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## It's all about location, location, location: Children's memory for the "where" of personally experienced events

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### Abstract

Episodic memory is defined as the ability to recall specific past events located in a particular time and place. Over the preschool and into the school years, there are clear developmental changes in memory for when events took place. In contrast, little is known about developmental changes in memory for where events were experienced. In the present research we tested 4-, 6-, and 8-year-old children's memories for specific laboratory events, each of which was experienced in a unique location. We also tested the children memories for the conjunction of the events and their locations. Age-related differences were observed in all three types of memory (event, location, conjunction of event and location), with the most pronounced differences in memory for conjunctions of events and their locations. The results have implications for our understanding of the development of episodic memory, including suggestions of protracted development of the ability to contextualize events in their spatial locations.

### Keywords

children; episodic memory; location memory; relational memory

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Episodic memory is defined as the ability to recall specific past events located in a particular *time* and *place* (e.g., Tulving, 1972, 1983). The temporal parameters of episodic memory have received a fair amount of attention. They figure prominently in theories of the organization of autobiographical memory, in particular (e.g., Conway, 1992), and there has been empirical work concerning adults' (e.g., Curran & Friedman, 2003; St. Jacques, Rubin, LaBar, & Cabeza, 2008) and to a lesser extent, children's (e.g., Friedman, 1996; Friedman, Reese, & Dai, 2010; Pathman, Larkina, Burch, & Bauer, in press), abilities to locate events in time. Indeed, the ability to subjectively "travel in time" has become almost defining of episodic memory (e.g., Tulving, 1998, 2005; Wheeler, 2000). Although association with a particular place also is important to identification of a unique episode of experience, spatial aspects of episodic memory have been relatively neglected in both the adult and the

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developmental literatures (though they have been of substantial interest in the animal literature: e.g., Clayton & Dickinson, 1998; Eichenbaum & Cohen, 2001). In the present research, we addressed the void in the developmental literature by examining 4-, 6-, and 8-year-old children's long-term memory for the locations in which they experienced controlled laboratory events.

The importance of spatial components in defining episodic memory is clear, by virtue of the fact that Tulving's (1972) introduction of the concept featured place as prominently as it did time. As discussed by Rubin (2006), the importance of spatial information to memory function is apparent in a number of phenomena, including the power of spatial location as a cue to recall (Bahrick, 1974; Bellezza, 1983), and the observation of neural activations in the spatial system (i.e., parahippocampal regions: e.g., Epstein & Kanwisher, 1998; Owen, Milner, Petrides, & Evans, 1996) during retrieval of episodic memories (e.g., Addis, McIntosh, Moscovitch, Crawley, & McAndrews, 2004; Cabeza, Prince, Daselaar, Greenberg, Budde, Dolcos, et al., 2004; Piolino, Giffard-Quillon, Desgranges, Chételat, Baron, & Eustache, 2004). Yet memory for the spatial aspects of unique episodes typically has been of concern in only one corner of the cognitive psychological literature, namely, that devoted to flashbulb memories. The concept of a flashbulb memory was introduced by Brown and Kulik (1977) and refers to seemingly highly accurate memory for the circumstances surrounding reception of important news, such as the assassination of John F. Kennedy in 1963 (Winograd & Killinger, 1983), the Challenger explosion in 1986 (Bohannon, 1988), and the planes crashing into the World Trade Center in New York City and the Pentagon in Washington, D.C. on September 11, 2001 (e.g., Pezdek, 2003). In studies of memory for these types of events, participants typically are asked to respond to a number of questions that contextualize their reception of the news, including "where were you" when they heard it. Subjects readily answer this question and rate their mental images of the scene as highly vivid and detailed (e.g., Rubin & Kozin, 1984; Talarico & Rubin, 2003).

With the exception of the flashbulb memory literature (in which location information is but one of several details of the reception experience entered into a composite score) there has been little attention to memory for the location of personally experienced events, in either the adult or the developmental literature. One exception in the adult literature is a study by Talarico and Moore (2011). They asked college undergraduate students to recall the location in which they stood (or sat) during a session in which a photograph was taken of the entire entering class of roughly 600 students. The photo session was one of several orientation-related activities in which students engaged upon arrival on campus, and as described in Talarico (2009), is vividly remembered by most students. Regardless of whether the photograph session took place 2, 6, 18, 32, or 40 months previously, the students had high levels of recall of their location in the large group. Accuracy was not related to delay. It was, however, related to speed, such that individuals who were faster to identify their location also had higher levels of accuracy. With this notable exception, the adult literature is largely devoid of studies of memory for the location of personally-experienced events.

