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Memory at Play: Examining Relations Between Episodic and Semantic Memory in a Children's Museum

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The relation between episodic and semantic memory was examined by testing how semantic knowledge influences children's episodic memory for events and their locations. Five-, six-, and seven-year-olds ($N = 87$) engaged in events in a children's museum designed as a town. Events were semantically congruent or incongruent with the spatial location (e.g., sorting mail at post office vs. grocery store). In addition to this experimental paradigm, a semantic interview assessed children's semantic knowledge about real-world locations. Accuracy in the experimental paradigm showed that children's semantic memory influenced memory for locations. Interviews revealed age-related improvements in children's semantic knowledge. Regression analyses examined factors that best supported episodic memory. These results provide novel insights and highlight the utility of research in naturalistic settings.

Whether one is networking as a business professional or "connecting the dots" to understand a new concept, building and maintaining relationships or connections is an important part of our lives. Similarly, relations in memory serve us well. Remembering that you collected seashells may aid in the retrieval of the location of your cousin's birthday party at the beach. The memory of a specific birthday party would be considered an episodic memory, defined by Tulving (1972) as memory for events that have occurred at a particular time and place. On the other hand, knowledge that shells can be found along a beach would be considered an example of semantic memory. Our semantic memory system allows for the retrieval of facts, concepts and world knowledge (Tulving, 1972). Tulving (1972) suggests episodic and semantic memory may be two parallel but partially overlapping systems. When entering a new event, we are bringing with us our knowledge about the world (see review Levine, 2004; see also Brod, Werkle-Bergner, & Shing, 2013). In other words, the episodic memory of a specific event may be influenced (supported or hindered) by one's semantic knowledge. This conceptualization provides opportunity for the examination of these memory systems and their relation. This study sought to embark upon this examination through the lens of development.

Both episodic and semantic memory undergo developmental changes throughout childhood (e.g., Bauer, 2007; Robertson & Köhler, 2007), yet relatively little is known about the relation between episodic and semantic memory in typical development. Here, we sought to explore this relation by asking how a specific aspect of semantic memory, semantic knowledge about spatial locations, may influence children's episodic memory for events and their locations.

Episodic and Spatial Memory Development

Episodic memory, memory for events and context, improves dramatically in early to middle childhood (see Bauer, 2007). Improvements in children's memory abilities during early to middle childhood, for example, are characterized by the increasing ability to encode and retain complex event representations inherent to episodic memories (Geng, Canada, & Riggins, 2018; Ghetti & Bunge, 2012). These advancements are likely driven by brain development during this time period, particularly in the hippocampus

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which supports the binding of items or elements presented together (Cohen & Eichenbaum, 1993; Olson & Newcombe, 2014; Riggins, Blankenship, Mulligan, Rice, & Redcay, 2015) and the prefrontal cortex, which is responsible for controlled, or strategic, processes crucial to episodic memory (Schacter, Norman, & Koutstaal, 1998). One may also consider this development in the context of increasing academic demands, given that testing in the school setting relies on episodic memory (Diaz, Blankenship, & Ann, 2018).

In this study, we focus on the spatial details (i.e., location) of events. Prior even to Tulving's (1972) conceptualizations, Underwood (1969) recognized space as a powerful attribute of memory and early work by Hasher and Zacks (1979) argued that the operations that encode the spatial locations of events are automatic. More recently, Rubin (2006) discussed the importance of spatial information in memory as serving functions including acting as a cue to recall (see also Bellezza, 1983). Furthermore, studies examining neural activity during episodic retrieval shed light on the prominence of spatial information in memory through activations in the spatial system coinciding with retrieval (Addis, McIntosh, Moscovitch, Crawley, & McAndrews, 2004; Cabeza et al., 2004; Piolino et al., 2004). Overall, the study of memory for space holds an important place in memory research and as such has been heavily studied in the adult (e.g., Robin, Wynn, & Moscovitch, 2016; Siedlecki & Salthouse, 2014; Uttl & Graf, 1993) and nonhuman animal (e.g., Howard & Eichenbaum, 2015; Veyrac et al., 2015) literatures.

Children's memory for space is thought to begin rudimentarily in infancy as infants become increasingly mobile and aware of their surroundings (see Lourenco & Frick, 2014, for a review). The literature extends from infant work and studies on children's understanding of space (e.g., Learmonth, Newcombe, Sheridan, & Jones, 2008; Newcombe, Ratliff, Shallcross, & Twyman, 2010; Sandberg, Huttenlocher, & Newcombe, 1996) to children's memory for the location of items viewed on a computer screen (e.g., Pathman, Coughlin, & Ghetti, 2018), physical objects in a "hide-and-seek" task (e.g., Hayne & Imuta, 2011), and personally experienced events (e.g., Bauer, Stewart, White, & Larkina, 2015; Bauer et al., 2012). Although classical spatial memory studies in animal models and in the adult memory literature often include memory for routes and navigation, studies of spatial memory in developmental research often involve testing memory for spatial locations associated with past events, like rooms in a house or around the laboratory (e.g., Bauer et al., 2012, 2015; Hayne & Imuta, 2011; Picard et al., 2012). Some of this literature on the development of children's memory for space has shown mixed results, particularly across methods. For example, Bauer et al. (2012) showed an increase between 4 and 8 years of age in the accuracy of children's memory for the location of personally experienced events, implying age-related enhancements in the ability to reflect on and recreate the event's context. On the other hand, age-related differences in children's memory for space were not found in early childhood in the work of Hayne and Imuta (2011) nor in middle to late childhood in a study by Pathman et al. (2018). Therefore, more work is needed to align an understanding of the development of children's memory for space. Further work is also needed to understand the factors that contribute to or support spatial episodic memory in childhood.

