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Episodic Memory and Future Thinking During Early Childhood: Linking the Past and Future

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Abstract

Despite extensive examination of episodic memory and future thinking development, little is known about the concurrent emergence of these capacities during early childhood. In Experiment 1, 3-year-olds participated in an episodic memory hiding task ["what, when, where" (WWW) components] with an episodic future thinking component. In Experiment 2, a group of 4-year-olds (including children from Experiment 1) participated in the same task (different objects and locations), providing the first longitudinal investigation of episodic memory and future thinking. Although children exhibited age-related improvements in recall, recognition, and binding of the WWW episodic memory components, there were no age-related changes in episodic future thinking. At both ages, WWW episodic memory performance was higher than future thinking performance, and episodic future thinking and WWW memory components were unrelated. These findings suggest that the WWW components of episodic memory are potentially less fragile than the future components when assessed in a cognitively demanding task.

Keywords

episodic memory; early childhood; longitudinal; memory binding; episodic future thinking; mental time travel

Memory is a critical component of cognition and survival. In order to function and adapt in the world, we rely on retrospective memory to reflect on past experiences and prospective memory to anticipate and plan for events in the future. This capacity to "pre-" and "re-experience" events is referred to as "mental time travel" (Suddendorf & Corballis, 2007; Tulving, 2005). Traditionally, the bulk of psychological investigations have focused on the retrospective aspects of memory – specifically, the capacity to mentally travel back in time

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to remember past events. In comparison, much less is known about the future-oriented components of mental time travel, despite the fact that our ability to think about future events, states, and needs is important to the survival and adaptation of our species. Indeed, Suddendorf and colleagues posit that the ability to reconstruct past events is not advantageous unless it benefits a present or future need (Busby & Suddendorf, 2005; Suddendorf, 2010a).

The present investigation examined the development of both retrospective and future-oriented aspects of episodic memory during early childhood. Our conceptualization of mental time travel ability was heavily influenced by Tulving's characterization of episodic memory. According to Tulving, episodic memory refers to recollection of personally experienced events and its contextual details (i.e., what, where, when: WWW); the capacity for mental time travel of past and future events; and a sense of autonoetic consciousness (Tulving, 1983, 1984, 2002). Through this aspect of autonoetic consciousness, individuals are able to "re-experience" an event in the past and project oneself into an event in the future. Evidence suggests that in adults, episodic memory and episodic future thinking are closely related (see Suddendorf, 2010a and Szpunar, 2010 for reviews). We know comparatively little, however, about how episodic memory and future thinking are linked during early childhood.

Tulving (2005) has proposed that children do not exhibit episodic memory with "adult-like" qualities (e.g., autonoetic consciousness) until 4 years of age. The extent to which autonoetic consciousness is measurable in preverbal infants and nonhuman animals has been questioned (Hayne & Imuta, 2011; Rovee-Collier & Cuevas, 2009). Research indicates that episodic and future-oriented memory development is protracted (see Hudson, Mayhew, & Prabhakar, 2011 and Olson & Newcombe, 2014 for reviews). As an initial step in understanding how episodic memory and future thinking are linked for the same event, we presented 3-year-olds with a hiding task designed to assess both components (Experiment 1). In the following sections, we provide brief overviews of the predominately separate literatures on episodic memory and episodic future thinking development during early childhood, and introduce a novel methodology which explores the integration of these two abilities in early childhood.

Episodic Memory

Binding refers to the process that encodes the relations among separate stimuli together into a cohesive unit, providing the experience that certain features of a memory episode belong together (Chalfonte & Johnson, 1996; Sluzenski, Newcombe, & Kovacs, 2006). The ability to bind individual elements of an event together (i.e., WWW) has been considered a hallmark of episodic memory (Olson & Newcombe, 2014). By 6 months of age, infants exhibit deferred imitation of a one-time event—a memory that includes WWW components (e.g., Barr, Dowden, & Hayne 1996; Cuevas, Rovee-Collier, & Learmonth, 2006). There is consensus that deferred imitation paradigms tap explicit memory processes, however, there is debate as to whether these representations are episodic in nature, requiring mental time travel as opposed to semantic memory (Colombo & Hayne, 2010; see Raj & Bell, 2010 for review).

A variety of different verbal and nonverbal paradigms have been used to assess episodic memory during early childhood, revealing two basic findings: (1) the components of episodic memory develop at different rates with spatial and temporal components emerging later (e.g., Picard, Cousin, Guillery-Girard, Eustache, & Piolino, 2012; Riggins, Miller, Bauer, Georgieff, & Nelson, 2009) and (2) children exhibit age-related improvements in their ability to bind components of an event together (e.g., Lloyd, Doydum, & Newcombe, 2009). For instance, although 4-year-olds can verbally recall factual information learned in an experimental setting, the ability to link this information with the corresponding source (e.g., puppet, experimenter) continues to improve through at least 8 years of age (Drummey & Newcombe, 2002; Rajan, Cuevas, & Bell, 2014). Similar patterns have been found using object-background binding tasks (Lloyd et al. 2009) as well as tasks that involve personally experienced events (Bauer, Doydum, Pathman, Larkina, Güeler, & Burch, 2012) with recent evidence of more advanced binding emerging between 7 years and adulthood (Yim, Dennis, & Sloutsky, 2013).

The research highlighted in the previous paragraph has all focused on children 4 years and older with the majority of the episodic memory tasks being too complicated for younger children. There is evidence to suggest that the early rudiments of episodic memory ability or "episodic-like" memory are evident by the age of 3 (Hayne & Imuta, 2011). In the present study, we were interested in the WWW components of episodic memory at 3 years of age, and we used a modified version of Hayne and Imuta's (2011) hiding task. In the original version of the task, a researcher visited 3- and 4-year-olds in their homes and hid a total of three objects in different locations within different rooms of the house. After a brief delay, children were asked to verbally recall the object that was hidden ("what"), the specific room and hiding location of the object ("where"), and the order in which the object was hidden ("when"). Although 4-year-olds performed better than 3-year-olds on all episodic memory components, a subsequent behavioral recall test for the "where" and "when" components revealed equivalent ceiling performance on the "where" component and poor performance by 3-year-olds on the "when" component. Thus, the hiding task appears to be an age-appropriate measure of episodic memory with children's memories exhibiting similar properties as found with other episodic memory tasks with older children (see also Newcombe, Balcomb, Ferrara, Hansen, & Koski, 2014). Further, adults use mental time travel when performing an age-appropriate version of the hiding task and their task performance is also associated with performance on other episodic memory tasks (Cheke & Clayton, 2013; Holland & Smulders, 2011).

