and five. By their first birthday, children are able to retain nonverbal memory of novel props they engaged with in conjunction with an experimenter in a past episode (Bauer, Hertsgaard, & Dow, 1994; McDonough & Mandler, 1994). Despite the demonstration of early nonverbal memory, mature episodic memory is not considered to emerge until at least three years of age. Mature episodic memory involves “re-living” a previous experience and is typically accompanied by autonoetic awareness (Wheeler, Stuss, & Tulving, 1997), which refers to a subjective sense of familiarity that one has experienced this event before (Buckner & Carroll, 2007).

Studies of amnesic individuals with severely impaired autonoetic awareness have suggested that the medial temporal lobe and the frontal lobe, particularly the prefrontal cortex, contribute to awareness of self in time (Wheeler et al., 1997). Very young children with naturally premature frontal lobes also lack this continuous causal
understanding of events and themselves in time (Naito & Suzuki, 2011). In the early preschool years, young children’s episodic memories are fragile, as reflected by frequent source errors, or memory errors regarding how one first acquired knowledge of a fact. With age, children become less susceptible to these source errors, possibly as they become more aware of themselves and are better able to discriminate among different time periods (Friedman, 1992).

Autonoetic awareness also accompanies future episodic thinking when one mentally places oneself in the future and more generally engages “mental time travel” beyond the immediate present (Buckner & Carroll, 2007). Argued to be uniquely human, the cognitive faculty to project oneself in either temporal direction allows us to mentally re-live past experiences and pre-live future ones. While remembering certain routinized or scripted information does not require mental time travel, re-experiencing the past and pre-experiencing the future are uniquely self-referential, often involving a visuospatial component (Hassabis & Maguire, 2007). Episodic thinking also requires an understanding that one’s personal past differs from and can contribute to the present, and that the future can be different from and affected by one’s current states.

Like episodic memory, the ability to consider one’s personal future emerges during the preschool years (Atance & O’Neill, 2005). Atance and Meltzoff (2005) define mature episodic future thinking as the ability to imagine a future state even when the state conflicts with the current self. Atance and Meltzoff (2005) tested this capability by presenting preschoolers with a picture book trip-planning task. The task involved color photographs of scenes unlikely to have been encountered yet by preschoolers (e.g., sunny desert, rocky river, long dirt road, snowy forest). The experimenter asked children to
describe the picture, pretend that they will walk across the scene, and choose the correct item out of three choices that they would need to bring with them (e.g., sunglasses, band-aids, water, winter coat). Only one of the three choices reflected a future physiological need (e.g., sunglasses for the sunny desert condition).

Atance and Meltzoff (2005) found that 3-, 4-, and 5-year-olds chose the correct item above chance. Differences between 5-year-olds and 3-year-olds were significant (92% vs. 61%), but not between 5-year-olds and 4-year-olds (92% vs. 75%). Furthermore, performance of three- and 4-year-olds, but not 5-year-olds, was negatively affected when one of the two distracters included an item that was semantically associated to the scene but irrelevant to a future need (e.g., ice cubes for the snowy forest condition). Though young children of 3 and 4 years are capable of causal reasoning, they are less able to fully anticipate certain situations than 5-year-olds and often mistake the necessary object to be one with the most salient connection (i.e., semantic association) to the scene. Examination of verbal explanations demonstrated that older children also exercised a higher proportion of future terms in their language than 3-year-olds to describe why they would need the item for the trip. Children’s frequency of “future talk” was not related to general language ability, suggesting that the level of recognition for future possibilities need not rely on language maturation (Atance & O’Neill, 2005). Despite having the language capacity to describe actions and motivations, 3-year-old children do not appear to have as firmly developed a sense of a future self as their 5-year-old counterparts.

Examination of children’s episodic memory and future thinking within limited temporal spans (e.g., yesterday, tomorrow) demonstrates improving understanding of
event sequence with age, which, in turn, may support more accurate mental time travel. Children begin to understand temporal terms such as “yesterday” and “tomorrow” by the third year of age, indicating that by this age, they are aware of basic temporal differences among the present, past and future (Atance & Jackson, 2009; Busby & Suddendorf, 2005; Suddendorf, 2010b). However, the ability to generate specific answers about things that occurred yesterday and that could happen tomorrow, as well as the accuracy or likelihood of those answers as rated by parents, is not reliable at 3 years and improves in both temporal directions by the 5th year (Suddendorf, 2010b). Suddendorf (2010b) found a significant positive association between the number of likely correct answers on “yesterday” and on “tomorrow” questions, suggesting that episodic memory and future thinking may be related. Grant and Suddendorf (2009) administered a task that involved simple timelines of past and future and asked preschoolers to place pictures representing different events at appropriate places of 24 hours, 12 months and several years. Five-year-olds were better able to differentiate among temporal categories of 24 hour-, 12 month- and several year-long intervals when compared to 3- and 4-year-olds (Grant & Suddendorf, 2009).

**Frontal Lobe Development and Executive Function**

What contributes to young children’s documented improvements in memory and future thinking? One possibility is that improvements in memory and in future thinking can result partly from natural cognitive improvements such as in executive function and in language (Tsujimoto, 2008). A wide host of abilities, including improved mental time travel to the past and future, may progress with ongoing frontal lobe development. In particular, the prefrontal cortex, which undergoes progressive age-related changes in
activity around 4 years of age, is known to be the seat of multiple higher general cognitive functions and executive function (Tsujimoto, 2008). Executive function is a multi-compartmental faculty conceptualized to manage attention resources among other cognitive processes. Adult executive function is widely considered to be composed of three separate but interrelated dimensions: working memory, inhibition of prepotent responses, and attention (Miyake et al., 2000).

Working memory (WM), often associated with the lateral prefrontal cortex, involves actively maintaining a temporary representation of information in immediate conscious and linguistic processing. WM is crucial to carrying out most learning and goal-oriented tasks (Baddeley, 1992; Gathercole, 2008). In particular, the visuospatial sketchpad briefly stores visual and spatial information that may be crucial in supporting episodic past and future thinking (Baddeley, 1992). Visuospatial working memory can be measured using the standardized Corsi block tapping test (Milner, 1971), a task that requires the participant to tap random patterns demonstrated by the experimenter on an array of nine fixed blocks. WM “span” refers to the maximum number of blocks that the participant is able to reproduce correctly. WM span typically increases to an average of five during childhood (Issacs & Vargha-Khadem, 1989). Young children’s limited visuospatial working memory may manifest itself in poor performance on memory and future thinking tasks that require mental construction of such visuospatial imagery.

Inhibition of prepotent responses, another representative prefrontal cortex function, is the ability to suppress irrelevant information and actions in order to complete a purpose (Tsujimoto, 2008). In the Grass/Snow inhibition task, 5-year-olds inhibit certain prepotent responses significantly better than 3-year-olds. In this task, children point to a
green color card when the experimenter says the word “snow” and to a white color card when the experimenter says “grass” (Sabbagh, Xu, Carlson, Moses, & Lee, 2006). Inhibition is perhaps most suspected to contribute to future thinking due to retraction from current states in order to anticipate needs of a future self (Carlson, Moses, & Claxton, 2004). Better inhibition may allow older children to better mentally insert themselves into the future than younger children, contributing to a more accurate anticipation of future physiological states. Lastly, shifting attention between tasks is an executive function that also naturally develops in young children, but does not appear to be as relevant to future thinking and episodic memory as are inhibition and working memory.