Semantic Memory Development

Nelson and Fivush's (2004) model of the development of autobiographical memory—memory for events that occurred in one's personal past—recognizes semantic memory as a contributing factor in the development of memory for the events of one's life. Thus, semantic memory development may be one source to examine in understanding the development of episodic memory development in childhood. Although not characteristically labeled semantic memory, literature examining script knowledge is one way to conceptualize this idea. Children may utilize script knowledge both when planning for (Hudson, Shapiro, & Sosa, 1995) and reflecting on (Fivush, Hudson, & Nelson, 1984) novel events and experiences. This latter exercise resonates with the idea that semantic knowledge, such as a script or schema, is carried with us into novel experiences. Fivush et al. (1984) examined this idea by studying children's knowledge of "what happens" during a trip to a museum and "what happened" during a specific field trip to a local museum. They found that children were able to report on general events ("what happens") and a specific event ("what happened"), and were also able to provide information on the latter even after a 6-week delay. A primary finding from this analysis was that children's reports of the specific episode differed in both structure and content from the general event representation. This finding led these researchers to posit that children use two different types of event representations: one for specific, one-time events, and a separate representation for general knowledge of events. Furthermore, Fivush, Hudson, and Nelson suggest that events that deviate from the general event representation are specially tagged in a unique natural memory representation whereas events consistent with previously held event schemata are absorbed into a memory representation used to structure general event knowledge. What Fivush and colleagues referred to as event schemata has elsewhere (e.g., Bar, 2004) been termed "context frames." Nevertheless, these terms encompass the organized structures representing a particular event or scene that facilitate or guide the processing of events.

Another way semantic memory is measured in childhood is through standardized assessments of language and vocabulary (e.g., picture-based tasks such as the Peabody Picture Vocabulary Task [PPVT]; Dunn & Dunn, 2007). For example, using a language-based task (specifically, the Receptive Vocabulary and Information subtests of the Wechsler Preschool and Primary Scale of Intelligence-III), Robertson and Köhler (2007) found that semantic knowledge increased with age. However, while it is recognized that language is an important aspect of semantic memory, these standardized tasks do not tap the full domain of semantic memory and all that it contains, so more studies are needed. This dearth of methods used to study semantic memory is especially apparent in the developmental literature and, as such, the trajectory of the development of semantic memory is not well defined. However, the development of semantic memory is sometimes understood through the events of childhood. For example, given their findings, Robertson and Köhler (2007) argue for the likely influence of the accumulation of knowledge about the world throughout childhood on semantic memory capabilities. Similar to episodic memory development, one may also consider how these gains in world knowledge are related to the transition to formal schooling by 5 or 6 years of age.

Relation Between Episodic and Semantic Memory

The relations between semantic and episodic memory have been conceptualized in many ways. Episodic memory "may be the route through which semantic memory must be acquired" (Yee, Chrysikou, & Thompson-Schill, 2013, p. 354; for reviews see Squire & Zola, 1998; Yee et al., 2013). This idea considers the fact that semantic knowledge is learned in the context of an event. For example, one may remember that in a fourth grade social studies class they learned the 50 states. Thus, while knowledge of the 50 states in the United States is considered semantic, the memory of learning this information in a fourth grade classroom is episodic. However, this viewpoint is challenged by studies on atypical populations, such as those with neurodevelopmental disorders (e.g., autism; Gaigg, Bowler, & Gardiner, 2014) or brain damage to structures known to be essential to memory, that have shown that some level of semantic memory can be acquired or exercised somewhat independently of episodic memory (Kensinger & Giovanello, 2005; Lah & Smith, 2014; Rzezak, Guimarães, Fuentes, Guerreiro, & Valente, 2011; Smith & Lah, 2011; Vargha-Khadem et al., 1997; see reviews Duff, Covington, Hilverman, & Cohen, 2020; Yee et al., 2013). Others have considered a cooperative relation between semantic and episodic memory (Martin-Ordas, Atance, & Caza, 2014). Consider reflecting upon the memory of last spring being rainy. This recollection may include memory of specific events such as buying new rain boots or experiencing flooding, however, it may also include general fact-based or semantic knowledge that the spring season is often rainy. Thus, there may be an interaction or cooperation of semantic (the spring season is rainy) and episodic (purchasing rain boots) memories that facilitates in the remembrance of a specific rainy spring season. Indeed, studies in the laboratory have shown that episodic memory can be enhanced by semantic knowledge in adults (e.g., Greve, van Rossum, & Donaldson, 2007; Kan, Alexander, & Verfaellie, 2009; see also Craik & Lockhart, 1972), for example, semantically related word pairs are remembered more accurately than semantically un-related word pairs (Greve et al., 2007).

Semantic memory as it relates to episodic memory development has not been thoroughly examined in developmental research of typically developing children. While this relation has been studied in atypical child populations, these studies primarily focus on functional relations, or how these systems operate and interact in the presence of brain damage or developmental deficits. Studies of this nature inform our understanding of the functional relations of these two memory systems, but it can be difficult to gain an understanding of the developmental relation of semantic and episodic memory in the absence of intact memory systems. However, two lines of work with typically developing children are relevant. First, a handful of studies with children in middle to late childhood have manipulated the match between audiovisual features (e.g., picture of horse presented with the sound of a horse vs. picture of a wolf presented with the sound of a violin; Heikkila & Tiippana, 2016) or match between words and imagined colors (e.g., word apple imagined with color red vs. blue; Maril et al., 2011) during study, and found that memory for stimuli was better for stimuli presented with matching perceptual features for children (8–12 years old) and adults. This work suggests that semantic knowledge (e.g., knowledge of what pictures and sounds match; knowledge of what objects and colors match) during the encoding of laboratory-based stimuli can affect accuracy of memory retrieval by late childhood. Second, motivated by a debate in literature examining semantic dementia (whether episodic memory requires semantic or perceptual processing at encoding), Robertson and Köhler (2007) directly assessed to what extent typically developing children's (ages 4–6 years) recognition memory (i.e., memory for item) could be explained by their semantic knowledge, as measured by language-based standardized tests. In other words, this team asked how children's semantic memory may relate to their episodic memory capabilities. In Robertson and Köhler's work children were administered three separate recognition tests in which target and distracter pictures were manipulated in terms of their semantic and perceptual qualities. For example, in the perceptual recognition test, if a child saw a photo of a black and white cat during encoding, this same black and white cat would be the target at test, and the distracter photo would be manipulated perceptually (a yellow cat), but not semantically (target and distracter are both cats). For this reason, children must successfully encode the perceptual qualities of the photo in order to correctly identify the target photo; only retrieving the semantic quality of the target photo (i.e., "cat") would not be sufficient as the distracter photo would also be a cat. Interestingly, for all three recognition tests, even the perceptual recognition test in which children do not "need" their semantic capabilities, Robertson and Köhler found semantic knowledge (based on performance on the language-based task) to be a significant predictor of performance. Building upon these findings, we examined how a different aspect of semantic memory—spatial knowledge—may relate to episodic memory for events and their spatial details in a naturalistic setting.