Studies of memory for the location in which specific events were experienced also are missing from the developmental literature. That is not to say that spatial memory has been neglected. There have been numerous studies of infants' and children's memory for the spatial location of hidden objects (see Lourenco & Frick, in press; Newcombe & Huttenlocher, 2006, for reviews). For example, when searching for hidden toys in a long rectangular sandbox, children 22 months of age and older can utilize visible landmarks in a room to aid in locating the objects (Newcombe, Huttenlocher, Drummey, & Wiley, 1998). Between 18 and 24 months, infants dramatically improve in their ability to remember more than one location at a time and the spatial relations among objects (Russell & Thompson,

2003; Sluzenski, Newcombe, & Satlow, 2004). Infants and young children also show high levels of competence in finding objects in large-scale spaces, such as their homes (e.g., DeLoache & Brown, 1983, 1984; Haden, Ornstein, O'Brien, Elischberger, Tyler, & Burchinal, 2011).

The literature also contains suggestions of developmental changes in memory for spatial location in childhood. In an object location learning task, Hund and Plumert (2002, 2003) reported that 7-year-olds are significantly less accurate in remembering object locations than 11-year-old children and adults. In tasks in which children must "bind" an object with a location (e.g., on a computer screen), children 9 and 12 years of age perform less well than young adults (Lorsbach & Reimer, 2005). These findings suggest that memory for object location continues to develop into late childhood. The possible implications of this pattern for memory for where personally-experienced events and episodes took place has yet to be evaluated: To date, there have not been direct empirical tests of possible age-related changes in this aspect of episodic memory.

Indirect evidence of developmental differences in children's memory for the spatial locations of personally experienced events comes from the literature on children's narratives about past events. Fivush (1984) noted that when kindergarten children told an interviewer about their day at school, they discriminated events based on location changes throughout the day. Subsequent studies suggested that over the course of the preschool years, the amount of spatial-temporal information that children include in their narratives increases. For example, Haden, Haine, and Fivush (1997) reported that between 40 and 70 months of age, the number of spatial-temporal orientations that children provided increased from less than 1 at age 40 months to 2 to 3 at age 70 months (though see Fivush, Haden & Adam, 1995, for suggestion of few age-related changes in the same developmental period). Bauer, Burch, Scholin, and Güler (2007) found that in about 70% of their narratives, 7- to 10-year-old children spontaneously included information about where specific past events took place. Thus it seems that at least by the end of the first decade of life, children relatively routinely orient their narratives of personal past events to location or place. Although this literature is informative, it is not sufficiently direct to plot the trajectory of developmental change in children's memory for the spatial locations of personally experienced events.

The purpose of the present research was to begin to fill the void in the literature on children's memory for the spatial locations of personal events or episodes. Four-, six-, and eight-year-old children took part in four specific activities, each in a unique location within a laboratory room. One week later, we tested the children's memory for the events and their associated spatial locations. The 4- to 8-year age range was chosen because it spans the period during which children have been shown to remember specific past events (e.g., Burch, Austin, & Bauer, 2004; Morris, Baker-Ward, & Bauer, 2009; Sales, Fivush, & Peterson, 2003), yet from which older children (e.g., Cleveland & Reese, 2008; Van Abbema & Bauer, 2005) and adults (e.g., Rubin, Wetzler, & Nebes, 1986; Wetzler & Sweeney, 1986) recall few specific events (i.e., the phenomenon of *childhood amnesia*: see Bauer, 2007, 2008; Pillemer & White, 1989; for reviews). Episodic memory develops rapidly in this period as a result of many factors including language, cognition, and social interactions (for reviews, see Bauer, 2007; Nelson & Fivush, 2004), as well as increases in source monitoring (Cycowicz, Friedman, Snodgrass, & Duff, 2001; Drummey & Newcombe, 2002), reality monitoring (Sluzenski, Newcombe, & Ottinger, 2004), and feature binding (Sluzenski, Newcombe, & Kovacs, 2006; Lloyd, Doydum, & Newcombe, 2009), for example. We imposed a one-week delay between experience of the events in their locations and the test for memory because 1-week is a period of time over which we may expect children in this age range to remember (e.g., Baker-Ward, Gordon, Ornstein, Larus,

& Clubb, 1993), yet to exhibit some degradation of the memory trace, thereby avoiding potential ceiling levels of performance.

