JOURNAL OF COGNITION AND DEVELOPMENT, 15(2):304–324
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ISSN: 1524-8372 print/1532-7647 online
DOI: 10.1080/15248372.2013.763809

The Contribution of Executive Function to Source Memory Development in Early Childhood

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Age-related differences in episodic memory judgments assessing recall of fact information and the source of this information were examined. The role of executive function (EF) in supporting early episodic memory ability was also explored. Four- and 6-year-old children were taught 10 novel facts from two different sources (experimenter or puppet), and memory for both fact and source information was later tested. Measures of working memory, inhibitory control, and set shifting were obtained to produce an indicator of children's EF. Six-year-olds recalled more fact and source information than did 4-year-olds. Regression analyses revealed that age, language ability, and EF accounted for unique variance in children's fact recall and source recall performance. These findings suggest a link between episodic memory and EF, and we propose that developmental investigations should further explore this association.

Explicit memory is conceptualized as memory for which one is consciously aware. In general, a distinction exists within the explicit memory system between semantic and episodic memory (Tulving, 1983, 1984, 2002). Semantic memory refers to our knowledge about the world and includes our knowledge about factual details (e.g., I know that hummingbirds are the only birds that can fly backward). Typically, recollection of semantic memories lacks detail about the specific contextual information that was acquired when the semantic memory was established. In contrast, episodic memory refers to memory for personally experienced events and their spatial and temporal relations (e.g., I remember learning that hummingbirds are the only birds that can fly backward during a fourth-grade field trip to the zoo). One of the hallmarks of episodic memory is to not only recollect that a particular event has occurred, but to also recollect specific details associated with the event—such as its time or place of occurrence.

Within the episodic memory framework, it is possible to distinguish between memories for the *content* of information (such as memory for facts) and memory for the *context* of how this

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information was acquired (the place or individual from which this information was obtained). Recollection for the contextual details surrounding a memory episode is referred to as source memory (Johnson, Hashtroudi, & Lindsay, 1993). Source can refer to a variety of qualitative characteristics, such as perceptual (e.g., sound, color), contextual (e.g., spatial, temporal), and affective information (e.g., emotional reactions) and cognitive operations (e.g., organizing, elaborating, retrieving, and identifying information). Memory researchers posit that recollection for the central content of information (item memory) and its source-specifying details (source memory) lays the foundation for episodic memory. Specifically, source memory tasks allow researchers to investigate the features or qualities that give memories their episodic nature (Johnson, 2005). The purpose of this investigation was to examine the development of episodic memory in early childhood, focusing on the role of item- and source memory processing and the contribution of higher-order executive functions (EF) to episodic memory formation.

Age-Related Improvements in Source Memory

Episodic memory is believed to be a complex memory system that does not emerge until later in development. Investigations into its formation have found that the rudiments of episodic memory may be in place by age 3 (Hayne & Imuta, 2011) and that improvements continue between ages 3 and 6 years (Newcombe, Lloyd, & Ratliff, 2007). Likewise, the source-monitoring capabilities of children also show improvement during this time in development.

Developmental investigations of source memory reveal that children have difficulty recollecting the contextual details associated with an event. For example, 6-year-olds, compared with 9-year-olds and adults, are worse at discriminating between self-generated memories of performed and imagined actions (Foley & Johnson, 1985; Foley, Johnson, & Raye, 1983). Compared with adults, young children are also more likely to misattribute sources (Ackil & Zaragoza, 1995) and perform worse on source tests when a delay is imposed (Parker, 1995). They are also more prone to making source memory errors when there is a high degree of similarity between sources (Lindsay, Johnson, & Kwon, 1991).

Improvements in source memory have been observed between ages 4 and 6 (Drummey & Newcombe, 2002; Lindsay et al., 1991). Drummey and Newcombe (2002) tested 4-, 6-, and 8-year-olds on a source memory task and found a steady age-related improvement in the ability to remember factual information. However, improvement in the ability to correctly monitor the source of such facts occurred between ages 4 and 6, whereas source memory performance between ages of 6 and 8 was equivalent. Four-year-olds also committed more source memory errors (i.e., incorrectly attributing something learned within the experimental context to something learned outside the experimental context) than did 6- and 8-year-olds. This specific source memory error refers to the phenomenon of source amnesia, in which an individual does not remember that an item was learned within the context of the experimental situation and incorrectly attributes learning the item to an outside source (extraexperimental error), such as through television or a parent. Schacter, Harbluk, and McLachlan (1984) differentiated between source amnesia and source forgetting, the latter of which involves remembering that a fact was learned within the experimental situation but attributing this fact to the wrong source (intraexperimental error). Consequently, we focused on examining source memory improvements specifically between the ages of 4 and 6 years old, when the most pronounced changes in source-monitoring ability were likely to occur.