Although development of this adult tripartite structure seems to be in place early in the preschool years, executive function seems to be mediated by a unitary cognitive maturation factor that continues to differentiate into its separate components at least until 8 years of age (Garon, Bryson & Smith, 2008; Weibe et al., 2011). Thus, though the studies in the preschool literature sometimes assess these abilities separately, these measurements may be assessing one cognitive faculty mediated by the frontal lobe.

**Current Study**

To examine the link between memory and future thinking, I took advantage of the co-development of these abilities in preschool children. To measure episodic memory, a narrative task and a non-narrative task were administered. The narrative paradigm was originally adapted from methods commonly used to assess episodic memory in adult amnesics (e.g., Race et al., 2011) and required children to generate a narrative of a memory in their past. In order to control for the accuracy and nature of the memory
recalled, each child experienced a special classroom event in which an experimenter performed a novel demonstration of static electricity. The non-narrative memory task included a list of short-answer questions to assess the accuracy of children’s memory of the static electricity demonstration.

To examine episodic future thinking, a narrative task similar to the narrative memory task was administered, in addition to a non-narrative task. In the narrative future task, children were asked to imagine that a friend would come and play at their house for the first time one day in the future. The richness of children’s memory of the past and imagination for the future was measured as the total number of details in their narratives, which were then subdivided into relevant episodic details and irrelevant external details. The non-narrative future thinking measure was the picture book trip-planning task (Atance & Meltzoff, 2005), which included photographs of scenes not typically familiar to preschoolers and required the child to select an item out of three choices that he/she would need to bring with them to the scene.

As a control task of narrative fluency, children were administered a narrative picture task that asked children to construct a narrative regarding a detailed picture. The picture was visually rich in order to eliminate the need to mentally generate descriptive elements, but still made the cognitive demands related to the narrative aspect of the task. This narrative picture task provided a baseline measure of children’s verbal output and had similar narrative construction demands as the narrative memory and future thinking tasks. Working memory, inhibition, and receptive vocabulary were also assessed since the memory and future thinking tasks likely recruited language and executive function to some extent.
The study had three aims:

**Aim 1: To examine age effects for episodic memory and future thinking.** The first aim was to demonstrate that children’s abilities to recall a past episode and foresee a future event improve significantly across the preschool years. Based on the literature (Atance & Jackson, 2009), significant and parallel improvements in memory and in future thinking were predicted across the 3rd and 5th year of age. Significant age effects were also predicted for narrative fluency, executive function, and language during this developmental period, consistent with previous literature (Carlson & Moses, 2001; Dun & Dun, 1997; Liles, 1993; Milner, 1971).

**Aim 2: To examine the relation between episodic memory and future thinking.** The second aim was to investigate whether children’s ability to recall an autobiographical event was directly correlated with their ability to anticipate a future scenario. If episodic memory and future thinking are positively correlated at their emergence, as is observed in healthy and amnesic adults (Race et al., 2011), the two abilities may rely on the same neurocognitive basis.

**Aim 3: To investigate whether the relation between memory and future thinking is mediated by other factors.** The third aim was to examine to what extent episodic memory, future thinking, and the relationship between them are supported by working memory, inhibition, verbal ability, and narrative fluency. A significant contribution of these factors may suggest that the relationship between episodic memory and future thinking may be heavily reliant on, and thus an artifact of, natural improvements in cognitive capacities.
Method

Participants

Thirty-six preschoolers from a laboratory preschool and a day care facility participated in the study. Seventeen younger preschoolers (\(M_{age} = 3.6\) years, range: 39 – 48 months, six females, 11 males) and 21 older preschoolers (\(M_{age} = 4.9\) years, range: 54 – 62 months; 11 females, 10 males) were recruited. Data from four additional children were not included in the analysis due to inadequate completion of test sessions. Written consent was obtained from each child’s parent or legal guardian prior to the beginning of the study. Children were predominantly Caucasian, of middle-to-upper-class backgrounds, and spoke English as their first language.

Standardized Measures

Non-narrative future thinking was assessed using the picture book trip-planning task (Atance & Meltzoff, 2005). For this task, children were presented with a photobook containing 10 colored photographs (8.5 in. x 11 in.), the first four of which are “warm-up” scenes of a birthday party, grocery store, swimming pool, and cookies. The remaining six “test” photographs were pictures of the scenes that children were unlikely to have encountered in real life (e.g., a long dirt road, a waterfall, a steep mountain, a snowy forest, a sunny desert, a rocky stream) in order to minimize reliance on “script-based” knowledge. In each scene, the child reported what was in the photograph, was told to imagine going to the scene, and then was asked to point to one of the three item choices they needed to bring with them to the scene. The three item choices paired with each scene colored were photographs (5 in. x 7 in.) that depicted various everyday objects (e.g., plate, shopping cart, shampoo). Only one of the choices was a target picture needed
to satisfy a future physiological need for each scene (e.g., coat for the snowy forest condition). The other two choices were distractor pictures, one of which was semantically related to the scene but irrelevant to a future need (e.g., ice cubes for snowy forest condition). (See Appendix A for full list of choices for each scene.) The placement of the choices on the table (i.e., left, right, or middle of child) was counterbalanced across scenarios so that the correct answer never appeared in each placement more than twice. The non-narrative future thinking score was computed as the proportion of scenes that the child chose the item that accurately predicted a future need.

Visuospatial working memory was tested using the Corsi block tapping test (Milner, 1977), a measure from the Working Memory Test Battery for Children (WMTB-C). In this working memory task, the child was presented with a random array of nine blocks and instructed to replicate the exact pattern of blocks tapped by the experimenter. After an initial practice trial, the experimenter tapped a pattern of X blocks and asked the child to repeat the pattern, and the subsequent five patterns involving the same number of blocks within the test trial. When the child correctly performed at least four of total six patterns within the test trial, the experimenter administered the next test trial, which involved an additional block in the patterns. The working memory span was recorded as the test trial that included the highest number of blocks that child was able to correctly reproduce in at least four of the six patterns.

Inhibition assessed with the Grass/Snow inhibition task (Carlson & Moses, 2001). The child was shown a solid green card on the left and a solid white card on the right. Children were asked to name the color of grass and snow and to point to its card. The task was then introduced as a game of opposites where the child would point to the green
card whenever the experimenter said “snow” and to the white card whenever the experimenter said “grass.” The experimenter demonstrated first and then allowed the child to have two practice trials before 16 trials were administered in a pseudorandom order (GGSGSSGGSSGGSSG). The proportion correct was recorded.

Verbal ability was assessed using the Peabody Picture Vocabulary Test-III Form B (PPVT-IIIB; Dunn & Dunn, 1997). In this task, an easel was placed in front of the child. Each page had a set of four pictures and the child was asked to point to the correct picture as the experimenter read a list of words. Children’s raw scores were recorded.