The Present Study

The primary goal of this study was to examine episodic and semantic memory in early middle childhood, and to understand how semantic memory influences episodic memory for events. Specifically, we were interested in how children's semantic knowledge of locations relates to memory for events and their spatial context. We chose to study early middle childhood as we could expect improvements in both episodic and semantic memory during these years. We assessed our goals two ways. First, in our episodic memory task, we experimentally tested how children's semantic knowledge of locations influenced memory for events and their spatial context. At a local children's museum, children of different ages participated in three types of events; the events differed in the degree to which the semantic properties of the location matched the event. By choosing to conduct this research in a naturalistic setting, we were able to capitalize on contextual details not present in the traditional laboratory setting. The second way we tested how children's semantic knowledge of locations may relate to memory for events and their spatial context was using a semantic interview task. In this task, we directly assessed children's semantic knowledge of the locations of interest to this study. We then tested how performance in the semantic interview task related to performance on the episodic memory task. In addition, we included a language-based task to parallel how previous literature (e.g., Robertson & Köhler, 2007) examined the relation between episodic and semantic memory in children.

Overall, we expected age-related improvements in children's episodic memory and semantic memory. In the episodic memory task, we hypothesized that greater semantic knowledge in older children would create memory differences between the event conditions. In contrast, we expected that younger children would not exhibit robust semantic knowledge of locations and therefore predicted we would observe relatively smaller memory differences between the event types. However, we also recognized the possibility that, across ages, children's memory for the events could be high due to the active nature of the events in the museum setting (as in Pathman, Samson, Dugas, Cabeza, & Bauer, 2011). For children's performance on the semantic interview task, we expected to observe an effect of age such that children would exhibit greater semantic knowledge with increasing age. Further we expected to see relations between the semantic interview task, episodic memory performance, and the language-based measure of semantic memory. However, given the novelty of this research, we did not make specific predictions about which predictors would best explain episodic memory performance. Thus this work represents a relatively exploratory, not confirmatory, effort.

Method

Participants

A total of 103 children took part in this study. Sixteen children were excluded from analyses due to computer software error ($n = 2$), because they did not return for the second visit ($n = 6$), did not complete tasks due to lack of time or fatigue ($n = 6$), or did not follow task instructions ($n = 2$). The final sample is comprised of three groups: 29 five-year-olds ($M = 65.03$ months, $SD = 3.62$; 15 females, 14 males), 29 six-year-olds ($M = 77.76$ months, $SD = 3.76$; 13 females, 16 males), and 29 seven-year-olds ($M = 89.48$ months, $SD = 3.45$; 15 females, 14 males). Note that the 5-year-old group includes two older 4-year-olds, and the 7-year-old group includes one young 8-year-old. All result patterns remained the same whether or not these participants were included, thus they remained in the final sample.

A demographics questionnaire completed by parents revealed that approximately 13% percent of the children were African American, 10% were of mixed race, 2% were Asian, 1% identified as Native American or Indigenous American, and 68% were Caucasian. An additional 6% of parents chose not to specify their child's race. The family income reported for 6%, 13%, 18%, 22%, and 30% of children was < \$25,000, \$25,000–40,000, \$40,000–60,000, \$60,000–90,0000, and > \$90,000, respectively. An additional 12% of parents chose not to specify family income. Participants were recruited from a volunteer pool of families who expressed interest in participating in research. In addition, the study was advertised via social media and paper flyers in the community. Participants were residents of Greensboro, NC, and surrounding cities. Data collection occurred from June 2016 to August 2017. All procedures were approved by a University Institutional Review Board. Parents provided written informed consent. Children provided verbal (5- and 6-year-olds) or written assent (7-year-olds). All families received free admission to the museum, and children received a small toy for participating in the study. All participants were tested by one of three female experimenters at each session. All experimenters received training and oversight from the lead experimenter.

Procedure

Episodic Memory Task

The primary setting of this study was the Greensboro Children's Museum, a local museum constructed to resemble a town with exhibits representing locations about the town. Six of these exhibits (hereafter "locations") were chosen for the purpose of the study: the bookstore, the construction zone, "Grandma's house," the market, the medical center, and the post office.

Prior to beginning the episodic memory task, children took a "tour of the town" with the experimenter. The intent of this activity was to briefly familiarize children with each location in the museum. During this activity, the experimenter walked the child through the town and, using a 1–2 sentence script for each location, pointed out the locations they would be visiting in the town that day. Children were told they would be visiting the locations with the experimenter to complete short games or activities and that later that day they would play a "computer game." The subsequent episodic memory task included a study phase (approximately 35 min) and, after a delay (10–15 min), a test phase (approximately 15 min). Participants were not told during the study phase that they would need to remember the events for later.