## Method

### Participants

Participants were 79 children: 28 4-year-olds (15 female;  $M = 4.11$ , range = 3.96–4.31), 27 6-year-olds (13 female;  $M = 6.13$ , range = 5.89–6.30), and 24 8-year-olds (11 female;  $M = 8.14$ , range = 8.02–8.33). Children took part in two 1.5-hour sessions that were spaced approximately one week apart ( $M = 7.34$ , range = 6–14 days). Twenty-one additional children participated in the study but were excluded because they did not complete the task ( $n = 7$ ), the delay between Session 1 and Session 2 exceeded the established range (i.e., 14 days,  $n = 2$ ), or they were tested in a different laboratory room that afforded only 3 rather than 4 locations ( $n = 12$ ). Participants were recruited from a pool of families maintained by the University of Minnesota. All participants were non-Hispanic and the majority were White. A university Institutional Review Board approved the protocol and written parental consent was obtained for each child. At the end of the second session, children received a small toy and parents were given a gift certificate to a local merchant for participating.

### Materials and Procedure

The sessions took place in a large laboratory room (approximately 270 sq ft; 15' × 18'; metric = 24 sq m; 4m × 6m) outfitted like a family room or playroom (see Figure 1 for a schematic of the room). Parents were present in the testing room during the sessions but were instructed not to aid their children or suggest behaviors or responses to them; all parents complied with this request. Participants completed several tasks during the sessions. The data from some of the tasks are published elsewhere (Larkina & Bauer, 2010, in press; Pathman et al., in press); all of the memory data presented here are unique to this manuscript. Four female experimenters administered the tasks; children were tested by the same experimenter at both sessions. All sessions were video recorded. Task procedures were outlined in a written protocol and experimenters regularly reviewed video recordings of the sessions to ensure protocol fidelity.

**Event and location memory tasks**—At Session 1, children experienced four unique events, each in a different location within the laboratory playroom: the experimenter (a) told the child a joke about an animal doctor, (b) showed the child a picture of a dog wearing sunglasses, (c) took the child's picture with a Polaroid camera, and (d) gave the child a pencil with a smiley face on it. The events were counterbalanced across four locations in the laboratory: (a) a small table, (b) a big table, (c) a couch, and (d) bean bag chairs. The events are described in Table 1 and a schematic of the testing space is shown in Figure 1. Encoding of the events and their locations was incidental. That is, the children were not informed that they would need to remember the events or the locations. The events were interspersed among a number of different activities and tasks over the course of the 90-min session; no two of the events occurred sequentially. The timing of experience of the events was fixed across participants.

At Session 2, children's memory for the events and their locations was tested. Testing took place approximately midway through the 90-min session. The testing was completed at the big table, which was one of the locations used at Session 1. For each of four trials, we first tested children's recall of the event, and then probed their recognition of where they experienced the event. Tests of recall are more sensitive to developmental differences relative to tests of recognition (e.g., Ackerman, 1985; Mandler & Stein, 1974; Perlmutter, 1984), thus making them more desirable for detection of age-related differences. In the

present research, we were able to arrange a test of recall for the events because they were not perceptually cued at the time of test. That is, hearing a joke, looking at a photograph, having a picture taken, and receiving a gift left no physical trace that was present at the time of test, thus making a test of recall viable. In the case of locations, however, the locations at which the children experienced the events—small table, large table, couch, bean bag chairs—were physically present when the children were tested thereby making recognition the only viable means of testing.

For each event in turn, we first tested children's recall using an open-ended prompt (see Table 1). For example, children were reminded that "Last time you were here, I gave you a gift," and then they were asked to describe it: "What was the gift I gave you?" If the child did not respond, the experimenter gave a cue (e.g., "Remember, it had smiley faces"). If the child did not recall the event after the cue, the experimenter provided the answer and showed the child the item or an identical item (e.g., "It was a pencil"). We then tested children's recognition memory for the location in which they experienced the event. Each trial of the recognition test featured all four locations as possible answers. For example, the child was asked: "Did I give you the pencil at the couch, bean bags, little table, or big table?" Children responded by either naming or pointing to a location. The order of testing was counterbalanced.