Episodic Future Thinking

Episodic future thinking and episodic foresight are terms used to describe an individual's use of episodic memory to direct future behavior, including the ability to pre-experience an event by "mentally time travelling" to a specific time in the future (see Hudson et al., 2011 for review). In response to criticism that autonoetic consciousness could only be measured verbally, Tulving (2005) proposed a potential nonverbal measure of mental time travel, typically called the "spoon test." Tulving describes an Estonian children's story in which a little girl dreams of being at a birthday party where all of the guests are eating chocolate pudding except for her because she did not bring her own spoon. The next night, the little girl brings a spoon with her to bed. Tulving proposed that the little girl's ability to “mentally time travel” was evident in her behavior, and a nonverbal measure similar to the “spoon test” could provide evidence of episodic future thinking. To rule out other factors, it is important that (a) the future-oriented behavior is not related to a current physiological state (e.g., thirst, hunger); (b) the future-oriented behavior is separated in both time (i.e., requiring long-term memory) and space (i.e., removing potential retrieval cues) from the original event; and (c) the future-oriented behavior is not potentially the result of action-outcome associations formed across multiple trials (Hampton & Schwartz, 2004; Suddendorf & Corballis, 1997, 2010; Tulving, 2005).

In general, children's future thinking appears to emerge between 3 and 5 years of age (e.g., Russell, Alexis, & Clayton, 2010), and one way that developmental researchers have applied Tulving's “spoon test” is to use choice tasks (Atance & Jackson, 2009; see Hudson et al., 2011 for review). In these tasks, children are exposed to one situation where a critical item is missing, such as going to a sand box, finding a treasure chest, and not having the key to open it. Children are then brought to a different context (e.g., room full of toys and books), and after a delay, they are told that they are going to return to the original location (with no mention of the target object), and are asked to choose to bring something with them. After an object is chosen, children are asked “why” they chose that object. The choice of the missing item (e.g., a key) amongst other distractor items (often more “exciting” objects) in conjunction with some reference to the target object is considered evidence of early episodic future thinking.

One of the only episodic future thinking studies that meets the aforementioned criteria (to rule out other factors) found that although the majority of 4-year-olds exhibited evidence of episodic future thinking after a delay of 1 week, 3-year-olds only demonstrated episodic future thinking when tested after a delay of less than 30 min (Scarf, Gross, Colombo, & Hayne, 2013). It appears that children younger than 4 years of age are able to form episodic memories and exhibit episodic future thinking, but this ability is limited with 3-year-olds not retaining episodic information over relatively long (i.e., 30 min or longer) durations. In the present study, we use a similar “spoon test” after a minimal delay (i.e., 6 min) to provide an age-appropriate assessment of young children's episodic future thinking to compare with their WWW episodic memory.

Episodic Memory and Future Thinking: Linking Past and Future

One way to assess children's episodic past and future is to ask them to describe something from their past (e.g., yesterday) and future (e.g., tomorrow). This evidence suggests substantial improvements in the accuracy of children's reports between 3 and 4 years of age, with children performing similarly on both past and future questions (Busby & Suddendorf, 2005; Suddendorf, 2010b). To help younger children with their limited understanding of temporal language, Hayne and colleagues used personalized timelines to interview children about events (provided by parents) in their past (i.e., yesterday, earlier today) and future (i.e., tomorrow, later today; Hayne, Gross, McNamee, Fitzgibbon, & Tustin, 2011). Although 5-year-olds reported more information than 3-year-olds, there was no difference in the accuracy of information as a function of age or question type. Together, evidence from interview-based assessments suggests that episodic past and future thinking are related during early childhood. However, these assessments are unable to examine concurrent links between episodic future and past thinking relating to the same experience.

In the context of an episodic foresight task (i.e., similar to choice tasks described in the previous section), Atance and Sommerville (2014) asked independent groups of 3- to 5-year-olds a memory question (e.g., “What's on the table in the snail room?”; indicating memory of the problem solving object) after they chose an object (i.e., missing item) to bring with them to the problem solving room (demonstrating future thinking). When controlling for age, they found a strong correlation (r = .53) between correct performance on the item choice (i.e., episodic foresight) and memory questions (i.e., episodic memory). However, 23%, 29%, and 15% of 3-, 4-, and 5-year-olds, respectively, failed the item choice task while correctly answering the memory question, suggesting that whereas episodic foresight and memory are linked, their onsets of functional development may differ. The aim of the present study is to provide a more detailed analysis of the binding between episodic past and future thinking, integrated within the same event.

Experiment 1: 3-year-olds

The goal of Experiment 1 was to examine whether and the extent to which episodic memory and future thinking were interrelated within the same event at 3 years of age; thus, providing a more comprehensive understanding of the emergence of episodic memory. To this end, we modified and combined measures of children's WWW episodic memory from a hiding task (Hayne & Imuta, 2011) with measures of children's episodic future thinking from a “spoon test” (Scarf et al., 2013). Newcombe and colleagues (Newcombe et al., 2014; Olson & Newcombe, 2014) have proposed that using a hiding task in a highly familiar environment potentially biases findings as demonstrated by spatial memory and episodic memory research (Feldman & Acredolo, 1979; Hupbach, Gomez & Nadel, 2009). Thus, in the present study, children visited a research laboratory and accompanied a researcher to hide a total of four objects in distinctive, novel contexts with a critical item missing for each object. We elected to use four objects and locations to afford additional opportunities for children to exhibit evidence of episodic memory and future thinking, allowing for individual differences in performance based on children's potential bias toward interesting objects/contexts/missing items. After a brief delay, children were asked to verbally recall the WWW components of the event. Because it is not always feasible for children to return to the scene of an event in order to provide a nonverbal measure of episodic memory (e.g., eyewitness testimony), we also provided children who failed to recall an object or room with a recognition test using meaningfully-related clipart images, and asking them to point to the image that reminds them of the room or object. Finally, the “spoon test” was used to examine episodic future thinking for remembered objects. To limit the influence of response-outcome associations across multiple trials (1) children did not return to the room with the object between missing item choice trials; and (2) children were not asked why they picked each item until all future-oriented responses were completed.

Based on the aforementioned research, we hypothesized that 3-year-olds would exhibit similar performance on episodic memory and future thinking with memory for “what” potentially being higher than the memory for “where” and “when”. Likewise, we posited that episodic past and episodic future performance would be correlated. Finally, we anticipated that binding might prove particularly difficult at 3 years of age with better performance on individual episodic memory elements as compared to bound sets of linked information (i.e., integration of the “where” and “what” components for a particular hiding object) .

Method

Participants—A total of 43 (29 girls; 3 Hispanic, 40 Non-Hispanic; 40 Caucasian, 3 Multi-Racial) three-year-olds (*M* = 3.25 years, *SD* = 0.11; 3.10 - 3.53 years) participated in our hiding task while visiting the laboratory as part of a longitudinal study examining cognitive and emotional development from infancy through early childhood. All children were born within 4 weeks of their expected due dates and had no diagnosed neurological problems or developmental delays. For parents who reported educational information (43 mothers,40 fathers), all completed a high school education (2.3% and 0% technical degree, 41.9% and 32.5% bachelor's degree, 27.9% and 30% graduate degree, respectively). Average maternal and paternal age at birth was 29.1 and 32.4 years (SD = 5.9 and 8.4), respectively.