Study phase. During the study phase of the episodic memory task, participants visited each of the six locations and at each visit to a location participated in one event that was classified as either congruent, incongruent, or independent. Thus, in total, children participated in 18 events (three events—congruent, incongruent, and independent—at each of the six locations) with a short midway activity occurring after the ninth event. A congruent event is an event for which semantic knowledge about where that event typically occurs matches the location in which it occurred, such as sorting mail at the post office. On the other hand, an incongruent event, is an event for which semantic knowledge about where that event typically occurs does *not* match the location, such as bagging groceries at the medical center. As a comparison condition, independent events were ones that did not have significant ties to any particular location in the museum. Examples of independent events are tying a shoe or listening to a joke, and did not match any particular location. Since independent events were not tied to a particular location, by definition, these events could not be counterbalanced with congruent and incongruent events. Event condition classifications were confirmed via surveys sent to adult volunteers (see Appendix S1). For a complete list of events see Appendix S2.

Congruent and incongruent events were derived from the same bank of events and counterbalanced such that what one child experienced as a congruent event (sorting mail at post office) another child may have completed as an incongruent event (sorting mail at the medical center). The "bank" of all events included 24 congruent or incongruent events (four events corresponding to each of the six locations) and 12 independent events. For additional details on creation of stimulus sets/counterbalancing see Appendix S3.

Stimuli for each event were most often toys or objects similar to those that children could play with at the museum. For example, a brown paper bag and plastic food items were used for the "bagging groceries" event. Although stimuli matched the intended locations, they were distinct from the objects at the museum. For example, the mail in the post office location were laminated postcards, whereas the mail stimuli used in this experiment were colored envelopes. The objects needed for a given participant's session were kept in a covered rolling cart managed by the experimenter throughout the study phase. Following the study phase there was a short delay (approximately 10–15 min), which involved a snack and optional restroom break. Importantly, the delay occurred in an area of the museum apart from the "town" portion of the museum.

Test phase. Children's memory for the events in which they participated, as well as the events' spatial and temporal details, were tested using a laptop computer in an area apart from the "town" portion of the museum. Children wore noise-cancelling headphones, which also allowed them to hear the test questions. E-prime software (Psychology Software Tools, Pittsburgh, PA; E-prime Version 2.0.10.252) was used to display images, play audio, and record responses. For each trial, children were presented with a photo of the object(s) used for the event (e.g., a pile of colored envelopes), while they heard the recognition test question such as "Did you sort colored envelopes?" Children were given the opportunity to answer by key press marked "yes" (i.e., old) or "no" (i.e., new). Two additional questions were asked for events to which children responded "yes." For these items, children were again shown the photo of the event object and were first asked a spatial question: "Where did you do this activity?" The following screen showed the six locations that were visited, and children responded by pressing a key corresponding to one of the six locations. Second, children were asked a time question. Specifically, children were asked if the event occurred before or after the midway activity. Data from the time question of the test is not included in this article. To ensure the child understood testing procedures, the experimenter conducted practice trials prior to beginning the test portion of the episodic memory task. All relevant keys were labeled and the experimenter also monitored the progress of the test and gave any needed reminders about the locations of particular keys on the keyboard. Some children with limited reading and typing capabilities provided responses verbally and the experimenter pressed the corresponding keys. In total, the memory test was comprised of 36 items with 18 of these items being events that the child participated in at the museum that day (i.e., "old"). The remaining 18 "new" items were those not experienced by the child at the museum that day, but may have been experienced by another participant.

Semantic Interview Task

Children completed a semantic interview task in order to assess their knowledge of the locations of interest. This task occurred prior to entering the museum town, and thus locations were spoken of in general terms that would be most identifiable to children. For example, rather than asking who might be at a medical center, children were asked who might be at a "medical center or a doctor's office." For each location, three questions were asked: "Who might be at a [location]?" "What kinds of things would you see at a [location]?" and "Why or when would you go to the [location]?" Order of the locations was randomized, but questions for each location always proceeded as indicated above. The experimenter took notes on the participant's responses, and this task was also audio-recorded.

Additional Semantic Memory Tasks

Children were also given two additional tasks, aimed at testing children's semantic memory in different ways. One was a standardized language-based task, the PPVT (Dunn & Dunn, 2007). In this task, the participant chooses one of four pictures displayed on a page that he or she believes to most accurately represent a word spoken by the experimenter. For example, a child may see an array of shapes and be asked to identify the one that reflects the word "diamond." Second, children were given a task created in our lab involving time-relevant semantic information. This task (which we will refer to as the CCT Task) is out of the scope of the present research and thus will not be discussed further.

Experience and Knowledge Parental Questionnaire

In addition to a demographics questionnaire, parents were asked to complete a questionnaire about their child's previous experience with informal learning environments like museums and science centers and to rate their child's knowledge about locations of interest (e.g., post offices, medical centers, etc.; See Appendix S4).

Task Order and Study Modifications

Construction at the museum midway through data collection resulted in minor changes to study procedures. First, the bookstore exhibit was closed, and thus for participants tested after construction ($n = 50$), the bookstore exhibit was replaced with the theater exhibit in the episodic memory task. Questions about "a theater" were also added to the semantic interview task, though scores for this location were not included in analyses as participants prior to museum construction ($n = 37$) were not asked questions about this location. Second, participants prior to museum construction completed all procedures in one session (approximately 2 hr in length) at the Greensboro Children's Museum. These participants completed the tasks in the following order: consent and assent procedures, semantic interview task, episodic memory task ("tour of the town", study phase, break, test phase), CCT Task, and PPVT. Participants after museum construction completed all tasks in two sessions: The first session in a university laboratory setting (approximately 1 hr in length) and the second session was at the Greensboro Children's Museum (approximately 1 hr in length). The motivation for this change was to reduce the length of the session at the museum. The overall order of tasks remained the same, with the exception of the CCT and PPVT. Specifically, children tested after museum construction first visited the laboratory to complete the following activities: consent and assent procedures, semantic interview task, CCT, and PPVT. Participants then came to the museum another day to complete the episodic memory task ("tour of the town", study phase, break, test phase). Independent samples t-tests revealed that there were no differences (ts < 1.23, ps > .22) in accuracy between participants tested before or after construction on any of our tasks.