**Children's language**—To test for possible relations between the spatial location task and language ability, we administered the Test of Verbal Comprehension from the Woodcock-Johnson III Tests of Cognitive Abilities (Woodcock, McGrew, & Mather, 2001) at Session 1. The four subscales of the Test of Verbal Comprehension (picture vocabulary, synonyms, antonyms, and verbal analogy) were combined into a single standardized measure of children's language ability.

## Scoring

During the session, the experimenters created a written record of children's responses to the event and location memory questions. The on-line recording sheets were used to derive three scores: (a) memory for the events (max. = 4), (b) memory for the locations at which the events were experienced (max. = 4), and (c) memory for the events and their corresponding locations (max. = 4; hereafter referred to as "event + location"). Children received 1 point for each event about which they recalled a detail, either prior to or after the cue. Prior to the cue, the child could receive credit for producing either of the pieces of information about the event; after the cue, the child could receive credit for producing the non-cued piece of information only. Using the event "receive a gift" as an example, prior to the cue, the child would receive credit for recalling the event by answering that the gift was a pencil or that it had smiley faces on it; after the cue, the child would receive credit only by answering that the gift was a pencil. Credit for recognition of the correct location could be earned even if the child had failed to recall the event itself. In the case of failed recall of the event, the experimenter provided the correct answer and then posed the location question. Children received 1 point for each location correctly identified. Finally, for the events that children recalled, they were credited with memory for event + location in instances in which they correctly identified the location at which they had experienced the event.

## Results

### Preliminary Analyses

We performed preliminary analyses to test the possibility that general language skills may serve as a potential source of variability in memory. Performance on the Verbal Comprehension subtest of the Woodcock-Johnson was not significantly correlated with

performance on any of the three measures (event, location, event + location; all  $ps > .29$ ). Nevertheless, there was individual variability associated with language. For this reason, verbal comprehension scores were used as covariates in analyses.

## Main Analyses

Depictions of the children's memory for events, locations, events + locations are provided in Figure 2. To test for age-related differences in performance, we conducted one-way between-subjects analyses of variance covariance (ANCOVAs) for each type of memory, with verbal comprehension scores as the covariate. All post hoc analyses were performed with Tukey Studentized HSD tests ( $p < .05$ ).

For all three types of memory, there were main effects of age: events,  $F(2, 72) = 7.15, p = .005, \eta^2 = .163$ ; locations,  $F(2, 72) = 7.42, p < .0001, \eta^2 = .170$ ; events + locations,  $F(2, 72) = 12.02, p < .0001, \eta^2 = .250$ . Relative levels of performance by the children in the three age groups were the same for the measures of recall of events and recognition of locations, and different for the measure of memory for events in their locations. Specifically, relative to the 4-year-olds, the 8-year-olds recalled significantly more of the events they experienced and recognized significantly more of the locations in which the events took place. Performance of the 6-year-olds was intermediate and did not differ from either the 4- or the 8-year-olds.<sup>1</sup> Second, analysis of the main effect for memory for events + locations revealed that all three age groups differed significantly from one another. As suggested by inspection of Figure 2, the 8-year-olds had the highest levels of recall of the events coupled with recognition of where they took place and the 4-year-olds had the lowest levels of memory for the events and their locations.

To determine whether correct identification of the location might have occurred by chance in instances in which an event was remembered, we assessed the probability of correct identification for each trial. Because for each trial, all four locations were provided as options, on any given trial, the probability of correct identification of the location at which an event took place is equal to 25%. However, a more conservative estimate of the probability associated with correct identification is to assume that children sampled locations without replacement. That is, the more conservative approach is to assume that once a child selected one of the four locations, she or he eliminated that location from subsequent consideration. This more conservative estimate would yield probabilities of 25%, 33% and 50% for Trials 1, 2, and 3, respectively. The fourth location question could not be analyzed because the answer could be inferred if the three preceding locations were successfully remembered.