**Procedure**

Four sessions of 10 to 15 minutes were conducted for each child. No child completed two sessions on the same day or completed more than three sessions in the same week. Each test was conducted in a quiet, separate area with the child seated across from the experimenter. All sessions were audiorecorded and/or videotaped and each child received a sticker for his/her participation at the end of each session.

**Session 1: Narrative memory task acquisition phase.** The purpose of the first session was to expose children to a prescribed event so that their memory of the event could be assessed at the next session. Children experienced a novel static electricity demonstration with an experimenter they had never seen before. Four children from the same class were seated on individual mats in the testing room. The children’s teacher introduced the experimenter, “Aimee”, as a guest who would present a special science demonstration. The teacher pointed out that Aimee was wearing a white lab coat. Aimee greeted the children and showed them her red hatbox decorated with yellow stars. (See Appendix A for full script.)
The experimenter opened her hatbox and took out a sock, balloon, and bowl of cereal and passed them around so that each child was able to hold each item. The experimenter first demonstrated that nothing happened when the balloon was placed on the bowl of cereal. She then demonstrated that the cereal would stick to the balloon after the balloon was rubbed with the sock for 10 seconds. After the experimenter performed this demonstration a second time, she explained that the cereal stuck to the balloon because of static electricity. Each child was then allowed to hold the balloon and stick it on the cereal and then hold the bowl of cereal for the neighboring child to press the balloon onto it.

**Session 2.** The main purpose of the second session was to administer narrative and non-narrative measures that tested children’s episodic memory of the static electricity demonstration. The second session was administered to each child on the day after the first session. To avoid indirect memory retrieval cues from the environment, the test phase of the memory task was administered by a different experimenter. This session also included the Grass/Snow inhibition task and the narrative picture task as a measure of executive function and narrative fluency, respectively.

**Narrative memory task test phase.** Episodic memory was assessed in a narrative task. Children were asked to recall the previous day’s static electricity demonstration in response to an open-ended question followed by a set of direct questions. In the initial open-ended section, children were first verbally reminded that something special happened at school the previous day and were briefly shown a color picture of the red hatbox with stars (e.g., “I want you to tell me about yesterday. I heard that a girl named Aimee came in before and did a special science demonstration with this box”).
experimenter indicated that she was not present at the science demonstration but wanted to know what happened in the event (e.g., “I wasn’t there, but I really want to know what happened”). Children were then asked an open-ended question about what happened at the special science demonstration: “I want to know who was with you in the science demonstration, where you were, what you saw and what you played with. I’m going to write down everything you say. So first what happened?”. They were given a maximum of two minutes to respond, unless their responses naturally ended earlier. Questions regarding the event were adapted from a study on preschoolers by Leichtman et al. (2000) and a study on adult amnesics by Race et al. (2011) so that questions were appropriate for 3-, 4- and 5-year olds. The experimenter gave general prompts to encourage children’s responses in the open-ended section (e.g., “Then what happened in the science demonstration?”, “Tell me more about the science demonstration”, “What else happened?”). The experimenter was under strict instructions not to introduce any new idea, concept, entity, or detail not previously brought up by the child. After 15 seconds of sustained silence or a clear demonstration from the child that he or she was finished, the child was given a series of specific prompts and a maximum of 30 seconds for each response (e.g., “Who was with you in the science demonstration and what are their names?”, “What things did the person bring to the science demonstration?”, “What did you do in the science demonstration?”). (See Appendix B for full list of prompts.)

Non-narrative memory task. Episodic memory was also assessed in a non-narrative format. Accuracy of the children’s memories of the static electricity demonstration was tested with a list of nine questions that required answers of one to a
few words (see Appendix B). Non-narrative memory scores were computed as the proportion of questions that the child answered accurately.

**Grass/Snow inhibition task.** After the non-narrative memory task, the experimenter administered the Grass/Snow inhibition task, which was then followed by the narrative picture task.

**Narrative picture task.** The narrative picture task provided a baseline measure of children’s narrative fluency, or ability to construct a story. A picture used in by Race et al. (2011) was also used in the current task (Fig. 1A). Children were asked to tell a story about what was happening in the picture. A maximum of one minute was given for children’s responses to end naturally before the aided response phase began. In this phase, the experimenter gave the following three prompts with a maximum of 30 seconds allowed in response to each: “What is happening in the picture?” “What are the people doing?” and “Anything else?”

**Session 3.** The third session had three purposes: a) to assess children’s narrative future thinking ability, b) to measure visuospatial working memory, and c) to assess episodic memory with a simpler picture-based task. The picture-based task will be correlated with the non-narrative and narrative memory tasks in order to see whether they all assessed similar constructs of memory. The third session was administered any day within four weeks ($M = 7$ days, $SD = 2.7$) of the first session.

**Narrative future thinking task.** Episodic future thinking ability was measured in a task similar to the narrative memory task. The future thinking task included an open-ended question followed a set of direct questions. In the initial open-ended section, the child first named a friend who he/she liked to play with, but who had not come to their
house before. The child was then asked to imagine what would happen if this friend came to their house on a day that had not happened yet. A maximum of two minutes was given for children’s responses and the experiment gave general prompts to encourage children’s responses in the open-ended section (e.g., “Try your best, it can be anything.”, “Then what would happen when you play?”, “What else would happen?”). The experimenter was under strict instructions not to introduce any new idea, word or theme not previously brought up by the child. After 15 seconds of sustained silence or a clear demonstration from the child that he or she was finished, the child was then given specific prompts by the experimenter and a maximum of 30 seconds to respond (e.g., “What would [X] want to do at your house?”, “What would you want to play with [X] at your house?”, “What would [X] do or say at your house?”)

**Picture episodic memory task.** Episodic memory was assessed in a simple picture task. The picture episodic memory task included an initial acquisition phase and a delayed test phase separated by the working memory measure described below. Only 25 children completed the picture episodic memory task due to timing and space constraints.

In the acquisition phase, the experimenter laid down 12 pictures of common objects in front of the child at once. Children were asked to name each picture as it was set down and the experimenter repeated or, if necessary, corrected the picture name for the child. The three groups of pictures—animals, fruits and house items—each included four different black and white drawings. Children were told to look carefully at each picture because the experimenter would take them away and ask them later what was in them. The child then repeated the name of each picture once more with the experimenter.
In the test phase, the child was asked to freely recall the picture items and were given general prompts such as “What else?” and “Anything else?” After the child freely recalled as many pictures as possible, he/she was shown 24 pictures, half of which were studied pictures and half of which were semantically related distractor pictures. The child was instructed to say “yes” or “no” to indicate whether he/she had seen the picture in the acquisition phase. Pictures were presented in a pseudorandom order so that target pictures came up no more than twice in a row.

**Working memory task.** Working memory was assessed using the Corsi block tapping test, which intervened between the acquisition and test phase of the picture episodic memory task.

**Session 4.** The purpose of the fourth session was a) to assess verbal ability and b) to assess future thinking using a non-narrative measure. This session was administered to all participants within five weeks of the first session ($M = 16$ days).