Scoring

Episodic Memory Task

We examined children's memory for item (i.e., events) and memory for location of the event (i.e., spatial context). Scores from the item portion of the episodic memory task were computed using standard protocol for tests of old/new recognition. Corrected recognition scores were computed for each participant for each condition by subtracting the proportion of false alarms (incorrectly judging new items as old) from the proportion of hits (correctly judging an old item as old). Scoring of children's memory for location of events (spatial accuracy) involved computation of the proportion of correct responses for each of the conditions (congruent, incongruent, independent).

Semantic Interview Task

Responses of the semantic interview task were first transcribed. Next, the beginning and end of children's responses to each of the three questions (i.e., "who" and "what" might be at a location and "why/when" one would visit the location) were identified so that an accurate representation of word count could be determined. Any "off task" talk was removed from the word count in addition to filler words (e.g., um, uh, etc.), phrases that buy more time (e.g., "Let me think about that…"), and phrases that signal completion (e.g., "That's all I can think of"). These steps were used to compute an "adjusted" word count for each location. Analyses make use of this adjusted word count summed across the original six locations.

The semantic interview task was scored for quality of response (overall content and correctness). Each question response was given a score of zero or one. To aid in differentiating zero versus one point responses, "defining features" for each location were determined. Examples of defining features include: librarian, grocer, doctor/nurse ("Who?" question); books, fruits/vegetables, medical tools ("What?" question); and to get a book, to buy groceries, to get a check-up ("Why?" question). In order to receive a score of one point, the child must have given at least one defining feature for that question. A score of zero was given if the response was incorrect, if the child responded "I don't know," or if the response lacked specificity or understanding of the location. For example, the response "a worker" to the question "Who might be at a library?", would be given a 0 because it lacked specificity (unlike responses "librarian," "the media specialist," etc.). Scores were summed, and proportion scores were used in analysis based on the number of points possible (i.e., 18; three questions for each of six locations).

To estimate the reliability of scoring, 20% of transcripts (randomly selected; equal representation from each age group) was scored by an independent rater. Interrater agreement was 96%. (18 participants × 3 scores for each question × 6 locations, thus a total of 324 individual scores. The primary and reliability coders' scores were identical on all except 14 of those individual scores.) The primary rater's scores were used in all analyses.

Results

Episodic Memory Task

As a reminder, the episodic memory task allowed us to track children's recognition memory for events and their locations. This task also allowed us to test the impact of spatial semantic knowledge on children's episodic memory for events (old/new recognition) and locations (spatial memory). The primary comparison of interest was spatial memory accuracy for the congruent and incongruent conditions.

The independent condition served as a baseline condition. For old/new recognition, we found no significant effect of Age, $F(2, 83) = 0.30$, $p = .74$, when corrected recognition scores for independent events were analyzed in a one-way analysis of variance (ANOVA). Likewise, no significant effect of Age, $F(2, 84) = 1.35$, $p = .27$, was found when spatial accuracy scores for independent events were analyzed in a one-way ANOVA.

Next, two 2 (Condition: congruent, incongruent) × 3 (Age: 5, 6, 7) repeated measures analysis of variance (RM ANOVAs) were used to investigate the influence of the spatial semantic manipulation (i.e., condition) and developmental changes (i.e., age) on episodic memory. The first of these RM ANOVAs assessed old/new recognition: analysis of corrected recognition scores revealed no main effects of Condition, $F(1, 83) = 0.09$, $p = .76$, or Age, $F(2, 83) = 1.31$, $p = .28$, and no interaction, $F(2, 83) = 1.12$, $p = .33$.

In the second RM ANOVA assessing children's memory for the location of events (i.e., the spatial question), there was also no main effect of Age, $F(2, 84) = 1.14$, $p = .33$, and no interaction, $F(2, 84) = 0.80$, $p = .46$. However, this analysis did reveal a significant main effect of Condition, $F(1, 84) = 46.97$, $p < .0001$, $\eta_p^2 = .36$, such that, across age groups, the locations of congruent events ($M = .910$, $SD = .155$) were identified more accurately than those of incongruent events ($M = .739$, $SD = .217$). Figure 1 depicts memory for location scores for the congruent and incongruent conditions, with the dashed line representing mean accuracy for the independent condition (baseline), for each age group.

Exploration of Errors

We examined the errors that were made in children's memory for the location of incongruent events. To do this, we separated errors into "match" and "nonmatch" errors. A match error would be incorrectly choosing the location that is congruent to the event (e.g., responding that bagging groceries took place at the market when it actually took place at the medical center). A nonmatch error is incorrectly responding that an event took place anywhere other than the correct location (the location where the event actually took place, for the particular child) or the congruent location. For this analysis, we compared the proportion of match and nonmatch errors to what we would expect by chance. With six possible locations for an event, chance responding for match and nonmatch errors is 1/6 and 4/6, respectively, summing to the five possible errors. Across all participants that made errors on incongruent trials ($n = 67$), we found match errors differed significantly from what we would expect by chance, $t(66) = 3.32$, $p = .001$. Nonmatch errors did not differ from what would be expected by chance, $t(66) = -0.22$, $p = .83$. To determine if there were any age-related differences in the match errors analysis, we conducted one-sample t-tests separately for each age group. We found that 5-year-olds who made errors on incongruent trials ($n = 25$), were more likely than chance to make match errors ($p = .01$); the t-tests were not significant for the older age groups (ps > .14).