In a series of experiments, Lindsay et al. (1991) manipulated the perceptual and semantic similarities of two sources of information (i.e., presenting two puppets speaking in the same vs. different voice). Four-year-olds were more affected than adults were by the similarity manipulation and had difficulty discriminating between sources in the same voice condition. Although children made more source-monitoring errors compared with adults, source-monitoring ability improved between 4 and 6 years old. Interestingly, for old/new item-recognition judgments, 4-year-olds were comparable to adults. This effect of younger children demonstrating comparable item recognition performance to adults, but greater age-related impairments in source memory has been replicated (Cycowicz, Friedman, Snodgrass, & Duff, 2001).

Recall Memory Versus Recognition Memory

When examining recognition memory, some models state that the process of recognition is unitary and exists on a continuum, with recognition cues being determined by the strength of the memory trace (Donaldson, 1996), whereas other models state that recognition is supported by two processes: recollection and familiarity (Jacoby, 1991; Yonelinas, 1994, 2002). Familiarity is thought to reflect a general assessment about previous encounters with a stimulus, without providing specific details. Familiarity can be interpreted as a vague sense of having encountered an item before. In contrast, recollection is thought to reflect the remembering of an item along with the retrieval of specific information about the item, such as its contextual details or source-specifying information.

Developmental investigations of recognition memory have compared familiarity-based and recollection-based judgments. In general, researchers found age-related improvements in recollection of contextual details from 8 to 24 years old, whereas familiarity-based recognition remained relatively stable across this time span (Billingsley, Lou Smith, & McAndrews, 2002; Ofen et al., 2007). In contrast to recognition memory, recall memory (i.e., retrieving information from memory in the absence of any perceptual cues) shows more age-related improvement (Schneider & Pressley, 1997). Retrieving information from memory using free recall is thought to be more difficult than retrieving information based on recognition, as recall depends more on encoding and retrieval strategies (Schneider & Pressley, 1997). As noted by Tulving (1985), free recall tasks also contain more episodic traces, compared with cued recall or recognition tasks in which one is provided with cues about a particular event.

The importance of this distinction in assessing recall versus recognition during tests of item and source memory is relevant to the developmental literature on source memory. Lindsay and colleagues (1991) found that children as young as 4 years old displayed rather intact source memory when distinguishing between two distinct external sources and only showed poor memory performance when sources were manipulated to be highly similar to one another. However, as noted by Drummey and Newcombe (2002), such an accomplishment at this early age may actually be a reflection on the methodological procedures used to assess source memory, rather than a demonstration of actual competence. For example, procedures that rely on forced-choice recognition are likely to make source-monitoring judgments easier. Therefore, it is possible that the comparable performance observed between children and adults may actually reflect the nature of the specific task used.

Drummey and Newcombe (2002) proposed an alternative method to assess source memory in 4-, 6-, and 8-year-old children. They adapted the fictitious fact paradigm developed by Schacter and colleagues (1984) and modified it to be used with children. We chose to use this modified version of the fact paradigm because it assesses free verbal recall memory for fact and source information. In addition, this paradigm is advantageous because it allows for a follow-up forced-recognition option if children are unable to provide a recall response. Using this approach, Drummey and Newcombe were able to compare age-related changes in children's fact recall and fact ''knowledge,'' which they included as an aggregate of children's recall and recognition responses to fact information. The present investigation also used this approach.