Procedure—Three-year-olds and their mothers visited the laboratory to participate in a variety of cognitive and interaction tasks. The experimenter established rapport with each child prior to task administration. Children were asked if they had ever hidden anything before and were invited to help the experimenter play a hiding game.

Familiarization: First, 3-year-olds were asked to name each of the four hiding objects (see Table 1) in the experiment room. If the child did not respond or provided an alternative name for the object, the experimenter verbally labeled the object for the child and recorded any alternative responses. The experimenter ensured that the child knew each object's name before beginning the hiding procedure.

Hiding: Children watched the experimenter hide objects in four different rooms (Table 1). Two of the room-object combinations were related (e.g., pirate room-treasure box) and two were unrelated (e.g., stairwell-juice box). As noted in Table 1, the room hiding order was identical for all participants. For each room, the experimenter began by asking the child to name the room. If the child did not respond or provided an alternative name for the room, the experimenter told the child the correct name of the room and recorded alternative responses. Next, the child was asked to stand on the “x” in the hiding room, to ensure that each child had a standardized and unobscured visual perspective of the following series of actions. The child was then shown the hiding object and asked to name the object. Afterwards, the experimenter emphasized that a critical object was missing—the future item (Table 1). The experimenter then asked the child to watch as she hid the object and narrated while hiding the object. The child was asked the name of the room one final time. The same procedure was repeated for the remaining three hiding rooms.

An example of the hiding narration: “We are going to hide the treasure chest, but wait, we forgot the key. We can’t open the treasure chest if we don’t have the key! We are going to hide it anyways. Let's hide the treasure chest on top of the desk.”

Retrieval: After all objects were hidden, the experimenter and child returned to the experiment room. The child was then engaged in unrelated games and activities for approximately 6 min to prevent the child from overtly rehearsing. Children were then asked to name a room that they visited during the hiding game (*Where-1 Recall)*, name what was hidden in that room (*What Recall*), and state the specific spatial location where the item was hidden within the room *(Where-2 Recall*). *Where-1* and *What* recognition questions were asked when children failed to recall a particular room or hiding object. On recognition trials, the experimenter said, “*Let me ask you in my special way*,” placed four clipart images equidistant from the child, and asked the child to pick the one that reminded him/her of a room that they visited (*Where-1 Recognition*) or an object that they had hidden (*What Recognition*). The distractor clipart images were from a similar category to the target image (e.g., children's activities, beverages). Correct recognition responses were followed by appropriate recall questions (e.g., *What* and *Where-2*). A general *What Recall* prompt, “Do you remember anything (else) that we hid?” was asked when there was at least one room that children could not remember via recall or recognition. Because the *Where-2* (object hiding location) and *Future* questions were dependent on the hiding object, these questions were asked only if children recalled or recognized the pertinent hiding object.

The *Future* question was asked immediately after the *Where-2 Recall* question. The experimenter said, “We are going to go back to this room. Pick something you want to bring with you.” She then placed four objects (1 future object and 3 distractor objects) equidistant from the child. Two of the distractor objects were toys and the other distractor object was a common object (e.g., binder clip, pipe cleaner). We refrained from asking children why they picked the future item in order to minimize potential influence of subsequent choices on the remaining *Future* questions. Children were separately shown each chosen future item and asked why they picked to bring each item with them. Finally, children were asked to identify the order (*When*) in which they visited each of the hiding rooms. The experimenter asked, “Which room did we visit first? Which room did we visit next?”

Children's responses were scored for the number of correct responses for each question category. It was possible for children to receive partial credit for the object hiding location (*Where-2*) question. For instance, for “under the chair” children would receive half credit if they said either “under” or “chair.”

Verbal ability: The Peabody Picture Vocabulary Test-IV (PPVT-IV; Dunn & Dunn, 2007) was administered to children during a recent laboratory visit (average delay 56 days, *SD* = 28) and provided data on their receptive vocabulary and verbal comprehension. The PPVT - IV is a nationally standardized instrument, and the measure of interest was participants’ standard scores.

Results and Discussion

Preliminary analyses tested for sex differences. There were no differences in boys' and girls' performance on any of the measures of interest. Thus, the data were collapsed across sex for both experiments because there were no sex differences in either data set (all *p*s > .05).

Three-year-olds' performance on the hiding task is presented in Figure 1. Most 3-year-olds recalled at least one room (56%), object (85%), or hiding location (70%), and 59% chose at least one missing item. For recall questions, a repeated measures analysis of variance (ANOVA) revealed a main effect for question type, $F(3, 105) = 28.48$, $p < .001$, $\eta_p^2 = .45$. As can be seen in Figure 1, post-hoc analyses ($p < .05$ with Bonferroni correction) revealed that 3-year-olds recalled the least information about the room hiding order (*When?*). In fact, only 22% of 3-year-olds recalled anything about the hiding order with 43% of children providing no response or no relevant response to the room hiding order question. Post-hoc analyses also revealed that 3-year-olds recalled more about the objects (*What?*) than the rooms (*Where-1?*). This difference remained significant when aggregating recall and recognition responses, $t(42) = 2.92$, $p = .006$, $d = 0.48$. However, whether or not the rooms and objects were meaningfully related (e.g., pirate room-treasure box vs. stairwell-juice box) did not impact recall performance even when considering integrated room + object + location (ROL; see below for more detail) sets of linked information, all *t*s ≤ 1.54, *p*s ≥ .13.

Because location (*Where-2?*) and missing item (*Future*) questions were based on remembering (recall/recognition) the corresponding object, it should be noted that an average of 2.6 ($SD = 1.1$) location and missing item questions were administered to each 3-year-old. The proportion of correct responses was .56 and .31 for location and missing item questions, respectively. Three-year-olds' performance on the missing item (*Future*) question was not significantly above chance [i.e., 1 out of 4: .25; $t(40) = 1.11$, $p = .27$; see Figure 1]. However, 70% of children who chose a correct missing item verbally referred to its future utility. There was no difference in 3-year-olds' language scores on the PPVT-IV in relation to whether or not they chose a correct missing item or referred to the item's future utility, all *t*s ≤ 1.62, *p*s ≥ .11.

As displayed in Table 2, children's memory of objects (*What?*), rooms (*Where-1?*), and locations (*Where-2?*) were correlated even when controlling for receptive language. Three-year-olds' overall poor performance on the room hiding order (*When?*) may be related to the few associations with other WWW components of episodic memory. Surprisingly, performance on the missing item question (*Future*) was only related to object (*What?*), which may be an artifact of our experimental procedure (i.e., missing item questions were only asked for remembered objects).