Semantic Interview Task

Scores from the semantic interview task were used to assess children's semantic knowledge of locations. An ANOVA revealed a significant effect of Age, $F(2, 84) = 6.91$, $p < .005$, $\eta_p^2 = .14$, and post hoc comparisons using Tukey's honestly significant different test revealed the following pattern: 7-year-olds ($M = .776$, $SD = .136$) provided more high-quality responses than both 5-year-olds ($M = .605$, $SD = .206$; $p < .005$) and 6-year-olds ($M = .651$, $SD = .192$; $p < .05$); however, 5- and 6-year-olds did not differ in the number of high-quality responses ($p = .599$). The same pattern of results emerges with Bonferroni correction for multiple comparisons. There was a significant relation between the number of high-quality responses and

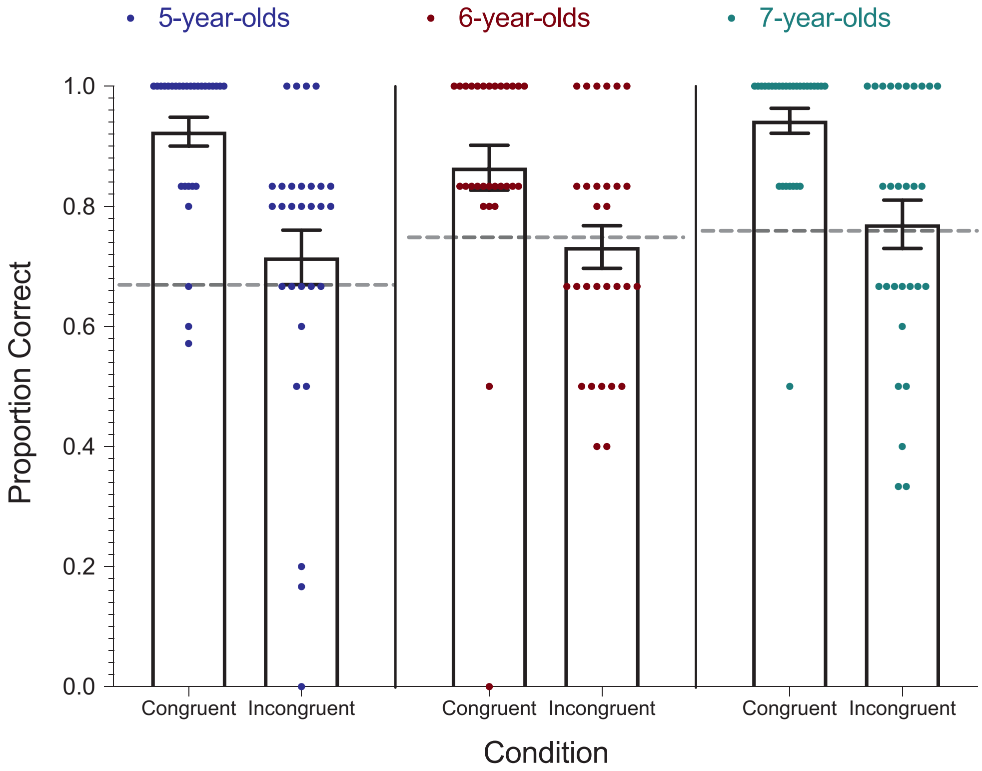

Figure 1. Effect of condition in children's memory for location in the Episodic Memory Task.
Note. Dots represent individual data points for the congruent and incongruent conditions. The dashed horizontal lines represent mean accuracy for the independent condition. Error bars are ± *SEM*.

age, which held even when controlling for word count in a partial correlation ($r = .293$, $p = .006$).

Analyses of Relations Between Episodic and Semantic Tasks

Finally, as exploratory analyses, we assessed which variables best predict individual differences in children's episodic memory for location (i.e., spatial memory accuracy). This step involved two separate regressions on spatial memory accuracy scores from the congruent and incongruent conditions. Predictors for both of these regressions included: age (in months), scores from the baseline recognition measure of the episodic memory task (specifically, corrected recognition scores for independent events) and scores from semantic tasks (specifically, standardized PPVT scores and scores from the semantic interview task). When spatial memory accuracy scores from the congruent condition were used as the outcome, the model was not significant, $R^2 = .06$, $F(4, 81) = 1.28$, $p = .28$. However, the regression on spatial memory accuracy scores from incongruent events was significant, $R^2 = .12$, $F(4, 81) = 2.66$, $p < .05$. Significant predictors in this model were Age ($\beta = .27$, $t = 2.24$, $p = .03$; variance inflation factor [VIF] = 1.3) and PPVT score ($\beta = .33$, $t = 2.59$, $p = .01$; VIF = 1.5).

Experience and Knowledge Parental Questionnaire

Descriptive statistics and analyses related to this parental report are provided in Appendix S4.

Discussion

The primary goal of this study was to examine the development of and relations between episodic and semantic memory—specifically, we asked how children's spatial semantic memory (knowledge about places/locations) relates to episodic memory for events and their locations. We examined this from multiple angles and methods (e.g., experimental paradigm, interview-based task, standardized measures) and used a naturalistic setting which is relatively rare in the memory literature. First, we examined these relations in a museum setting by having children in early middle childhood participate in short events and then later testing their memory for the events and their spatial location. The events were manipulated by the extent to which the activity matched, did not match, or had no relation to the location in which it occurred. In other words, our experimental conditions allowed us to assess the extent to which children's semantic memory influences their episodic memory by manipulating the degree to which the event matched the semantic properties of the location. We examined accuracy scores, but also explored errors made. We found that accuracy for memory for locations was influenced by our experimental manipulation: across age groups, children more accurately remembered the spatial location for the event when there was a semantic match between the location and the event, compared to when there was no such match. In other words, we found experimentally that spatial semantic memory influenced spatial episodic memory, across age groups. Our exploration of errors revealed that when children made errors in the incongruent condition (no semantic match between location and event), younger children were more likely to incorrectly choose the location that matched their semantic knowledge. We also used a novel interview task to assess children's semantic knowledge of locations and the developmental trajectory of this knowledge and found age-related improvements. Finally, we used a set of regressions to better understand the factors that influence or drive children's episodic memory development, and found that age and the language-based assessment of semantic knowledge predicted an aspect of episodic memory.