EF and Source Memory

EF refers to higher-order cognitive processes (e.g., working memory, inhibitory control, set shifting) that organize and coordinate goal-directed actions (Miyake et al., 2000). Our study focused specifically on the role of EF in supporting source monitoring. Difficulties in source monitoring have been attributed to poorer EF in adults and children (Chastelaine, Friedman, & Cycowicz, 2007; Glisky, Polster, & Routhieaux, 1995; Ruffman, Rustin, Garnham, & Parkin, 2001). Wheeler, Stuss, and Tulving (1997) argue that source monitoring may require EF abilities because source monitoring involves the use of strategic processes, such as performing complex attributions based on the qualitative characteristics of the memory record. Most of the research informing the link between EF and source-monitoring abilities has come from the adult and aging literature. These investigations have revealed that frontal-lobe factor scores on tasks of EF processes are generally associated with better performance on source memory tests (Davidson & Glisky, 2002; Dywan, Segalowitz, & Webster, 1998; Glisky, Rubin, & Davidson, 2001; Spencer & Raz, 1994) and lower rates of source memory errors, particularly lower false-alarm rates (Rubin, Van Petten, Glisky, & Newberg, 1999).

Using confirmatory factor analysis (CFA), Miyake et al. (2000) found that EF in adults clusters into three common components: mental set shifting, working memory, and inhibition. However, a different picture emerges in preschool children. Using CFA in a sample of children aged 2;3 to 6;0, Wiebe, Espy, and Charak (2008) found that a unitary model of executive control (i.e., a single executive control factor) best explained the structure of EF. Therefore, for our study, children participated in tasks assessing working memory, inhibitory control, and set shifting, and we used an EF composite to examine the role of a general executive control process in episodic memory formation.

Most studies have focused on the relation between individual EF components (i.e., working memory, inhibition, set shifting) and source-monitoring ability. When assessing the interrelations between these variables, a complicated picture emerges. For example, Ruffman et al. (2001) found that working memory was related to children's accuracy in source monitoring and that higher inhibitory control resulted in fewer source memory errors in 6-, 8-, and 10-year-old children. However, Drummey and Newcombe (2002) found no correlation between frontal-lobe function measures assessing EF skills (i.e., Wisconsin Card-Sorting Test [WCST]) and source memory performance in their sample of 6-year-old children. For 4-year-olds, source memory was correlated to WCST performance, but only in a subsample of children. EF skills have also been linked to individual differences in children's suggestibility and eyewitness testimony (Bruck & Melnyk, 2004), but these results have also found a mixed pattern. For example, some studies have found that greater inhibitory control is associated with fewer inaccuracies to free recall and yes/no misleading questions (Alexander et al., 2002) and greater resistance to false suggestions (Roberts & Powell, 2005), whereas other studies reported a nonsignificant relation between EF and suggestibility (Roebers & Schneider, 2005). However, most of these investigations focus on one single component of EF (e.g., working memory or inhibition) and have relied on a single task as an indicator of EF ability. The problem with identifying EF processes with a single task is that tasks are not process-pure and a direct one-to-one relation may not exist (Jacoby, 1991). In addition, this approach discounts the fact that EF skills are multifaceted. Thus, a novel approach in the present investigation is to incorporate the multiple dimensions of EF skills by including a variety of tasks assessing working memory, inhibitory control, and set shifting to examine the role of a general executive control process in source monitoring.

Overview of the Present Study

The purpose of our investigation was to assess the ability to recall factual information and correctly monitor the source of such information in a sample of 4- and 6-year-old children. These abilities were thought to be relevant to episodic memory, as tasks assessing free recall contain more episodic memory traces and source memory tasks provide an avenue for researchers to investigate the qualities that make a memory ‘‘episodic’’ in nature. Based on the relevant literature, the following hypotheses were made.

1. Age-related improvement on measures of fact memory and source memory will be observed. As we noted previously, recall memory shows more age-related improvement (Schneider & Pressley, 1997) and children’s source-monitoring abilities undergo a dramatic shift between 4 and 6 years of age (Drummey & Newcombe, 2002). Therefore, we hypothesized that 6-year-olds would recall more factual and source information than would 4-year-olds.

2. Tasks that recruit more episodic traces will depend on EF. As we mentioned previously, tasks assessing recall memory (in contrast to recognition memory) contain more episodic traces, depend more on encoding and retrieval strategies, and are thought to be more difficult in nature. Likewise, source memory judgments (an index of episodic memory) are also thought to be more demanding than recognition memory judgments because they require the retrieval of content-item information and matching of item–source pairs (Glisky et al., 2001). Thus, we hypothesized that EF would predict performance on tasks that recruit more episodic traces, specifically children’s fact recall and source recall performance. In contrast, responses that contained more item recognition questions (such as fact knowledge) would rely less on episodic traces and would not be related to children’s EF. We hypothesized that these associations would exist after controlling for other relevant variables, such as age and language ability.