**Verbal ability.** Verbal ability was assessed using the Peabody Picture Vocabulary Test (PPVT).

**Non-narrative future thinking task.** Non-narrative future thinking was assessed with the picture book trip-planning task (Atance & Meltzoff, 2005).

**Coding**

Performance on the narrative episodic memory and narrative future thinking tasks was scored with an adapted version of the Levine, Svoboda, Hay, Winocur, and Moscovitch (2002) autobiographical interview scoring procedure. Each narrative was broken into details, which were then broadly categorized as *episodic* details or *external* details. Episodic details, which included occurrences and/or people internal to the
respective episode were further categorized as event, place, time, perceptual, and thought/emotion details. External details included external event details (details from events other than the main event recalled or imagined), semantic details (general knowledge and facts, ongoing events, and extended states of being), repetition (unsolicited repetition of details) and other details (metacognitive statements and any editorializing).

**Reliability**

Interrater reliability was calculated for one third of independently coded narratives. The second rater was blind to the hypotheses and subject age, but the primary rater was not. Intraclass correlation analysis revealed high agreement between scorers for most of the memory details (Cronbach’s α = 0.97 for total details; α = 0.59 for total external details, α = 0.99 for total episodic details) as well as for all future details (Cronbach’s α = 0.90 for total details; α = 0.81 for total external details, α = 0.92 for total episodic details). Low reliability was accepted for the number of total external memory details as we found that mistakes in coding were due to one rater’s more expansive inclusion of metacomments and repetitions (e.g., “I’m not sure”). Interrater reliability on the narrative picture task also ranged from moderately low (Cronbach’s α = 0.67 for total details; α = 0.70 for total episodic details) to sufficient (α = 0.88 for total external details). The somewhat low reliabilities for the narrative picture task qualified my interpretation of the results. Scores given by the primary, more experienced rater were used in the final data analysis.
Results

The present study was conducted with three aims: a) to examine age effects for episodic memory and future thinking, b) to examine the relationship between episodic memory and future thinking and c) to investigate whether the relation between memory and future thinking is mediated by working memory, inhibition, verbal ability, and narrative fluency. In line with these three aims, results are presented as 1) developmental analyses of all tasks, 2) relation between episodic memory and future thinking, and 3) contribution of other factors to the relation between memory and future thinking.

Developmental Analyses

Cognitive factors. Working memory, inhibition, verbal ability, and narrative fluency were hypothesized to improve significantly between younger and older children in the preschool years. This hypothesis was supported (see Table 1). Independent sample t-tests indicated that older preschoolers outperformed younger preschoolers on the Corsi block tapping test of working memory, Grass/Snow inhibition task, and PPVT of receptive vocabulary. In the narrative picture task (which measured narrative fluency), as well as in other narrative tasks, all details were classified into two broad categories: episodic details or external details. An independent samples t-test was performed on the mean number of total episodic details generated in the narrative picture task, with older children also outperforming younger children. This result was qualified, however, by the low reliability scores in the narrative picture measure.

Episodic memory and future thinking. Episodic memory and future thinking were hypothesized to improve between the ages of three and five. Four total tests were administered: the narrative memory task, the narrative future thinking task, the non-
narrative memory task and the non-narrative memory task (picture book trip-planning task). The mean number of total episodic details was compared between the narrative tasks (Table 1). The hypothesis was supported for three of the four tasks. Older children outperformed younger children on the non-narrative future thinking task, the non-narrative memory task, and the narrative memory task. In the narrative future task, however, older children did not differ from younger preschoolers in the number of episodic details generated.

In a separate analysis, the total number of episodic details reported by each child in the narrative memory and future thinking tasks was categorized into five episodic subcategories. These subcategories corresponded to event, place, time, perceptual details, and thought/emotion details. (See Figure 1 for means in each category for the narrative memory and the narrative future thinking tasks.) In addition, external details that did not pertain to the prompted memory or future episode were divided into subcategories of external events, semantic details, repetitions, and other details. Due to the low mean numbers of overall external details in both the narrative memory task and the narrative future thinking task, and the non-significant differences between younger and older groups (p values > .10), external details are not further discussed.

The distribution of episodic details for the narrative memory and future tasks were compared in a 2 (age: older, younger) x 2 (temporal direction: past (memory), future) x 5 (detail category: event, place, time, perceptual, thought/emotion) mixed factorial analysis of variance (ANOVA). This exploratory analysis was performed without any prior hypotheses except for any a main effect of age. Specifically, older children were expected to produce more episodic details in both conditions than younger children. The
ANOVA revealed no main effect of age, \( F(1, 36) = 2.67, p > .10 \), and no main effect of temporal direction, \( F(1, 36) = 0.60, p > .40 \), indicating that the overall number of episodic details did not differ between younger and older preschoolers (contrary to expectation) or between the memory and future thinking tasks. However, the main effect of detail subcategory was significant, \( F(1, 36) = 25.26, p < .001 \). Follow-up pairwise analyses indicated that the number of event details and perceptual details did not differ (\( p > .50 \)) and was greater than the number of place details, time details and perceptual details (\( t \) values > 7.40, \( p \) values < .001), which did not differ (\( p \) values < .05).

The presence of a detail category x temporal direction interaction indicated that the pattern of details across subcategories differed between the memory and future tasks, \( F(1, 36) = 7.53, p < .010 \), with the narrative future thinking task elicit[ing more time details (posthoc \( t(64) = 3.92, p < .001 \)) and marginally significantly more place details (posthoc \( t(74) = 1.69, p = .095 \)) than the narrative memory task. There was no age x detail category interaction. However, an age x temporal direction interaction was observed, \( F(1, 36) = 7.31, p < .05 \), indicating that older children generated significantly more details in the memory task, \( t(37) = 2.41, p < .05 \), but not in the future thinking task \( t(23) = 0.13, p > .50 \). Lastly, no 3-way interaction emerged, \( F(1, 36) = 0.028, p > .50 \).

**Relation Between Episodic Memory and Future Thinking**

**Correlation between episodic memory and future thinking.** A positive correlation between episodic memory and future thinking was predicted. Bivariate Pearson’s correlations indicated that generation of episodic memory details was positively correlated with generation of episodic future thinking details in the narrative tasks. A positive correlation was also observed between performance on the non-
narrative memory and future thinking tasks ($r$ values > 0.30, $p$ values < .05). Scatterplots of both correlations are presented in Figure 2 with regression lines and the respective Pearson correlation coefficient.

**Contributions of other cognitive factors to memory and future thinking tasks.** Pearson correlation coefficients were obtained between the four memory and future thinking tasks and the four ancillary cognitive tasks, and are presented in Table 2. As expected, narrative fluency and verbal ability were positively correlated with nearly all measures of memory and future thinking. The exception was between verbal ability and narrative future thinking. None of the narrative memory and future thinking measures were correlated with inhibition (See Table 2), though the non-narrative future thinking measure was correlated with working memory span $r = 0.47, p < .010$.