Initial evidence of binding the *Where-1&-2* and *What* details was observed at 3 years of age with 37% of children recalling at least one ROL (room + object + location) set (see Figure 1). Half of this subset of 3-year-olds (19%) also chose the corresponding missing item (*Future*; see Figure 1). Children who recalled at least one ROL set had higher receptive language scores ($M = 126.63$, $SD = 8.65$) than children who did not ($M = 110.48$, $SD = 14.41$), $t(41) = 4.06$, $p < .001$, $d = 1.36$.

In Experiment 1, 3-year-olds performed better on the WWW episodic memory components than the future thinking components with few associations across episodic past and future components. Using an interview-based assessment, Richmond and Pan (2013) found that although episodic past and future responses were correlated, 3- to 5-year-olds provided more episodic details about past events than future events. Likewise, within an episodic foresight task, 23% and 29% of 3- and 4-year-olds, respectively, passed a retrospective memory question while failing a corresponding episodic-future thinking question (Atance & Sommerville, 2014). Although Attance and Sommerville's task also had a total of four episodic future questions, children were only asked a single memory question (a “what” question) and it appears that each future question was presented separately (i.e., each item response was immediately followed by the outcome). It is likely that our four object/location hiding task in a novel location was challenging for 3-year-olds. Although this was not the aim of the study, these findings suggest that the WWW components of episodic memory are potentially less fragile than the future component when assessed in a cognitively demanding task. Our findings might also indicate a sequential functional emergence of the episodic memory and future-thinking. To further investigate this unexpected pattern of findings, we conducted an extension of this investigation at age four (Experiment 2).

Experiment 2: 4-year-olds

Despite the hypothesized emergence of episodic memory with “adult-like” qualities (e.g., autonoetic consciousness) at 4 years of age (Tulving, 2005) this transition has not been empirically examined among individual children via longitudinal investigations. The episodic memory literature is limited to independent groups of 3- and 4-year-olds, with the exception of repeated interviews regarding an event memory (e.g., Tizzard-Drover & Peterson, 2004). During early childhood, the limited longitudinal literature on episodic memory has focused on (1) children's memory reports (i.e., number of features and event elaborations) as a function of mother-child conversational style from 2.5 to 3.5 years (Haden, Ornstein, Eckerman, & Didow, 2001) and 3 to 3.5 years (Hedrick, Souci, Haden, & Ornstein, 2009); and (2) free recall in the context of an examination of metamemory from 4 to 6 years (Schneider & Sodian, 1991) and 6 to 10 years of age (Schneider, Kron-Sperl, & Hünnerkopf, 2009).

Experiment 2 focused on developmental improvements in mental time travel ability during early childhood, beginning at 3 years (Experiment 1) with the emergence of WWW episodic memory and charting the transformation to a more complex form of memory that includes the ability of mental time travel for past and future events. To our knowledge, no other investigation has conducted a longitudinal examination of mental time travel ability during the preschool years. To this end, we tested a subset of the children from Experiment 1 again when they were 4 years of age. In addition, a naïve control group of 4-year-olds, who had not participated in the hiding game at 3 years of age, were included to examine potential effects of repeated testing. Because performance on the hiding order question was at floor levels at 3 years of age, we elected to include a nonverbal follow-up probe to see if this would facilitate performance.

We hypothesized that 4-year-olds would exhibit age-related improvements in episodic future thinking as well as the WWW episodic memory components. Likewise, we anticipated substantial improvements in children's ability to bind the elements of episodic memory together. Finally, although episodic future thinking was not related to WWW episodic memory components at 3 years of age in the context of a cognitively demanding task (Experiment 1), we predicted that these association would be present at 4 years of age when children's episodic memory abilities are thought to be more nuanced or more "adult-like" (Tulving, 2005).

Method

Participants—A total of 38 (18 girls; 3 Hispanic, 35 Non-Hispanic; 35 Caucasian, 3 Multi-Racial) four-year-olds[1] (*M* = 4.10 years, *SD* = 0.07; 3.99 - 4.26 years) participated our hiding task with 27 children returning from Experiment 1 (testing interval *M* = 326.42 days, *SD*= 36.73) and 11 children performing the hiding task for the first time. All children were born within 4 weeks of their expected due dates and had no diagnosed neurological problems or developmental delays. For parents who reported educational information (37 mothers,35 fathers), all completed a high school education (2.7% and 0% technical degree, 37.8% and 48.6% bachelor's degree, 35.1% and 25.7% graduate degree, respectively). Average maternal and paternal age at birth was 29.8 and 31.9 years (SD = 5.1 and 6.2), respectively.

Procedure—The procedure was identical to Experiment 1 and is detailed in Table 1 with the exception that the PPVT-IV was administered during the same session as the hiding task. At the very end of the session, immediately after answering the hiding order question, 4-year-olds (n = 35) were asked to point to one of four clipart images that reminded them of the room that they went to first, next, etc. (*nonverbal When?*).

Results and Discussion

Four-year-olds—Prior to combining the data from longitudinal and first time hiding game participants, it was necessary to determine whether there were any repeated testing effects. Independent *t*-tests indicated that 4-year-olds did not differ in any variable of interest as a function of group, all ts ≤ 1.77, ps ≥ .085 (see Table 3). These groups were combined for subsequent analyses.

Four-year-olds' performance on the hiding task is presented in Figure 1. Most 4-year-olds recalled at least three rooms (71%), objects (53%), or hiding locations (66%), and 60% chose at least one missing item. For recall questions, a repeated measures ANOVA revealed a main effect for question type, $F(3, 108) = 68.34$, $p < .001$, $\eta_p^2 = .65$. As can be seen in Figure 1, post-hoc analyses ($p < .05$ with Bonferroni correction) revealed that 4-year-olds recalled the least information about the room hiding order (*When?*). Although 60% of 4-

[1]Thirty-eight of the 43 children from Experiment 1 returned to the laboratory. The first 11 children were tested in an identical 5-room protocol that included the pirate room and treasure chest (from Experiment 1) as a fifth hiding location. However, preliminary analyses suggested that the increased difficulty of the task potentially masked longitudinal changes in episodic memory. Thus, the remaining 27 children were tested using the 4-room protocol. An additional 14 children (5 room: n = 3; 4 room: n = 11) performed the hiding task for the first time at 4 years of age. In order to make direct comparisons with Experiment 1, we only report the results from the 4-room protocol.

year-olds recalled something about the order, 30% provided no response or no relevant response to the hiding order question. Children's hiding order performance was not significantly enhanced when a pointing response was used in a follow-up question (*nonverbal When?)*, even when excluding the 12 four-year-olds who pointed to the cards from left-to-right or vice versa, all *t*s ≤ 0.38, *p*s ≥ .70.