METHOD

Participants

Twenty-six children aged 3 years 10 months to 4 years 3 months (3;10 to 4;3) (11 boys, 15 girls; 25 Caucasian, 1 African American) and 26 children aged 5 years 9 months to 6 years 5 months

(5;9 to 6;57) (11 boys, 15 girls; 24 Caucasian, 2 African American) were participants in this study. Children were seen in the research lab 5 months before or after their respective birthdays. Children were eligible for participation if they were born within 4 weeks of their expected due date, experienced no prenatal or birth complications, were healthy and medication-free at the time of testing, and had no developmental or neurological diagnoses. Of the original sample, two 4-year-old children were excluded, 1 due to developmental diagnosis and the other due to refusal to play games. Thus, all analyses are reported on a sample of 50 children (4-year-olds, $n = 24$; 6-year-olds, $n = 26$).

Children were recruited using a database compiled from commercial mailing lists and e-mail contact via a local Working Mother's listserv. Recruitment letters were mailed to parents of eligible participants, and subsequent phone conversations took place with those interested in participation. During the phone conversations, specific details of the research design were further explained and a lab visit was scheduled. All parents had at least a high school diploma (mothers, 48% bachelor's degree, 42% graduate degree; fathers, 29% bachelor's degree, 49% graduate degree). Average maternal age was 35 years old (range = 27–44) and average paternal age was 38 years old (range = 26–54) at the time of the laboratory visit. As compensation for participation, children received a gift bag filled with arts and crafts supplies and parents were entered into a lottery drawing for one $50 gift certificate.

Procedure

Upon arrival to the research laboratory, signed parental consent and verbal child assent were obtained prior to the introduction of study procedures. The order of task administration was as follows: source memory encoding phase, EF tasks, and source memory test phase. All tasks were videotaped and later scored for accuracy. The parent was seated in the room with the child at all times.

Source memory task—encoding phase. This task was originally developed by Drummey and Newcombe (2002) for use with children and was adapted from the fictitious fact paradigm developed by Schacter and colleagues (1984). The source memory task was divided into two phases. The first phase was the source memory encoding phase in which children were taught a series of 10 novel and interesting facts. Each fact was presented by one of two sources, either the experimenter or a puppet (operated by a research assistant), both of which were introduced to the child at the beginning of the session.

For the source memory task, it was necessary that each fact presented to the child was a novel fact and that children had not learned these facts prior to the experimental session. To ensure these facts had not been encountered prior to the encoding phase, each fact was asked in the form of a question. This procedure allowed the experimenter to gauge each child's prior knowledge of the presented facts. For example, a child was asked the question, ''What do butterflies taste with?'' If an answer was not given, then it was assumed the child had no prior knowledge of this fact and the answer was provided to them: ''Their feet. Butterflies taste with their feet.'' If the child responded with a correct answer, however, then it was assumed the child learned the fact outside of the experimental situation. These trials were then discarded, and an alternative fact of equal difficulty was asked in its place. By choosing to present novel information of which children had presumably little prior knowledge, there were very few instances in which additional replacement questions were required. Out of the entire sample, only 10 children (one 4-year-old and nine 6-year-olds) required more than 10 facts to meet our criteria of 10 novel questions. This process continued until it was clear the child had been presented with a total of 10 novel facts, 5 from the experimenter and 5 from the puppet. Facts were presented from these sources in a blocked sequence (i.e., first 5 facts from one source, and second 5 facts from other source) rather than a random sequence, and the order of presentation was counterbalanced (Drummey & Newcombe, 2002). After 10 novel facts were presented, each fact was then repeated to the child in a random sequence by the same previous source.