The work of Fivush et al. (1984) perhaps provides one framework through which to consider memory differences between congruent and incongruent events, as we may liken our congruent events to these researchers' assessment of "what happens" on a trip to a museum. In this study, memory performance for congruent events may reflect a "boost" from children's semantic memory as knowledge of what generally happens in a location guided the encoding of congruent events. In other words, the existing semantic knowledge that children held might have served to support the encoding of congruent events through the perception of additional "matching" semantic details that could be absorbed consistently into their schema. For example, consider the difference in spatial details when setting a place setting at the kitchen table (in "Grandma's house") versus at a workbench (in the construction zone). Then, at test, these additional details could also be recruited and used to identify the correct location and reject incorrect locations. This interpretation of this study falls in line with the work of Robertson and Köhler (2007).

These ideas are also consistent with research on relational memory. When an item is encoded into memory, it is bound to a number of contextual features, these features could then be used to compare and contrast the individual items in memory (Olson & Newcombe, 2014). Relational binding is a process inherent to forming episodic memories, and a source to credit with changes in episodic memory in childhood (Lee, Wendelken, Bunge, & Ghetti, 2016; Olson & Newcombe, 2014). It is also possible that this type of binding or the associations made link aspects of episodic memory (features of event) and semantic knowledge. Our results seem to suggest that children's memory for events and their locations in the congruent condition (congruent based on semantic knowledge) were "bound more tightly" in memory than event-location combinations in the incongruent condition (see also Heikkila & Tiippana, 2016).

Like relational binding, understanding controlled processes shed light onto the development of children's memory for events. Age-related improvements in controlled, or strategic, memory processes are to credit, in part, with developments in episodic memory during childhood (see Ghetti & Lee, 2011). Enlisting controlled processes such as semantic or organizational memory strategies can support encoding and retrieval of episodic memories (Bjorklund, Dukes, & Brown, 2009). Robertson and Köhler (2007) discuss the influence of elaborative semantic encoding processes on later recognition of items. Children who were able to utilize their semantic competencies at encoding displayed more accurate recognition at test. In the present work, results of the congruent condition indicate that children may have likewise applied a semantic strategy when encoding events. However, this study cannot test this, especially because children were not explicitly told they would need to remember event-location combinations, and we did not test for the use of any explicit memory strategies. This, however, would be a fruitful line of future work.

An important question to ask is *how* semantic memory influenced episodic memory in our study-did it boost or hinder performance? By definition, the independent condition could not be counterbalanced with the two experimental conditions, and so out of caution we did not include the independent condition in the analysis directly comparing conditions. However, based on the statistical analysis between the congruent and incongruent condition, and visually comparing these conditions to the independent or baseline condition, it seems like semantic memory *boosted* accuracy in the congruent condition. It did not seem like semantic memory hindered accuracy in the incongruent condition, at least based on visual comparison to the baseline condition.

Further evidence for semantic memory boosting episodic memory comes from our use of the standardized language-based assessment of semantic memory. The regression on children's memory for locations in the incongruent condition, the condition that would most tax the memory system, showed positive relations between scores on the PPVT and spatial episodic memory accuracy. As discussed, language is only an aspect of semantic memory, but this finding is perhaps reminiscent of Robertson and Köhler's (2007) perceptual recognition test in that children do not necessarily "need" their semantic memory to remember the location of incongruent events, yet there still exists a relation between performance on these trials and children's semantic memory assessed via language. Therefore, one possibility is that children can efficiently employ their semantic memory via language during incongruent test trials. In support of this idea, it could be argued that just as the congruent semantic spatial details are perceived and utilized in congruent trials, the incongruent semantic spatial details could be used to create memory flags of these events. In other words, a child could say, "It's weird that I'm setting a place setting at a work bench in a construction zone. I should be doing this at Grandma's house. I'm going to remember this because it's kind of odd." Indeed, this was anecdotally observed in the study phase as some children, especially 6- and 7-year-olds, would note that incongruent events "should have actually taken place at [location X]." These observations fall in line with Fivush et al. (1984) view that events that deviate from the general event representation are specially tagged in memory. In the study by Fivush and colleagues, children could remember a specific event up to a year later; however, a cue was needed to remember the events motivating these authors to conclude that the distinctive tag (i.e., cue) was needed to retrieve the event from memory. All trials in our episodic test were equivalent in that no cues were given as to the location of events. Future studies could test whether our same pattern of results would be obtained when spatial memory is tested via free or cued recall (see also Bauer et al., 2012, 2015) rather than recognition, as these methods may bring about more memory differences particularly for children who may have been more attuned to the oddity of the incongruent events.

On the other hand, results of our exploratory analysis of errors made on incongruent trials perhaps support the idea that semantic memory can also hinder memory for the location of events. As a reminder, a match error is made when a child incorrectly responds that an event occurred at the location that would be congruent to the event. A nonmatch error is made when a child responds that the event occurred in any location other than the congruent location or the correct location. The exploratory examination of these errors may be one way to consider intrusions between event types. Specifically, if there were no intrusions of the general event representation on the specific events, as discussed by Fivush et al. (1984), we would expect that match errors would be rare and incorrect responses on these trials would be random (nonmatch errors) in nature. However, the finding that match errors differed from chance provides support for the idea that semantic memory, or the general event representation of what children would expect, perhaps played a hindering role in how children responded in recognizing the locations of events.

Our original prediction was that since older children may have higher semantic knowledge of the locations, which was confirmed by our findings from the semantic interview task, that they also may show stronger effects in the experimental paradigm. In other words, we predicted that the experimental manipulation would have a larger effect (i.e., a larger difference between congruent and incongruent trials) for older compared to younger children. However, this was not the case, as we found no interaction between condition and age group: the effect of experimental manipulation was not detectably stronger for our oldest (7-year-olds) compared to our youngest (5-year-olds) children. This is consistent with studies with older children (8+ years) and adults, in which congruency between different features of laboratory-based stimuli was tested; no age by condition effects were found (Heikkila & Tiippana, 2016; Maril et al., 2011). Thus, it is possible that some threshold level of semantic knowledge is enough to show semantic congruency effects. However, future experimental studies are needed to test the limits of this possibility. Moreover, although we did not find age differences in accuracy, we did detect some age group differences. Specifically, our exploration of errors analysis suggests that younger children, whose episodic memory system may be more fragile, are more dependent on semantic memory than older children, and in this case led them astray. These particular results should be interpreted with caution as there are some statistical limitations (e.g., limited number of trials), and thus more work is needed to investigate the influence of semantic memory on incorrect responding in the incongruent trials. However, future longitudinal studies, should explore the possibility that the relation between episodic and semantic memory development is such that when children are younger there is more reliance on the semantic memory system to support episodic memory, but as the episodic memory system becomes more robust, less support from semantic memory is necessary.