There was no difference in the magnitude of recall performance for the room, object, and location questions (*What?, Where-1?, Where-2?*). When recall and recognition responses were combined, however, 4-year-olds remembered more objects than rooms, $t(37) = 3.09$, $p = .004$, $d = 0.60$. Similar to our findings at 3 years of age, whether the rooms and objects were meaningfully related had no effect on recall performance including ROL sets, all *t*s ≤ 1.54, *p*s ≥ .13, respectively.

Because the majority of 4-year-olds remembered all of the objects, an average of 3.7 ($SD = 0.6$) questions were administered to each child. The proportion of correct responses was .77 and .21 for location and missing item questions, respectively. Four-year-olds' performance on the missing item (*Future*) question was at chance [i.e., .25; see Figure 1]. However, 72% of children who chose a correct missing item referred to its future utility. There was no difference in 4-year-olds' language scores on the PPVT-IV in relation to whether or not they chose a correct missing item or referred to the item's future utility, all *t*s ≤ 0.16, *p*s ≥ .87.

As can be seen Table 4, we found similar patterns of effects at 3 and 4 years of age (Table 2). Four-year-olds' memory of objects (*What?*), rooms (*Where-1?*), and locations (*Where-2?*) were correlated even when controlling for language. Although 4-year-olds' performance on the room hiding order (*When?*) question was better than at 3 years of age (see Figure 1 and *Longitudinal Analyses* section below), performance remained very poor (i.e., naming only the first room visited correctly). This likely underlies the few significant associations amongst room hiding order and other WWW episodic memory components. Once again, performance on the missing item question (*Future*) was not related performance on any other the other WWW episodic memory components. Although children's performance on the WWW episodic memory components improved from 3 to 4 years (see Figure 1 and *Longitudinal Analyses* section below), there was no concurrent improvement in episodic future thinking performance.

The majority of 4-year-olds were able to bind the *Where-1&2* and *What* details during the hiding task with 84% of children recalling at least one ROL (room + object + location) set (see Figure 1). Eleven children (37% of children with usable data[2]) also chose the corresponding missing item (*Future*; see Figure 1). Although there were no differences in children's scores on the PPVT-IV as a function of whether or not the recalled any ROL sets, $t(36) = 1.63$, $p = .11$, language scores were correlated with the number of ROL sets recalled $r = .39$ (see Table 4).

[2]Some children did not have usable future item data because of experimenter error (e.g., referring to the object during the missing item choice question) that was not identified until the data were coded.

Longitudinal findings—The performance of children who participated in the hiding task at both 3 and 4 years of age is displayed in Figure 2. A 2 (Age) × 4 (Question Type) repeated measures multivariate analysis of variance (MANOVA) of recall performance revealed a main effect for age, $F(1, 20) = 31.06$, $p < .001$, $\eta_p^2 = .61$; a main effect for question type, $F(3, 18) = 44.28$, $p < .001$, $\eta_p^2 = .88$; and an Age × Question Type interaction, $F(3, 18) = 5.03$, $p = .011$, $\eta_p^2 = .46$ (see Figure 2). Paired *t*-tests confirmed that children's recall performance for each question type (i.e., *What?*, *Where-1?*, *Where-2?*, *When?)* improved between 3 and 4 years of age, all *t*s ≥ 2.45, *p*s ≤. 023, *d*s≥ 0.77. Likewise, there were age-related improvements in children's memory for the room and object when recall and recognition responses were combined, all *t*s ≥ 3.80, *p*s ≤. 001, *d*s≥ 1.15. Between 3 and 4 years of age, children's performance improved for both related and unrelated room-object pairs, all *t*s ≥ 5.12, *p*s ≤. 001, *d*s≥ 0.91, with the exception of unrelated object recall performance, $t(23) = 1.97$, $p = .061$, $d = 0.61$.

Based on the pattern of findings for all 3- (Experiment 1) and 4-year-olds (Experiment 2), the Age × Question Type interaction was likely driven by the congruence of object and room recall performance at 4, but not 3, years of age. Repeated measures ANOVAs confirmed that there was a significant main effect of question type at 3 and 4 years of age, $F(3, 60) = 5.03$, $p = .011$, $\eta_p^2 = .46$ and $F(3, 69) = 55.08$, $p < .001$, $\eta_p^2 = .71$. Post-hoc analyses ($p < .05$ with Bonferroni correction) indicated that object recall (*What?*) was significantly greater than room recall (*Where?*) at 3, but not 4, years of age. At both ages, recall was better for room, object, and location questions as compared to the hiding order questions.

There was no significant change between 3 and 4 years of age in children's performance on the missing item questions or relevant why responses (*Future?*; Figure 2), even when accounting for the number of questions asked at each age, all *t*s ≤ 0.82, *p*s ≥ .42. As can be seen in Figure 2, children's ability to bind the individual components of the event (ROL sets) did improve from 3 to 4 years of age, $t(23) = 4.59$, $p < .001$, $d = 1.10$.

General Discussion

The present set of experiments provides the first comprehensive longitudinal analysis of 3- and 4-year-olds' WWW episodic memory and future thinking for a single experience. We found developmental changes in binding and memory for individual WWW episodic memory components as suggested by previous work (Bauer et al., 2012; Hayne & Imuta, 2011; Lloyd et al., 2009; Picard et al., 2012). Interestingly, our findings regarding 3- and 4-year-olds' associations between episodic future thinking and WWW episodic memory did not support our hypotheses; at both ages, episodic memory and future thinking were not associated. This lack of association is potentially related to children's poor performance of the episodic future thinking task. Children performed better on most of the WWW episodic memory components than the future thinking component.

Previous research using interview-based assessments that did not require children to remember a particular event have found that (1) 3- and 4-year-olds' past and future episodic memory abilities are related; and (2) 3- and 4-year-olds performed similarly on past and future episodic memory components (Busby & Suddendorf, 2005; Hayne et al., 2011;

Suddendorf, 2010b). However, there are exceptions to this pattern of findings, even within the relatively low task demand setting of the interview-based assessment (Busby & Suddendorf, 2005: Experiment 2; Richmond & Pan, 2013). We hypothesize that the discrepancy between our findings and previous developmental research is related to differences in task demands; the present task was likely a cognitively challenging, and perhaps taxing, task for 3- and 4-year-olds. We interpret our findings to indicate that when episodic memory is challenged during early childhood, differences in episodic past and future thinking emerge. Our findings suggest that the WWW components of episodic memory are potentially more robust to the challenge of cognitive load than are future mnemonic components (i.e., four hiding objects and locations in a context that is not highly familiar).