**Partial correlations.** Partial correlations were conducted to determine whether the correlation between episodic memory and future thinking was the result of contributions of narrative fluency, and other cognitive factors to memory and future thinking. Table 3 shows the correlations between narrative memory and future thinking, and between non-narrative memory and future thinking, after these factors were partialled out. Though both Pearson correlation coefficients decreased, episodic detail generation in the narrative memory task and narrative future task remained positively correlated after performing partial correlations, $r = 0.38, p < .05$, in line with my hypothesis. However, the correlation between the non-narrative memory and non-narrative future thinking ability ($p > .10$) did not remain significant after controlling for outside variables.
Discussion

The present study used narrative and non-narrative measures to examine episodic memory and future thinking in preschoolers. The narrative measures were adapted from a paradigm commonly used in amnesia studies (Race et al., 2011) whereas the non-narrative measures were similar to those more commonly used in developmental studies (Atance & Meltzoff, 2005; Naito & Suzuki, 2011). Three of the four memory and future thinking tasks demonstrated age effects over the course of the preschool age range, indicating substantial development of non-narrative memory, non-narrative future thinking and narrative memory between the age of 3 and 5 years. However, children did not improve with age on the narrative future thinking task, possibly due to inherent differences between narrative future thinking and narrative memory.

Nevertheless, the positive correlations revealed that narrative memory and narrative future thinking abilities were associated, as were non-narrative memory and non-narrative future thinking. These correlations suggest that memory and future thinking are related, and that this relationship may stem from a shared dependence on a common neurocognitive core. However, outside factors could potentially contribute to the relationship between memory and future thinking especially during the extremely rich developmental period of the preschool years. The literature indicates marked improvements across multiple domains (Carlson & Moses, 2001; Dun & Dun, 1997; Liles, 1993; Milner, 1971) that could be involved in memory and future thinking tasks. In line with the literature, older preschoolers in the present study outperformed younger preschoolers on narrative fluency, working memory, inhibition, and verbal ability tasks. To examine whether these other developing cognitive factors contribute to the
relationship between memory and future thinking, partial correlations were conducted to see whether the correlation between memory and future thinking would persist even after controlling for narrative fluency, working memory, inhibition and receptive vocabulary. The relationship between narrative memory and future thinking remained significant even after these factors were partialled out. By contrast, the relationship between non-narrative memory and future thinking disappeared after these factors were controlled for.

These results demonstrate that the relation between narrative memory and narrative future thinking is not due to shared dependence on narrative fluency, working memory, inhibition or receptive vocabulary. However, the relation between the non-narrative memory and non-narrative future thinking can be explained by a common reliance on at least one of these other factors. These findings are unexpected since non-narrative tasks were assumed to have less narrative, working memory and language demands than the narrative tasks. Specifically, the non-narrative tasks required children to answer short, direct questions about a novel science demonstration in the memory task and to select a picture of the item they would bring with them to a trip in the future task. Out of the four ancillary cognitive factors, verbal ability accounts for the greatest amount of the variance in the relation between the non-narrative tasks. However, because the non-narrative tasks did not strongly depend on verbal output, verbal ability is not likely to be a causal factor, but rather an age-related predictor.

Interestingly, to reiterate an above point, the relationship between narrative memory and future thinking was not due to their common reliance on narrative fluency. Both abilities are highly related to performance on the narrative picture task, which can be interpreted as a baseline measure of narrative fluency. The striking finding, however,
is that though the positive relation between narrative memory and future thinking weakened after controlling for the contributions of narrative fluency, it continued to be significantly correlated. Similar results were observed in the original study of amnesia conducted by Race et al. (2011) study, in which highly correlated impairments in narrative memory and future thinking were not accounted for by performance on a narrative picture task. Taken together, these findings negate the hypothesis that the positive correlation between narrative memory and future thinking is an artifact of their common dependence on narrative fluency/construction. Furthermore, this relationship persists even after more conservative partial correlations controlled for the contribution of verbal ability, working memory, and inhibition, in addition to narrative fluency.

Zero-order correlations can be examined for a finer-grained understanding of the relations among episodic memory, future thinking, and other abilities such as narrative fluency, working memory, inhibition and receptive vocabulary. With one exception, memory and future thinking were positively correlated with narrative fluency and verbal ability. More specifically, children who generated more episodic details when describing a picture and possessed greater receptive vocabularies also tended to score better on the memory and future thinking tasks. Although not crucially contributing to the relationship between memory and future thinking, narrative fluency and verbal ability appear to be associated with performance on these tasks.

Surprisingly, working memory and inhibition were not correlated with any task, except non-narrative future thinking ability. This finding is unexpected given what is known about working memory and inhibition, and the likelihood that these abilities are recruited in order to perform well on episodic memory and future thinking tasks.
Working memory and inhibition are two components of executive function, a multifaceted general system that manages and controls other cognitive processes, and heavily engages the frontal lobes. Better working memory and inhibition were hypothesized to be related to performance on narrative tasks in particular, especially since these abilities were expected to aid children in holding information in mind and inhibiting irrelevant information while constructing a story. Instead, working memory correlated with non-narrative future thinking, perhaps by providing online capacities of the prefrontal cortex to hold information in temporary storage. A possible explanation for the lack of correlations between executive function tasks and other memory and future thinking tasks is that executive function has not sufficiently developed by the preschool years to be reliably recruited for these tasks. Executive domains generally improve across preschool and childhood at different rates and are mature by 12 years of age (Anderson, 2010). In older age ranges, successful episodic memory and future thinking might recruit the goal-directed, attention and cognitive resources offered by executive function. Thus, correlations may be expected between executive function and memory/future thinking tasks in children older than preschoolers.

**Relationship between narrative memory and future thinking**

Narrative memory and future thinking share fundamental commonalities that may explain their link in development. At least two different possibilities have emerged in the literature as possible “core” cognitive mechanisms underlying narrative memory and future thinking: a) similar use of mental travel into another time, place or perspective (Schacter et al., 2007; Tulving, 2002) or b) similar reliance on scene construction (Hassabis & Maguire, 2007).
Memory and future thinking invoke mental time travel beyond immediately present states, but in different directions. The ability to mentally project oneself to re-live past experiences and pre-live future events is naturally acquired in development and becomes embedded in daily and adaptive functioning in later years (Atance & Jackson, 2009; Suddendorf & Corballis, 1997). Mental time travel depends on various capacities such as self-awareness, mental representation, and differentiation between imagined and current states (Suddendorf & Corballis, 1997; Wheeler et al., 1997). Both narrative and non-narrative tasks in the present study required mental time travel and these supplementary capacities, though an important distinction should be made between the narrative and non-narrative tasks. The narrative tasks specifically required children to recall/generate a novel science demonstration or a play date almost “from scratch.” For this reason, performance on the narrative tasks, but not on the non-narrative tasks, was considered to reflect scene construction in addition to mental time travel. Scene construction is a type of mental imagery that entails generation, maintenance and visualization of events in their setting (Hassabis & Maguire, 2007).