To test the possibility of chance recognition of the location of a recalled event, we conducted separate binomial tests for each age group to compare the proportion of children who correctly recognized location after recalling an event against the proportion that would be expected by chance. On Trial 1 (chance = 25%), all three age groups recognized location more than would be expected by chance (all  $ps < .006$ ). On Trial 2 (chance = 33%), the 6- and 8-year-olds recognized location more than would be expected by chance ( $ps < .001$ ). The performance of the 4-year-olds did not differ from chance ( $p = .371$ ). On Trial 3 (chance = 50%), only the 8-year-olds recognized location more than would be expected by chance ( $p = .019$ ). The performance of neither the 4- nor the 6-year-olds differed from

<sup>1</sup>The pattern was the same when only free recall (i.e., prior to the cue) was considered:  $F(2, 72) = 8.66, p < .0005, \eta^2 = .19$ . That is, 8-year-olds had higher levels of free recall of the events they experienced, relative to 4-year-olds. The level of free recall of the 6-year-olds was intermediate and did not differ from the younger or the older group. We report the results of total recall (free recall plus cued recall) because the modal number of events recalled prior to cueing varied substantially by age: 1, 2, and 3 events recall for 4-, 6-, and 8-year-olds, respectively.

chance ( $p$ s = 1.000 and .301, respectively). Therefore, in instances in which events were recalled, 8-year-olds were the only age group for whom placement of the events in their correct locations was reliably greater than chance for all trials. (As noted above, Trial 4 could not be analyzed in this manner.)

Another approach to examining the relation between memory for events and memory for locations was to test the degree of correlation between the scores. Across age groups, memory for events and memory for locations was moderately correlated:  $r(77) = .35$ ,  $p = .0015$  (partial correlation with age controlled:  $pr = .21$ ,  $p = .065$ ). However, separate analyses for each age group revealed a significant correlation only for the 8-year-olds:  $r(22) = .55$ ,  $p = .005$  ( $pr = .54$ ,  $p < .008$ ). For the 4- and 6-year-olds, the correlations were not statistically significant ( $r$ s = .18 and .24, respectively;  $pr$ s = .16 and .28, respectively).

## Discussion

The purpose of the present research was to inform a currently relatively neglected aspect of development, namely, memory for the spatial location of personally experienced events. We examined 4-, 6-, and 8-year-old children's memories for specific events, for the locations in which the events were experienced, and for the conjunctions of the events and their locations. On all three measures, the 8-year-olds performed at higher levels relative to the 4-year-olds. For recall of events and recognition of the locations in which they took place, the performance of children 6 years of age was intermediate and did not differ from performance of either the younger or the older children. On the measure of memory for the conjunction of events and locations, the performance of the 6-year-olds differed from that of both the younger and older children. Also, it was only among the 8-year-olds that memory for events and memory for the locations at which they took place seemed tightly bound to one another, as indexed by above-chance recognition of the location of recalled events and positive correlation between memory for events and memory for their locations.

The results of the present research indicate that between 4 and 8 years of age there is substantial development in children's long-term memory for the locations at which they experienced specific events. Four-year-olds clearly were capable of participating in the task. They recalled approximately 45% of the events and they responded appropriately on the location memory task (though they were above chance in their location identifications only on the first trial). The 4-year-olds were not especially reliable at situating events in their locations, however: having recalled an event, they correctly identified where they experienced it only roughly 25% of the time. Because the assessment of memory for events and locations was obtained only after a 1-week delay, we cannot determine whether 4-year-olds' difficulty remembering where they experienced a particular event is due to under-specified encoding of the relation, failed consolidation of the relation, difficulty with retrieval of it, or any combination thereof. Each of these phases in the life of a memory is a plausible source of vulnerability of the trace (see Bauer, 2006, in press, for reviews). What can be implied from the results of the present research is that 4-year-olds do not have especially robust memories for unique events in unique locations, at least as measured in the present research.

Six-year-old children showed substantially more robust memory for the conjunction of an event and its location, relative to 4-year-olds. When they recalled an event, they identified where they had experienced it 40% of the time. We observed significantly higher performance for the conjunction of event + location among the 6-year-olds, relative to the 4-year-olds, in spite of the fact that the age groups did not differ in recall of events or recognition of locations. Thus the source of the age-related improvement between 4 years and 6 years was in the ability to relate an event to its location, rather than remember either of

the individual elements. Superior relational memory also was apparent among the 8-year-olds relative to the 6-year-olds. When 8-year-olds recalled an event, they correctly identified where it took place almost 60% of the time. Their memory for the conjunction of event + location was significantly higher than the 6-year-olds. The advantage was observed in spite of the fact that the 6- and 8-year-olds did not differ in recall of the events or recognition of locations. Thus as for the 4- relative to the 6-year-olds, the source of the age-related improvement between 6 years and 8 years was in the ability to relate an event to its location.