In discussing evidence of young children's retrospective memory despite a lack of episodic foresight, Atance and Sommerville (2014, p. 125) state that "episodic foresight requires more than memory for the past event". Specifically, they highlight that future events are often less certain, more hypothetical, and potentially require a stronger imaginative component (Atance & O'Neill, 2005; McColgean & McCormack, 2008). Episodic future thinking might also be more challenging because of its reliance on advanced executive function skills, such as planning (McCormack & Atance, 2011). Thus, if episodic future thinking requires more cognitive resources in low task demand situations, such as Atance and Sommerville's (2014) study, then our additional task demands (i.e., multiple hiding objects-locations in a novel context) likely overwhelmed this system. This notion is particularly interesting because the missing item choice task used to assess episodic future thinking was a nonverbal task with relatively low memory demands as compared to the verbal recall responses required for the retrospective components of episodic memory. It would be informative if future research also included an open-ended future thinking question prior to the item choice question to enhance the similarity across assessments.

In the naturalistic context of children's daily routines, although there is evidence that mothers engage their children in talk about both the past and future, it is likely that young children have more experience describing specific episodes from their past, as compared to the future (see Hudson et al., 2011, for review). This would be consistent with the literature on maternal conversational style supporting children's narratives (Haden et al., 2001). We acknowledge that our task demands hypothesis is a post-hoc explanation of our unanticipated findings, and future research that intentionally manipulates the task demands (e.g., memory requirements) in the context of past and future episodic memory is critical to testing this hypothesis. Furthermore, within-subjects analysis across both interview-based and event-specific (as in the present study) assessments is critical to providing a more comprehensive understanding of episodic memory development, permitting researchers to compare these capabilities in low- and high-demand situations.

Our findings suggest that recognition questions facilitate memory retrieval during early childhood, with similar findings to research using behavioral reenactment (Hayne & Imuta, 2011). Although 3-year-olds performed better on the "what" component than the "where" component (i.e., room), by 4 years of age this difference was not significant unless both recall and recognition responses were combined. Hayne and Imuta (2011) found the opposite pattern of findings (i.e., room performance > object), but we attribute this discrepancy to the potential influence of testing in a highly familiar environment (i.e., children's home). Recent evidence from a two room hiding task (in a novel context) with children between 15 and 72 months of age indicates that the ability to integrate the contextual details of episodic memory is protracted (Newcombe et al., 2014).

At both ages, children's performance on the hiding order question (*When?*) was worse than all other episodic memory components (i.e., *What?* and *Where?*). Temporal order memory appears to exhibit protracted development in a variety of paradigms (Hayne & Imuta, 2011; Picard et al., 2012; Riggins et al., 2009), and our nonverbal pointing procedure with 4-year-olds did not enhance performance as compared to verbal recall. However, using behavioral reenactment [i.e., children are asked to show the experimenter which room they went to first (or next)] also appears to be ineffective at enhancing temporal order performance (see Hayne & Imuta, 2011, Figures 1 and 2). Although there is evidence that even 3-year-olds understand the meaning of “first” (Friedman & Seely, 1976), it is plausible that a modified version of a personalized timeline similar to that used be Hayne et al. (2011) might facilitate children's performance on the this component of episodic memory. Furthermore, children might perform better on the temporal order question if it was more integrated into the interview (i.e., “What room did you go to first?” to assess both order and room recall; Hayne & Imuta, 2011) as compared to asking the same question as a separate question at the end of the interview as we did in the current experiment.

Our results also complement the relational memory binding literature, in that children were able to demonstrate intact memory for individual features, but experienced greater difficulty retaining memory for the bound ROL information. Although there is some evidence to suggest that 9-month-olds demonstrate recognition of familiar face-scene combinations (Richmond & Nelson, 2009), relational memory is still under-developed in infancy (Koski, Olson, & Newcombe, 2013; Olson & Newcombe, 2014) and continues to show improvement throughout the preschool years (Lloyd et al., 2009; Sluzenski et al., 2006). Indeed, in our investigation, the linked association between episodic memory components continued to show improvement between 3 and 4 years of age. As noted by Shing, Werkle-Bergner, Li and Lindenberger (2008), it is only by middle childhood that the associative component of episodic memory is relatively intact and shows adult-like qualities.

It is possible that our episodic future thinking responses were affected by some children not being able to solve the missing item problem. Atance and Sommerville (2014), for instance, included a knowledge question in which children who picked the incorrect item on the episodic foresight task were shown the items again and the problem solving object to see if they could choose the correct item in the present. Thus, only children who could pass the criterion in the present were included in subsequent analyses. We believe that this control could enhance the interpretation of future research combining episodic future and past memory components. In order to rule out the effect of potential action-outcome associations in studies that use multiple trials, we recommend that the knowledge questions are not administered until the end of the experimental protocol as to not affect any subsequent future-oriented responses.

Finally, although our study failed to find evidence that episodic memory and future thinking were related during early childhood, this lack of association is potentially driven by children's poor performance on our version of the “spoon task”. There is evidence that when 3- and 4-year-olds are presented with a single episodic future thinking problem, they can pass the spoon task (Scarf et al., 2013). Thus, additional research is necessary to determine whether “spoon task” performance is associated with concurrent episodic memory performance under more optimal task demand conditions (i.e., fewer than four concurrent future thinking problems). In addition to the potential influence of task demands, it is also possible that children's poor performance in the current episodic future thinking test was related to experimental fatigue, as the hiding task was part of a larger experimental protocol. Although our protocol includes multiple preventatives (e.g., snacks, breaks) and subjective measures of experimental fatigue (e.g., compliance, engagement), we did not have an objective measure of fatigue (e.g., administering a standardized task at the beginning and end of the session). It seems unlikely, however, that experimental fatigue would result in poor performance on one component of hiding task performance, but not other components. Although experimental fatigue cannot be ruled out as a potential contributor to our current patterns of findings, based on evidence highlighted throughout the discussion, we conclude that task demands are likely the major contributor. Clearly, future work directly examining the proposed influence of task demands on children's episodic memory and future thinking is essential to testing our hypotheses.

In sum, using a longitudinal design, we replicated many of the developmental transitions noted in previous episodic memory research with 3- and 4-year-olds. Our findings reveal that when considering the retrospective and future-oriented aspects of episodic memory for a single experience, episodic future thinking is potentially more susceptible to the detrimental effects of a cognitively demanding context as compared to WWW episodic memory components.