Non-narrative tasks, rather than measures of scene construction, are more exclusive measures of mental time travel ability (Atance & Meltzoff, 2005). Non-narrative tasks did not require the effortful generation of a scene. Instead, the experimenter aided children with direct, short-answer questions about the science demonstration in the non-narrative memory task and visually presented the scenarios and a set of choices in the non-narrative future task. These measures tested exclusively for the accuracy of mental time travel since children needed to correctly recall specific details and anticipate a likely need. However, results of the present study show that the correlation between non-
narrative memory and non-narrative future thinking disappeared after factors of narrative fluency, executive function and verbal ability were controlled for. Thus, mental time travel is not the exclusive mediator of the significant correlation between memory and future thinking when measured by non-narrative tasks.

In contrast to the non-narrative tasks, the narrative memory and future thinking tasks remained positively correlated even after controlling for narrative fluency, working memory, inhibition, and verbal ability. Due to the narrative tasks’ emphasis on detail generation, scene construction is suspected to be the major common process in both narrative memory and narrative future thinking. In line with the scene construction hypothesis (Hassabis & Maguire, 2007), a core network underlying memory and future thinking may be activated by the simulation process and visuospatial aspects of scenes. Scene construction also appears, theoretically, to involve detail generation and detail combination/recombination inherent to the reconstructive nature of episodic memory and future thinking. Thus, the persistent correlation between the narrative tasks, but not between the non-narrative tasks, supports the possibility that scene construction, in addition to mental time travel, is an important process involved in both abilities, rather than mental time travel exclusively.

According to the constructive episodic stimulation hypothesis (Schacter et al., 2007), the future thinking system draws upon the inherently combinatory nature of memory to flexibly reassemble details from past events. In this view, memory and future thinking are independent abilities that rely on scene construction and are thus positively correlated due to similar engagement this key mechanism. An alternative interpretation of the link between memory and future thinking is that a child may be able to generate
more details and imagine a richer future event if he/she has a larger reservoir of personal experiences to assemble into new possibilities (Suddendorf, 2010a). Put another way, episodic memory itself may play an essential part of future thinking by providing the actual raw details for the future thinking system to recombine in novel scenarios.

Findings from the original Race et al. (2011) study do not rule out either of the above views on the relationship between memory and future thinking. Race et al. (2011) demonstrated that the medial temporal lobe is critically involved in narrative memory and future thinking. One interpretation of this result is that the memory deficit that arises from brain damage to the hippocampus may cause impaired future thinking. However, an alternative interpretation is still permissible. Since the hippocampus is also involved in the binding of details and perhaps scene construction, hippocampal damage may cause a binding/scene construction deficit that is the true cause of both memory and future thinking deficits. Further research is needed to fully understand how best to conceptualize the link between memory and future thinking.

**Differences between narrative memory and future thinking.**

Though linked, narrative memory and narrative future thinking abilities develop differently during the preschool years. Whereas older preschoolers demonstrated better narrative memory than younger preschoolers, no age effect was observed for narrative future thinking. Remarkably, narrative memory and future thinking were still correlated, even after accounting for the influences of narrative fluency, working memory, inhibition and receptive vocabulary. This stable relation between narrative memory and future thinking, in spite of inconsistent age effects, indicate that the mechanism by which they are supported may be age-independent. Furthermore, this age-independent factor—
perhaps scene construction or another capacity—permits enough individual variability for narrative future thinking to still be positively correlated with narrative memory.

In order to better understand the link between narrative memory and narrative future thinking, differences between the two are examined. Perhaps the most obvious distinction is that past episodes are already represented and can be recalled, whereas future episodes have virtually infinite possibilities and need to be constructed. Thus, the distribution of readily accessible details is asymmetrical, in favor of relatively prescribed and concrete memory episodes (Suddendorf, 2010a; Viard et al., 2011). Narrative future thinking requires more cognitive effort than narrative memory because children are required to generate a completely unfamiliar scene from scratch. Differences in future thinking ability between younger and older children became visible when the scenes were presented in front of them; an age effect for future thinking was demonstrated in the non-narrative future thinking task, which visually aided children with photographs of the scenes they were supposed to imagine. Presentation of the scenes allows children to circumvent the more effortful mental generation of scenes involved in narrative future thinking.

Behavioral studies in children also support the differential development of episodic memory and future thinking. The ability to project oneself to the future appears to develop later than the ability to project oneself to the past (Friedman, 1992; Friedman, 2002). Four-year-olds fail to differentiate distances ranging up to a year in the future (Friedman, 2002), but are able to retrieve accurate memories from nearly all of the following times: yesterday, last weekend, last summer, and several holidays in the past year (Friedman, 1992). A self-awareness of time continues to develop well into primary
school, with eight-year-olds and nine-year-olds able to mentally represent times of the year in accurate order. Delayed discrimination of future time in young preschoolers may reflect a nascent transition from current states to consideration of future possibilities. Furthermore, brain imaging data in adults demonstrate differential activation of certain brain regions for future thinking and episodic memory, particularly in the anteromedial frontal pole and MTL (Okuda et al., 2003; Suddendorf, 2010a). These findings indicate that despite substantial overlap in the neural correlates for episodic memory and future thinking, differences still exist between the two abilities that can manifest on the cognitive level.

Future thinking not only involves mental scene construction and mental time travel, but an additional requirement of recombining details in novel ways (Atance & Jackson, 2009; Hassabis et al., 2007). In support of this observation, Suddendorf (2010b) revealed an association between preschoolers’ divergent thinking, which is also involved in creativity, and the number of answers children generated about what they would do tomorrow. However, divergent thinking did not correlate with the number of answers children gave pertaining to what they did the day before, suggesting that spontaneous imagination is more specific to future thinking. Moreover, in a pilot study with eight children, I found that preschoolers had marked difficulty imagining a play date with a friend in a new place they had never been to before, such as a tree house. Despite the fact that preschoolers could readily identify what a tree house was and that they could play whatever they wanted in it, children were rarely able to come up with possibilities of what they could do. Children continued to have difficulty in another trial that asked them to play with three different everyday toys (e.g., stick, sock, and paper) by themselves.
Children often cited reasons such as “I don’t know,” “I never went there,” or “I never played with them together before” and seemed unfamiliar even with the possibility that these events could happen.

In order to avoid floor effects, the narrative future thinking task in the present study was created so that the novel event would occur in a familiar place: the child’s home. Children invoked episodic future thinking in this narrative future thinking task because the friend had never come to his/her house before and children had to imagine this new event. However, children’s ritualized scripts of their home and personal knowledge of their friend likely aided them in thinking of possibilities such as where and with what activities and toys he/she could play with the friend. This information should be accounted for in interpretations explaining the lack of an observed age effect on the narrative future thinking task but persistent correlation with narrative memory.

One view is that the wide variability in children’s familiarity and episodic memories of their homes, friends and play dates obscured the narrative future task’s sensitivity to measure age differences in episodic future thinking. At the same time, this source of age-independent variability could allow narrative memory and future thinking to be correlated on an individual basis. For example, the richness of children’s past experiences playing in certain areas of their house, with certain toys or friends may support children’s responses for what to do on a future play date. In another words, children with more specific and accessible details in their memories are likely, by extension, to have more raw materials to construct more detailed possibilities than children with fewer accessible details. This interpretation assumes that the narrative future thinking task designed for the current study was not sensitive enough to
demonstrate age effects, particularly because of variable contributions from semantic knowledge and past memories. Nonetheless, the persistent correlation between narrative memory and future thinking remains consistent with the possibility that episodic memory may actually contribute to future thinking ability.