What do the findings of the present research imply about the developmental status of episodic memory? Retrieval of episodic memories is argued to entail subjectively traveling back in time as if re-experiencing the event, presumably in the temporal and spatial context in which it originally occurred. Consistent with this expectation, adults' recollections of past events are accompanied by activations in the spatial system (e.g., Addis et al., 2004; Cabeza et al., 2004; Piolino et al., 2004). The relatively low levels of memory for events and their locations among 4-year-olds implies that they may have difficulty mentally re-creating the spatial-temporal context in which they experienced an event. The steady increases among 6- and especially 8-year-olds in memory for the conjunction of an event and its location imply age-related enhancements in the ability to re-create the spatial-temporal context in which an event took place. These general conclusions are consistent with findings based on the unobtrusive measure of children's narratives about past events. Four-year-olds make few spontaneous references to place in their narratives about past events, whereas by 6 to 8 years of age, such references are more common (e.g., Haden et al., 1997). Yet even 7- to 10-year-olds spontaneously feature references to "where" events occurred roughly 70% of the time (Bauer et al., 2007), whereas adults routinely place events in both spatial and temporal context (Reese, Haden, Baker-Ward, Bauer, Fivush, & Ornstein, 2011). Failure to consistently ground event memories in spatial context may contribute to the seemingly accelerated loss of personal past events from memory that has been observed at least through the end of the first decade of life (Bauer et al., 2007).

Improved ability to remember specific events experienced in unique locations among 6-year-olds and especially among 8-year-olds is consistent with demonstrations in the literature of their greater mnemonic prowess in a number of domains. The later preschool and early school years are times of rapid and substantial development of deliberate and strategic memory and metamemory (awareness of one's own memory processes), in particular (see Bjorklund, Dukes, & Brown, 2009, for a review). The developments are apparent in children's performance on laboratory tasks of episodic memory, as well as in tests of memory for specific attributes of experience, such as the source of information (e.g., Cycowicz et al., 2001), and in children's judgments as to the strength of their memories (e.g., Ghetti, Lyons, Fazzarin, & Cornoldi, 2008). What remains to be seen is whether developmental changes in the formation of conjunctions in memory between what happened in the course of an event and where the event took place contribute unique variance in memory for personally relevant episodes of life, and thus figure in the solution to the mystery of childhood amnesia (Bauer, 2007, 2008).

Further research also is needed to clarify the components of the ability to form and retain memory for the conjunction of events and their locations. In the present research, verbal comprehension, as measured by the Woodcock-Johnson Test of Cognitive Abilities, was not an important determinant of event memory, location memory, or the conjunction of event and location. Previous research has found differences in the preschool to early-school years in the integration of learned spatial descriptions into representations of a space (Uttal, Fisher, & Taylor, 2006) and systematic use of prepositions such as "by" to describe locations (Hund & Naroleski, 2008). These findings suggest that a fruitful direction for future research may be to conduct more fine-grained assessments of spatially-relevant



language and test the contribution of such language to the ability to remember locations and the conjunction of events and locations, in particular.

Another fruitful direction for future research is examination of the implications for behavioral performance of developmental changes in the neural substrate of relational memory. There is general agreement that the ability to encode, consolidate, and subsequently recall past events is dependent on a temporal-cortical network involving the hippocampus and prefrontal cortex. The hippocampus in particular is implicated in binding or relating individual elements into an integrated memory trace (e.g., Cohen & Eichenbaum, 1993; O'Keefe & Nadel, 1978). This suggestion is supported by findings that individuals with focal medial-temporal lesions have impaired relational memory deficits in the face of intact memory for the individual items (e.g., Giovanello, Verfaellie, & Keane, 2003). Additionally, in neuroimaging studies, there are relations between hippocampal activation during relational processing and subsequent memory performance (e.g., Davachi & Wagner, 2002). As reviewed elsewhere (e.g., Bauer, 2006, 2007, in press; Richman & Nelson, 2008), the temporal-cortical network implicated in recall of past events undergoes a protracted course of development throughout the first decade and into the second decade of life. The implications of structural and functional changes in the temporal-cortical network for behavioral changes in relational memory are ripe for examination.