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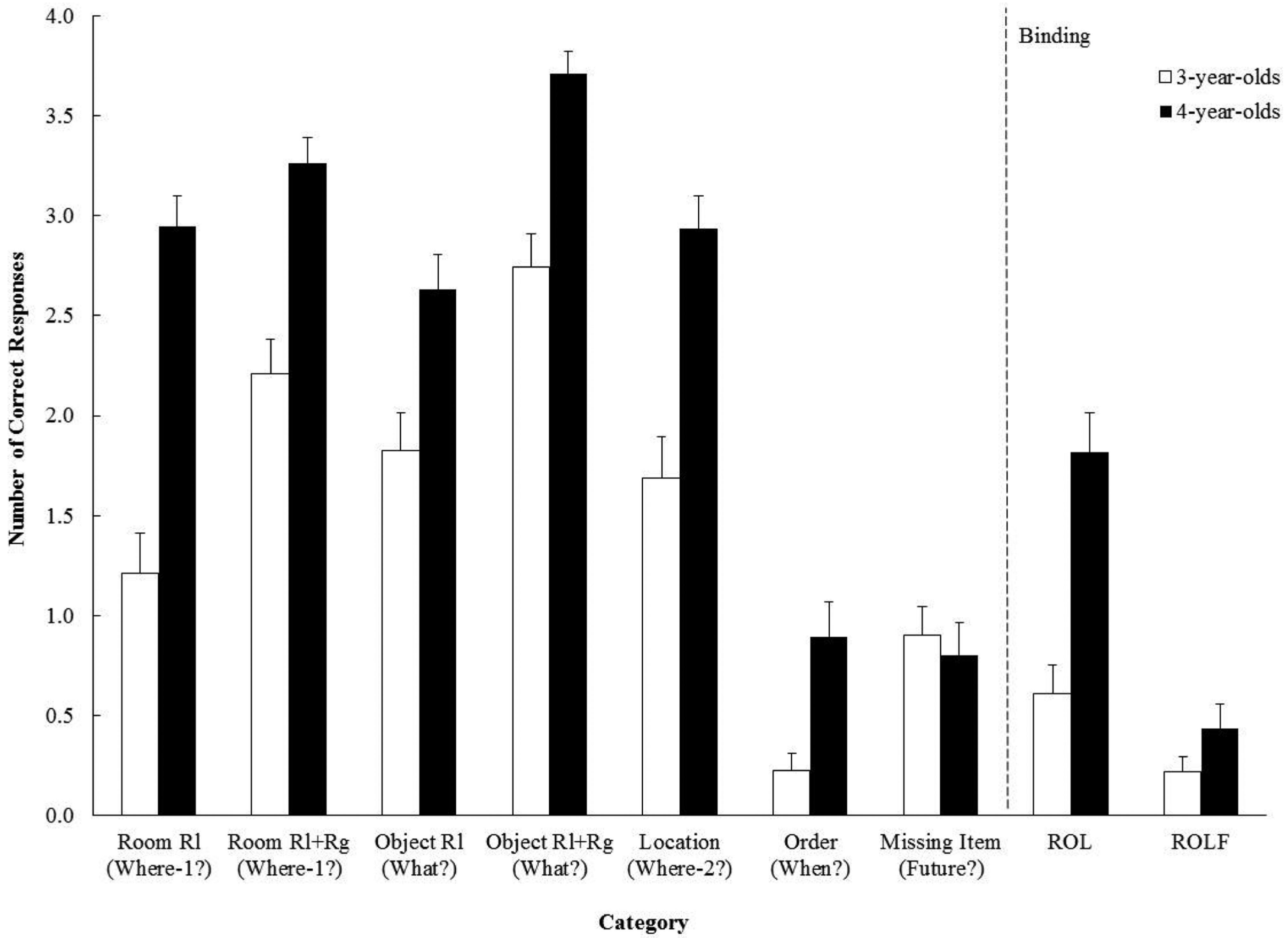

Figure 1.

The mean number of correct responses (+ *SE*) as a function of category for all 3- (*n* = 43; Experiment 1) and 4-year-olds (*n* = 38; Experiment 2). Rl = Recall; Rg = Recognition; ROL(F) = Room + Object+ Location (+ Future) sets

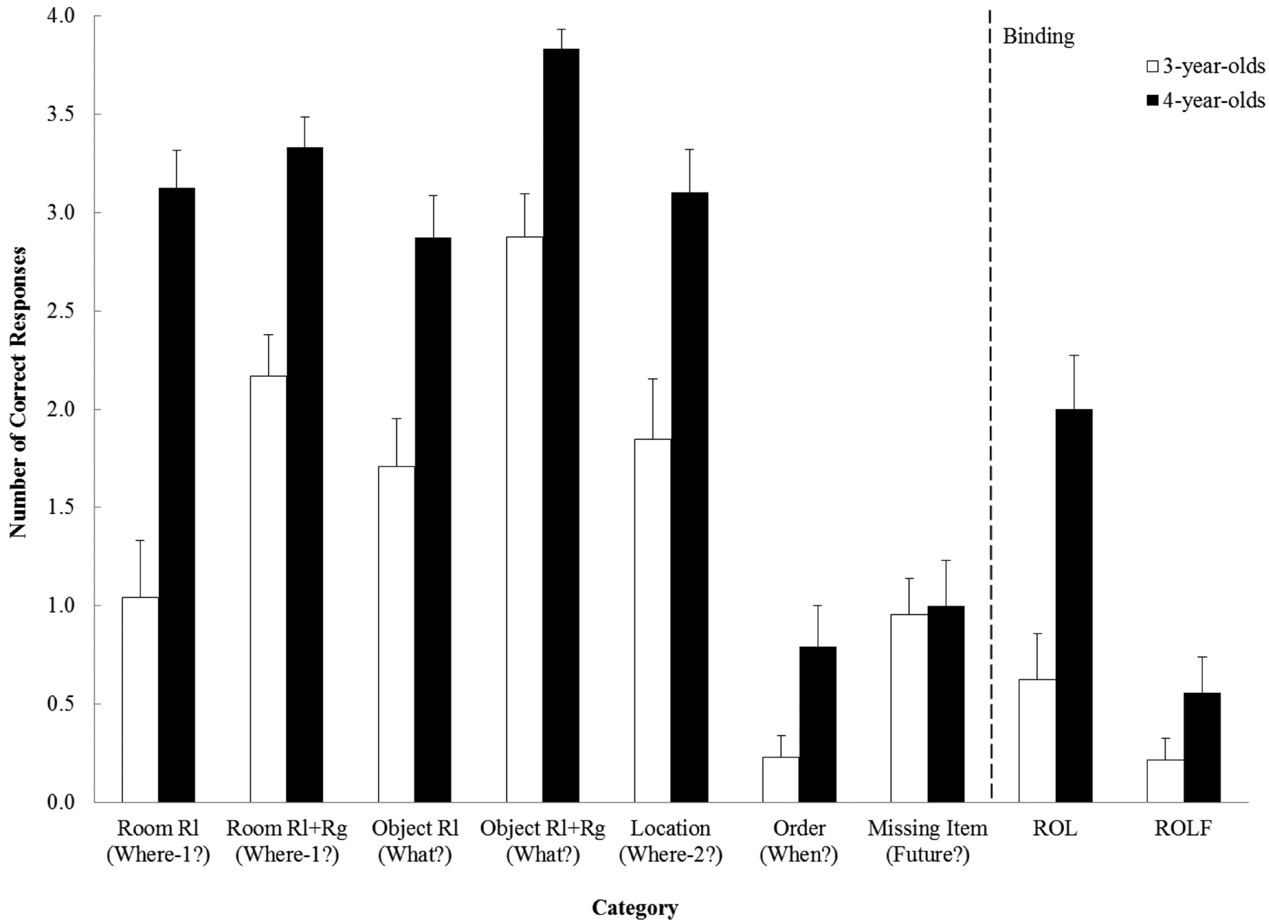

Figure 2.
The mean number of correct responses (+ *SE*) as a function of category for the subset of children (*n* = 27; Experiment 2) from Figure 1 who were seen at both 3 and 4 years of age. Rl = Recall; Rg = Recognition; ROL(F) = Room + Object+ Location (+ Future) sets

Table 1

Outline of the Hiding Task for 3-year-olds (Experiment 1) and 4-year-olds (Experiment 2).