This study examined the relations between episodic and semantic memory in early middle childhood. To our knowledge, the present work and Robertson and Köhler (2007) are the only studies to explore this question in this age range for *typical* child development, although a body of literature does exist examining these relations in *atypical* development or conditions. For example, the work of Smith and Lah (2011) studied how semantic and episodic memory function in children with temporal lobe epilepsy and concluded that the memory systems may develop independently in the presence of this pathology. Furthermore, the study of developmental amnesics (see Elward & Vargha-Khadem, 2018 for a review) provides an analysis and debate of the relations of episodic and semantic memory in the presence of damage to the hippocampus.

In terms of the old/new recognition task, we hypothesized that we would observe age-related improvements between 5-, 6-, and 7-year-olds. However, we did not find effects of age in children's memory for events in either the experimental nor the baseline conditions. Children were able to both recognize events that they did participate in (i.e., "old") and reject events that they did not participate in (i.e., "new") at ceiling levels. The nature of the recognition test in some ways "set participants up for success." Specifically, memory probes were distinct and were accompanied by a photo representing an object that was used for the event. For example, for the "tie a shoe" event, children heard "Did you tie the laces on this shoe?" accompanied by a photo of the exact red shoe that they would have tied the laces on. Furthermore, studies have shown that children's memories are more accurate when the events are encoded in an autobiographical or self-relevant way (e.g., Pathman et al., 2011). In this way, high recognition performance was foreseen as a possibility. However, the ease of the old/new recognition portion of the memory test was deliberate so that we could examine the context portion of the memory test (software was programmed to advance to space and time questions if the child responded "yes" to the event question). In other words, in order to adequately assess children's memory for the details of events, we needed them to be able to advance beyond simply recognizing the event. High recognition memory performance may have also been due to a short delay between the study phase and test. Future work in this line of research could include a longer delay (e.g., days or weeks) that could possibly bring out episodic memory differences across age groups.

Although effects of age were not observed in the episodic memory task (at least in terms of accuracy), we did find an effect of age in the semantic memory task, specifically, a novel interview assessing children's knowledge of locations. The effect of age was such that children in the 5- and 6-year-old groups demonstrated less semantic knowledge of the locations than the 7-year-old group. (The age-related improvements in semantic knowledge based on our interview task were not found with our parental report measure, in which parents were asked to judge their child's knowledge of the locations, suggesting experimenter-based interviews are useful in documenting developmental differences. However, individual differences in parent report of knowledge was consistent with that for our semantic interview scores. See Supporting Information. The age-related improvements found using our semantic interview task are also consistent with studies showing age-related increases in semantic knowledge across childhood based on performance on the Deese–Roediger–McDermott procedure (see review Brod et al., 2013). Likely contributors in the development of this memory system include the transition to formal schooling during our age range of interest as well as accumulating world experiences throughout childhood (Murphy, 2002). In fact, exploratory supplemental analyses revealed that individual differences in number of prior visits to the museum (and thus prior experience with naturalistic versions of the locations of interest) were correlated with scores on our semantic interview task. While findings allow us to further understand or chart the trajectory of children's semantic memory development, we also hope that this task provides another method or means of assessing children's semantic memory. Studies of children's memory development have often looked to language-based measures to assess children's semantic memory; however, we know that language is only an aspect of semantic knowledge. Furthermore, at present, little is known about children's memory for an important aspect of semantic memory—that is, their knowledge of locations.

This study looked to a naturalistic setting (i.e., a children's museum) to examine our questions of interest. Studies conducted in naturalistic settings have the chief benefit of bringing research into the active, social context in which learning most organically occurs. Furthermore, pioneers of developmental psychology (i.e., Piaget, 1970; Vygotsky, 1978) established the learning benefits inherent to hands-on interaction long ago. This idea is perhaps demonstrated in this study in that children actively participated in events and recognition performance was relatively high across conditions and ages, and consistent with other museum studies showing that age group differences can be minimized with naturalistic and self-relevant events (e.g., Pathman et al., 2011). Therefore, this study joins this perspective that naturalistic settings may allow for greater memory performance in children, though more work is needed to fully understand the potential of children's memory across development.

In conclusion, we looked to a naturalistic setting to examine the development of the relations of children's semantic and episodic memory. Our experimental manipulation allowed us to understand the contribution of semantic and episodic memory in children's memory for different types of events, particularly the location of these events. We have also contributed a novel examination of children's semantic memory with a narrative interview task designed to assess what children know about locations and observed development across our age groups using this task. This contribution is important as semantic memory has most often been assessed with language-based tasks and little is known about children's knowledge of space. Age effects were not found in the episodic memory task, likely due to the active nature of encoding. Future work may benefit from using different testing (e.g., recall rather than recognition), and a longer delay between study phase and test (e.g., days or weeks rather than minutes). Finally, we would emphasize the utility of research that takes place in informal learning environments like children's museums or science centers, as these settings provide an environment in which children can naturally experience learning and memory. These settings are ideal for testing both episodic and semantic memory, and to further our understanding of their development.

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Supporting Information

Additional supporting information may be found in the online version of this article at the publisher's website:

Appendix S1. Additional Information on Adult Pilot Surveys Used to Determine the Events to be Used in the Episodic Memory Task

Appendix S2. Table That Shows the Different Events Used in the Study

Appendix S3. Additional Information on Counterbalancing for Episodic Memory Task

Appendix S4. Methods and Results Related to the "Experience and Knowledge Parental Questionnaire"