In conclusion, the developmental relationship between episodic memory and future thinking is highly complex. Preschoolers improve on nearly all measures of episodic memory and future thinking, except for narrative future thinking. Differential age effects for narrative memory and narrative future thinking highlighted some of the fundamental differences between memory and future thinking. Nevertheless, memory and future thinking appear to at least partially share some neurocognitive resources. This interpretation is supported by a correlation between narrative memory and narrative future thinking even after controlling for narrative fluency, working memory, inhibition and receptive vocabulary. The persistence of the correlation between the narrative tasks but not between the non-narrative tasks after partial correlations suggests that scene construction and mental time travel, rather than exclusively mental time travel, may be crucially involved in both abilities during the preschool years.
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memory: Remembering the past and imagining the future. *Philosophical Transactions of the Royal Society Biological Sciences, 362*, 773-786.


Table 1

Comparisons of Older and Younger Preschoolers on all Tasks.

<table>
<thead>
<tr>
<th>Task</th>
<th>Younger preschoolers (n = 17)</th>
<th>Older preschoolers (n = 21)</th>
<th>Age effects</th>
</tr>
</thead>
<tbody>
<tr>
<td>Executive function</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Working memory (Corsi block span)</td>
<td>2.47 (0.12)</td>
<td>3.33 (0.16)</td>
<td>$t(36) = 4.11^{***}$</td>
</tr>
<tr>
<td>Inhibition (max = 1.00)</td>
<td>0.51 (0.07)</td>
<td>0.74 (0.06)</td>
<td>$t(36) = 2.03^*$</td>
</tr>
<tr>
<td>Verbal ability</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(PPVT raw score)</td>
<td>50.71 (3.1)</td>
<td>78.67 (2.97)</td>
<td>$t(36) = 6.46^{***}$</td>
</tr>
<tr>
<td>Narrative Picture</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(total # episodic details)</td>
<td>16.12 (1.95)</td>
<td>23.19 (1.78)</td>
<td>$t(36) = 2.68^*$</td>
</tr>
<tr>
<td>Episodic memory</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Narrative (total # details)</td>
<td>19.82 (3.50)</td>
<td>31.95 (2.74)</td>
<td>$t(36) = 2.77^{**}$</td>
</tr>
<tr>
<td>Non-narrative (max = 1.00)</td>
<td>0.60 (0.06)</td>
<td>0.78 (0.04)</td>
<td>$t(36) = 2.84^{**}$</td>
</tr>
<tr>
<td>Episodic future thinking</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Narrative (total # details)</td>
<td>27.29 (4.56)</td>
<td>27.81 (1.81)</td>
<td>$t(21) = 0.11$</td>
</tr>
<tr>
<td>Non-narrative (max = 1.00)</td>
<td>0.54 (0.05)</td>
<td>0.87 (0.03)</td>
<td>$t(22) = 5.17^{***}$</td>
</tr>
</tbody>
</table>

*Note: Standard Errors of the Mean reported in parentheses.

$p < 0.05$. $**p < 0.01$. $***p < 0.001$. 
Table 2

Correlations between Key Episodic Task Performance and Verbal Ability, Working Memory, Inhibition, and Narrative Picture.

<table>
<thead>
<tr>
<th>Task</th>
<th>Verbal Ability</th>
<th>Working Memory</th>
<th>Inhibition</th>
<th>Narrative Picture</th>
</tr>
</thead>
<tbody>
<tr>
<td>Narrative Memory</td>
<td>0.45**</td>
<td>0.23</td>
<td>0.029</td>
<td>0.56***</td>
</tr>
<tr>
<td>Narrative Future</td>
<td>0.14</td>
<td>-0.093</td>
<td>-0.13</td>
<td>0.41*</td>
</tr>
<tr>
<td>Non-narrative Memory</td>
<td>0.36*</td>
<td>0.27</td>
<td>0.073</td>
<td>0.35*</td>
</tr>
<tr>
<td>Non-narrative Future</td>
<td>0.60**</td>
<td>0.47**</td>
<td>0.18</td>
<td>0.40*</td>
</tr>
</tbody>
</table>

*Note.*
*p < .05. **p < .01. ***p < .001.*
### Table 3

Partial Correlations between Narrative and Non-narrative Memory and Future Thinking Tasks after Controlling for Age, Narrative Fluency, Executive Function (Working Memory & Inhibition) and Verbal Ability.

<table>
<thead>
<tr>
<th>Task</th>
<th>Narrative Future</th>
<th>Non-narrative Future</th>
</tr>
</thead>
<tbody>
<tr>
<td>Narrative Memory</td>
<td>0.38*</td>
<td></td>
</tr>
<tr>
<td>Non-narrative Memory</td>
<td></td>
<td>0.075</td>
</tr>
</tbody>
</table>

*p < .05
Figure 1. Mean number of episodic details generated by younger and older preschoolers across each episodic detail category for the narrative memory and narrative future thinking tasks. Error bars indicate Standard Error of the Mean.
Figure 2. Bivariate Pearson’s correlations between narrative memory and future thinking scores and between non-narrative memory and future thinking scores. (a) The number of narrative-generated memory details was positively correlated with the number of narrative-generated future details. (b) Non-narrative memory scores were positively correlated with non-narrative future scores. *$p < .05$. **$p < .01$. 
Appendix A

Narrative Future Thinking Task

Free Response Instructions

“My game is about writing down what children say and I’m going to write down what you tell me on my piece of paper. Who is one friend from your class that you like to play with? Has [X] ever gone to your house before? (If not: “Who is another friend from you class that has not gone to your house? Has [Y] ever gone to your house before?”) What if [X] came to your house sometime on a day that hasn’t happened yet. Let’s think about what could happen and how you would want to play with [X]. I want to know what kinds of things you play with, what you would do, and where you would play in your house. So first what would happen?”

Prompts allowed: “Try your best.”, “This can be kind of hard.”, “Let’s think about it for a while.”, “Then what would happen.”, “Tell me more about what would happen.”, “What is one more thing that could happen?”, “What else could you do?”, “What is one last thing that could happen?”, Anything else?”

Aided Response Instructions

1. Can you tell me what [X] would want to do at your house?
2. What would you want to play with [X] at your house?
3. What would [X] do or say at your house?
4. When would you play with [X] at your house?
5. Where would you play with [X] at your house? What would the room look like?
6. How would [X] feel if he/she could play with you at your house?
7. How would you feel if [X] could come and play at your house?
Note: If a child responds with “I don’t know”, the experimenter can say any of the following: “Try your best,” “Then what could happen,” and “Tell me more.” If the child already answered a question in the initial free-response minute, the experimenter will add, “I forgot to write all of it down. Tell me again.”