The present investigation is a valuable starting point for understanding the processes underlying memory for events, locations, and their conjunctions, and how these types of memory change over development. The results of the research must be interpreted with caution, nonetheless. A major consideration in interpretation of the findings already has been mentioned: the locus of failure to remember the conjunction of events and their locations cannot be determined based on this research alone. The present research included no assessment of the success of encoding of the events or their locations. Neither did it feature a test of the strength of the memory traces for these elements of experience at some point shortly after encoding, to determine how successfully the traces had been consolidated (see Bauer, 2006, for discussion). In infancy (Bauer, Cheatham, Cary, & Van Abbema, 2002) and in the preschool years (Bauer, Larkina, & Doydum, in press), measures of the success of encoding (immediate recall) and of trace strength shortly after encoding each have proven predictive of long-term recall; measures of trace strength during the period of consolidation contribute unique variance beyond that explained by encoding. In future research it will be important to determine the locus (or loci) of vulnerability of memory traces for events in their locations, in order to understand the processes and determinants of developments in episodic memory.

A second major consideration in interpretation of the findings of the present research is that encoding of the events, their locations, and the conjunctions of events and their locations was entirely incidental. That is, children received no warning that they later would be probed for memory for the activities or their locations. These conditions were adopted in order to mimic encoding of events outside the laboratory. It will be left for future research to determine whether age-related differences such as observed in the present research are minimized when children are explicitly instructed to remember the elements of their experiences. Alternatively, it is possible that age-related differences may be accentuated by explicit instructions to remember. Such an effect would not be surprising given the greater command that older children have over their memories, relative to younger children (Bjorklund et al., 2009), and thus their greater abilities to marshal their resources to respond to task demands.

A third consideration in interpretation of the findings of the present research is that the events that the children experienced were personal, in that they were directly experienced by

the child, yet they were not especially personally relevant, significant, or even especially distinctive. The activities were substantially more personally relevant than those often undertaken in research on the development of episodic memory, such as studying and remembering a list of words or pictures (e.g., Güler, Larkina, Kleinknecht, & Bauer, 2010; Larkina, Güler, Kleinknecht, & Bauer, 2008). Yet they cannot be said to rise to the level of significance of the birth of a sibling, welcoming of a new puppy into the family, or losing a grandparent. Moreover, the locations, though unique, all were within the same large room, and thus were not as distinctive from one another as the varying locations in which personally relevant episodes of experience occur. In future research it would be beneficial to more closely approximate the personally relevant and distinctive episodes and experiences that make up one's life story or personal past, while still maintaining experimental control over the events. With more personally relevant or autobiographical events, we may expect to see smaller age-related differences in performance, relative to those observed in the present research. This outcome was observed in Pathman, Samson, Dugas, Cabeza, and Bauer (in press), in which school-age children either took photographs of museum exhibits themselves (greater personal relevance) or viewed on a laptop computer photographs taken by another (lesser personal relevance). Children's performance more closely approximated that of adults' when they took the photographs themselves than when they viewed the photographs on a computer.

In conclusion, the present research was an initial test of 4-, 6-, and 8-year-old children's memory for specific events, their locations, and the conjunctions of events and their locations. Age-related differences were observed in all three types of memory, with the most pronounced differences in memory for conjunctions of the events the children experienced and the unique locations in which they took place. The results have implications for our understanding of the development of episodic memory, including suggestions of protracted development of the ability to contextualize events in their spatial locations.