Order ***(When?)***	**Room** ***(Where-1?)***	**Object** ***(What?)***	**Location** ***(Where-2?)***	**Missing Item** ***(Future?)***
3-year-olds				
1	Pirate Room	Treasure box	On top of desk	Key
2	Stairwell	Juice box	Behind door	Straw
3	Music Room	Xylophone	Under chair	Mallet
4	Bathroom	Bubbles	In cabinet	Bubble Wand
4-year-olds				
1	Art Room	Pencil	Behind couch	Sharpener
2	Stairwell	Pudding	Next to red pole	Spoon
3	Space Room	Flashlight	On top of TV	Batteries
4	Bathroom	MagnaDoodle	In sink	Doodle Wand

Table 2

Bivariate and Partial Correlations Among Episodic Memory Components and Verbal Ability at 3 Years of Age (Experiment 1).

	2	3	4	5	6	7	8	9	10
1. PPVT	.42**	.40**	.53***	.46**	.47**	−.01	.24	.50***	.32*
2. Room Rl (*Where-1?*)	--	.77***	.70***	.58***	.54***	.42**	.13	.80***	.50***
3. Room Rl+Rg (*Where-1?*)	.73***	--	.59***	.42**	.44**	.29+	.07	.64***	.37*
4. Object Rl (*What?*)	.62***	.49**	--	.68***	.57***	.16	.29+	.72***	.52***
5. Object Rl+Rg (*What?*)	.48***	.30+	.58***	--	.68***	.26	.43**	.45**	.35*
6. Location (*Where-2?*)	.42**	.32+	.43**	.59***	--	.24	.14	.69***	.45**
7. Order (*When?*)	.47**	.32*	.19	.30+	.28	--	.12	.35*	.50**
8. Missing Item (*Future?*)	.03	−.02	.20	.37*	.03	.13	--	.18	.57***
9. ROL sets	.76***	.56***	.61***	.28+	.59***	.41**	.08	--	.67***
10. ROLF sets	.43**	.28+	.43**	.24	.36*	.53***	.53***	.62***	--

Note. Bivariate correlations are presented above the diagonal, and partial correlations controlling for verbal ability (PPVT scores) are presented below the diagonal. PPVT=Peabody Picture Vocabulary Test; Rl = Recall; Rg = Recognition; ROL(F) = Room + Object+ Location (+ Future)*

*** $p < .001$

** $p \leq .01$

* $p \leq .05$

+ $p < .06$.

Table 3

T-test Comparisons of Episodic Memory Components at 4 Years of Age for Longitudinal and First Time Hiding Game Participants (Experiment 2).

Measure	**Longitudinal *M* (*SD*)**	**First Time *M* (*SD*)**	***t* (*df*)**	***p***	**Cohen's *d***
Room Rl (*Where-1?*)	3.00 (1.00)	2.81 (0.87)	−0.53 (36)	.60	0.20
Room Rl+Rg (*Where-1?*)	3.30 (0.78)	3.18 (0.87)	−0.40 (36)	.69	0.15
Object Rl (*What?*)	2.78 (1.05)	2.27 (1.10)	−1.33 (36)	.19	0.47
Object Rl+Rg (*What?*)	3.81 (0.48)	3.45 (1.04)	−1.11 (11.82)*	.29	0.44
Location (*Where-2?*)	3.04 (1.10)	2.68 (0.72)	−.0.98 (36)	.33	0.39
Order (*When?*)	0.77 (0.99)	1.18 (1.25)	1.07 (35)	.29	0.36
Missing (*Future?*)	0.90 (0.94)	0.56 (0.73)	−0.99 (28)	.33	0.40
ROL	1.89 (1.34)	1.64 (0.92)	−0.57 (36)	.57	0.22
ROLF	0.48 (0.75)	0.33 (0.50)	−0.52 (28)	.61	0.24
Related Room Rl	1.48 (0.58)	1.09 (0.70)	−1.77 (36)	.085	0.61
Unrelated Room Rl	1.52 (0.70)	1.72 (0.47)	0.91 (36)	.37	0.33
Related Object Rl	1.44 (0.75)	1.09 (0.70)	−1.34 (36)	.19	0.48
Unrelated Object Rl	1.30 (0.72)	1.18 (0.60)	−.46 (36)	.65	0.18

Note.

*Levene's Test for Equality of Variances $p < .05$; equal variances not assumed. Rl = Recall; Rg = Recognition; ROL(F) = Room + Object+ Location (+ Future)

Table 4

Bivariate and Partial Correlations Among Episodic Memory Components and Verbal Ability at 4 Years of Age (Experiment 2).

	2	3	4	5	6	7	8	9	10
1. PPVT	.31^{+}	.15	.34*	.11	.52***	.52***	.20	.39*	.29
2. Room Rl (*Where-1?*)	--	.80***	.64***	.38*	.59***	.38*	.11	.66***	.19
3. Room Rl+Rg (*Where-1?*)	.80***	--	.56***	.29	.53***	.27	.10	.58***	.12
4. Object Rl (*What?*)	.59***	.55***	--	.47**	.66***	.40*	.18	.75***	.17
5. Object Rl+Rg (*What?*)	.37*	.28	.46**	--	.55***	.00	.14	.35*	−.02
6. Location (*Where-2?*)	.52***	.53***	.60***	.58***	--	.28	.30	.77***	.36^{+}
7. Order (*When?*)	.27	.23	.27	−.07	.02	--	−.13	.36*	.06
8. Missing Item (*Future?*)	.05	.07	.12	.12	.23	−.28	--	.30	.78***
9. ROL sets	.62***	.57***	.71***	.33*	.72***	.20	.24	--	.50**
10. ROLF sets	.11	.08	.07	−.05	.25	−.11	.77***	.44*	--

Note. Bivariate correlations are presented above the diagonal and partial correlations controlling for verbal ability (PPVT scores) are presented below the diagonal. PPVT=Peabody Picture Vocabulary Test; Rl = Recall: Rg = Recognition; ROL(F) = Room + Object+ Location (+ Future)*

*** $p < .001$

** $p \leq .01$

* $p \leq .05$

$^{+}$ $p < .06$.