Non-narrative Future Thinking Task

*Picture book trip-planning task scenarios and choices (Atance & Meltzoff, 2005)*

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Correct Item</th>
<th>Distracter 1</th>
<th>Distracter 2</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Warm-up</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Birthday party</td>
<td>Balloons</td>
<td>Book</td>
<td>Toothpaste</td>
</tr>
<tr>
<td>Grocery store</td>
<td>Shopping cart</td>
<td>Towel</td>
<td>Bear</td>
</tr>
<tr>
<td>Swimming pool</td>
<td>Water wings</td>
<td>Gloves</td>
<td>Mirror</td>
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<tr>
<td>Cookies</td>
<td>Plate</td>
<td>Shampoo</td>
<td>Blanket</td>
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<tr>
<td><strong>Test</strong></td>
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<tr>
<td>Road</td>
<td>Water</td>
<td>Present</td>
<td>Plant</td>
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<tr>
<td>Waterfall</td>
<td>Raincoat</td>
<td>Money</td>
<td>Rocks</td>
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<tr>
<td>Mountain</td>
<td>Lunch</td>
<td>Bowl</td>
<td>Sticks</td>
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<tr>
<td>Snow</td>
<td>Winter Coat</td>
<td>Swimming suit</td>
<td>Ice cube</td>
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<tr>
<td>Desert</td>
<td>Sunglasses</td>
<td>Soap</td>
<td>Seashell</td>
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<tr>
<td>Stream</td>
<td>Band-aids</td>
<td>Pillow</td>
<td>Fish</td>
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*Note.* Warm-up and test scenarios are listed with their three item choices. In the test phase, Distracter 2 items were semantically associated with their respective test scenarios.

**Warm-up Task**

“We’re going to play a game with pictures. It has two parts.” Experimenter points to first picture. “What do you see in this picture? Okay, let’s pretend that we’re going to this [scenario]. It’s time to get ready to go. Which one of these do you need to bring
with you?” Three choice items are placed in front of the child in a counterbalanced order. Questions repeated for scenarios 2-4.

**Experimental Task**

The following instructions are read for their respective scene with the placement of three choice items in front of the child in a counterbalanced order.

1. “What do you see in this picture? Okay, let’s pretend that we’re going to this walk across the long road. It’s time to get ready to go. Which one of these do you need to bring with you?
2. “What do you see in this picture? Okay, let’s pretend that we’re going to this walk next to the waterfall. It’s time to get ready to go. Which one of these do you need to bring with you?
3. “What do you see in this picture? Okay, let’s pretend that we’re going to this walk across the mountain. It’s time to get ready to go. Which one of these do you need to bring with you?
4. “What do you see in this picture? Okay, let’s pretend that we’re going to this walk across the snow. It’s time to get ready to go. Which one of these do you need to bring with you?
5. “What do you see in this picture? Okay, let’s pretend that we’re going to this walk under the sun. It’s time to get ready to go. Which one of these do you need to bring with you?
6. “What do you see in this picture? Okay, let’s pretend that we’re going to this walk across the rocks. It’s time to get ready to go. Which one of these do you need to bring with you?
Appendix B

Narrative Memory Task Acquisition Phase

Full Script

Static Electricity Objects: sock-balloon-cereal

Teacher: “This is a special day because Aimee is here to do a special science demonstration. She is standing right there and wearing a white lab coat. Hello Aimee!”

A: “Hello, I’m Aimee and I have my red box with stars with me.” *(Sits on floor and lifts up lid of box).*

A: “First I want to know a little bit more about you. What is your name? I’m Aimee.” *(repeat to each child)*

A: “I’m going to take out three special objects from my box.” *(Take out one at a time).*

“The first one is a red sock! I’m going to pass around the sock so that everybody gets a turn holding it! The second one is the white balloon! The third one is a bowl of cereal!”

A: “Now I’m going to put the balloon on the cereal. Nothing happens! But watch what happens when I do this! I’m going to rub the balloon with the sock and count to 10. 1-2-3-4-5-6-7-8-9-10! Now I’m going to put the balloon on the cereal. Look, the cereal is sticking to the balloon! Lets do it again and this time you can count with me. 1-2-3-4-5-6-7-8-9-10!”

A: “This because of something called static electricity. Static electricity is making the cereal stick to the balloon after I rub it with the sock. Before there was no static electricity when I didn’t rub the balloon with the sock. But this time the balloon sticks to the cereal after I rubbed it with a sock! Now I’m going to come around to each of you so that you can all have a turn to try.
A: “Have you ever seen anyone else make static electricity with a sock, balloon and bowl of cereal before? No? It looks like this is new for everybody!”

A: “I’m going to put my three special objects back into my box: the sock, the balloon, and bowl of cereal. Now I’m all done!”

A: “Now since you were all good children, I’m going to give you all a sticker.”

Teacher: “That is a really neat project. Now Aimee is going to leave! Let’s say goodbye!”

A: “Thanks for letting me show you my special science demonstration!”

Narrative Memory Test Phase
Free Response Instructions

“My game is about writing down what children say and I’m going to write down what you tell me on my piece of paper. I want you to tell me about yesterday. I heard that a girl named Aimee came in before and did a special science demonstration with this box (shows above color picture briefly). I wasn’t there, but I really want to know what happened. I want to know who was with you in the science demonstration, where you were, what you saw and what you played with. I’m going to write down everything that happened. So first what happened?”

Prompts allowed: “Try your best.”, “This is kind of hard.”, “Let’s think about it for a while.”, “Then what happened in the science demonstration.”, “Tell me more about the science demonstration.”, “What is one thing that happened?”, “What else happened?”, “What is one last thing that happened?”, “Anything else?”.

Aided Response Instructions

1. Who were with you in the science demonstration and what are their names?
2. What things did the person bring to the science demonstration?
3. What did you do in the science demonstration?
4. What did the people do or say in the science demonstration?
5. When did this science demonstration happen?
6. Where did this science demonstration happen and what did the room look like?
7. How did children feel during this science demonstration?
8. How did you feel during the science demonstration?

Note: If a child responds with “I don’t know” or “I don’t remember,” the experimenter can say any of the following: “Try your best,” “Then what happened in the science
demonstration,” and “Tell me more.” If the child already answered a question in the initial free-response minute, the experimenter will add, “I forgot to write all of it down. Tell me again.”

Non-narrative Memory Task

1. How long do you have to rub the balloon with the sock for it to stick? (What number did you count to)
2. What color jacket was Aimee wearing?
3. What color was the sock?
4. What color was the balloon?
5. What color was the bowl?
6. What color was the cereal?
7. What did you sit on?
8. Why did the balloon stick to the cereal after you rubbed it with a sock?
9. What color was the square mat you sat on?
Appendix C

Narrative Picture Task

Free Response Instructions

“I’m going to show you a picture. I want you to tell me a story about what’s happening in the picture. I want to know about the people, where they are, and what they are doing and I’m going to write down everything that you say. So first what’s happening?”

*Prompts allowed: “Do you see anything?”, “What else?”, “Is there one thing that is happening?”, “Is there one last thing?”, “Anything else?”.}
Aided Response Instructions

1. What is happening in the picture?

2. What are the people doing?

3. Anything else?

Note: If a child responds with “I don’t know”, the experimenter can say any of the following: “Try your best,” “Anything else?” and “What else?” If the child already answered a question in the initial free-response minute, the experimenter will add, “I forgot to write all of it down. Tell me again.”