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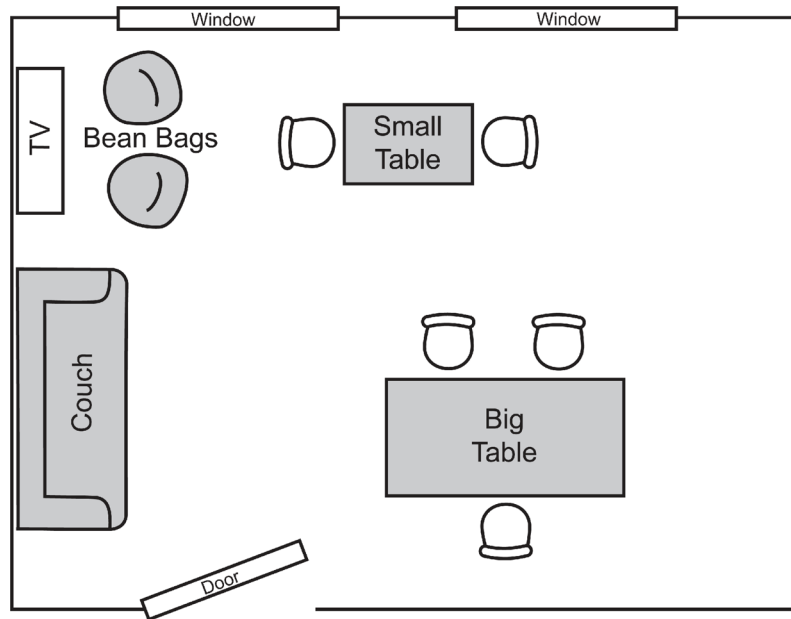
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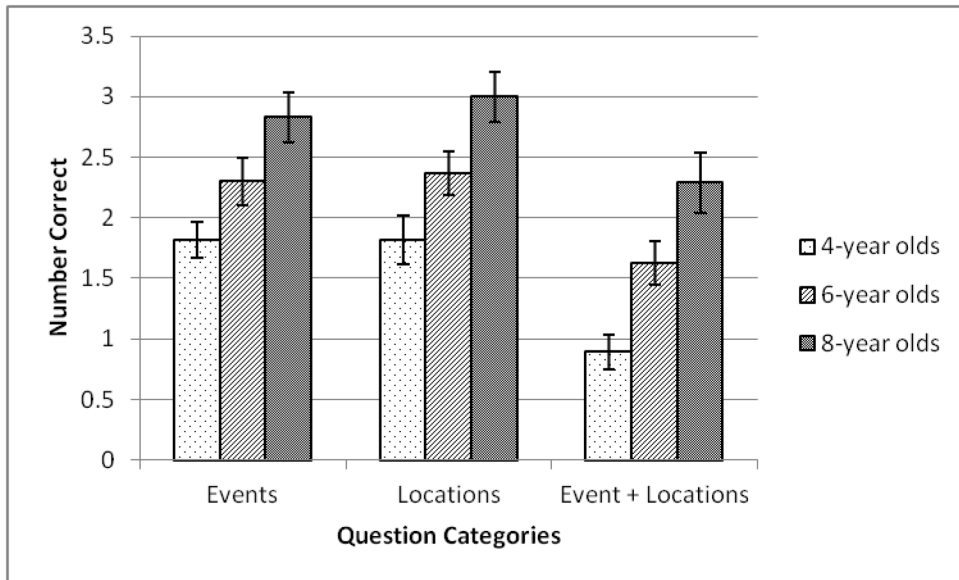
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Four-, 6-, and 8-year-old children remember personally experienced events  
Four-, 6-, and 8-year-olds remember the locations of personally experienced events  
Age effects in memory for the conjunction of events in their locations are pronounced  
Findings have implications for traveling in space and time in episodic memory



**Figure 1.** Schematic of 15' × 18' testing space (approximately 270 square feet).





**Figure 2.** Number correct for recall of events, recognition of locations, and the conjunction of events in their locations, as a function of age. Error bars indicate standard error.

**Table 1**

Events Experienced at Session 1 and Questions Posed at Session 2 to Probe Recall of the Events

Event (Experienced at Session 1)		Recall of Event (Queried at Session 2)	
Name	Description	Open-ended recall	Cued recall
Hear a joke	When is an animal doctor the busiest? When it's raining cats and dogs.	Last time you were here, I told you a joke. What joke did I tell you?	It was about an animal doctor. Can you tell me the rest?
Look at a photo	A picture of a dog wearing sunglasses.	Last time you were here, I showed you a photograph. What was the photo I showed you?	It was a picture of a dog. What was the dog wearing?
Get a picture taken	A photograph of the child was taken with a Polaroid camera. The child held a sign with her name written on it.	Last time you were here, I took your picture. What were you holding when I took your picture?	It was a sign. What was on the sign?
Receive a gift	A pencil with smiley faces on it.	Last time you were here, I gave you a gift. What was the gift I gave you?	It had smiley faces. What was it?