Source memory task—test phase. After a delay of approximately 20 minutes, children's memory for the previously taught facts was tested along with their ability to correctly attribute the source from which this information came. During this test phase, children were presented with the 10 facts they previously heard during the source memory encoding phase, along with 5 novel facts that were intended to be of equal difficulty because it was presumed the children did not have prior exposure to these novel facts (e.g., ''What animal walks on its tippy toes?''). An additional 5 facts were also presented at test, but these questions were intended to be relatively easy for the child to answer (e.g., ''What do you use to brush your teeth?'') and were likely to be facts the child learned prior to the experimental session. Inclusion of these questions allowed for each child to provide some answers with relative ease and also allowed for a variety of source responses. Therefore, a total of 20 questions (10 old, 10 new) were asked during the test phase. All facts were presented in a random sequence.

For each test question, the procedure was as follows: First, the experimenter tested each child's verbal recall memory (i.e., fact recall) for each of the previously heard facts along with the novel and easy facts introduced at test. If a child answered the fact recall question correctly, then the source test question was administered. However, if a child failed to demonstrate fact recall (either by failing to produce a response or by answering incorrectly), a four-alternative forced-choice recognition test was given. The recognition question was administered to ensure that children would provide an answer to every trial and allowed for the follow-up source question to then be administered. Children were asked the follow-up source question regardless of how they answered the fact-recognition memory assessment (i.e., whether correct or incorrect). After this assessment of fact recall/recognition, children were then asked to recall how this information was learned and identify the source of this information (i.e., source recall) for all of the facts, including old and new, presented at test. If the child produced some type of source recall response (whether correct or incorrect), then the experimenter moved on to the next test question. Only if the child failed to provide a source response was a four-alternative forced-choice test given. In this case, children were instructed to choose from one of four options: the experimenter, the puppet, a parent, or a teacher. Prior to the administration of the test, children were given practice trials of sample questions similar to the ones given during test to ensure they understood the format of the test procedure. Practice trials were praised or corrected and testing only began once children demonstrated understanding of the task. The total administration for the test phase lasted approximately 10 min. The proportion correct was calculated as the dependent measure of interest for fact recall, fact knowledge (recall plus recognition), and source recall. The percentage of agreement between two coders for 20% of the sample was calculated, and interrater reliabilities ranged from .92 to 1.00.

EF tasks. Three EF tasks were administered during the delay period and each child received the tasks in the following order. First, set-shifting ability was assessed using the standard and border versions of the Dimensional Change Card Sort (DCCS; Zelazo, Muller, Frye, & Marcovitch, 2003). For this task, children were instructed to sort cards based on two different dimensions (i.e., color or shape). The order of the first sorting dimension (e.g., color first vs. shape first) was counterbalanced. Two sorting trays were used and contained target cards (i.e., a red flower and a blue car) affixed to the top of each tray that remained visible during administration of both versions of the sorting task. Test cards displayed the same shape but had colors opposite to the target cards (i.e., blue flowers and red cars). The experimenter began by teaching children a pair of rules based on the sorting game they were playing (e.g., shape game rules or color game rules). For example, if the task began with the ''color game,'' children were instructed that all the blue things go in the blue tray and all red things go in the red tray. Before the preswitch phase began, children were given two practice trials in which the experimenter sorted two test cards facedown in the appropriate tray to demonstrate the rules of the game.

After these demonstration trials, the preswitch phase of the sorting task began. During the preswitch phase, the child was randomly presented with seven test cards, with the constraint that the same card type was not presented on more than two consecutive trials. For each trial, the experimenter stated the relevant sorting rules, labeled each card by the relevant dimension, and had the child sort each card by asking, ''Where does this card go?'' Children were instructed to place the card facedown in the tray. No feedback was provided after sorting trials. After all seven preswitch trials were completed, children were then instructed to stop playing the color game and switch to the shape game. In the ''shape game,'' children were instruced that all flower things go in the flower tray and all car things go in the car tray. Seven postswitch trials were adminstered in an identical manner to the preswitch trial, with the exception that children were now told the rules for sorting according to the shape dimension. The proportion correct during the postswitch condition was used as the measure of interest. The percentage of agreement between two coders for 20% of the sample for the preswitch and postswitch versions of the standard DCCS task were 100% and 99%, respectively.

Children who passed the postswitch phase of the DCCS standard version were given a more difficult border version of the task, which has been administered in children ages 3 to 5 years old (Hongwanishkul, Happaney, Lee, & Zelazo, 2005). This was done to fully capture the developmental changes in set-shifting ability across our entire age range of interest. This version of the task contained two different types of test cards: ones that were identical to those used in the standard version and ones that were similar to those used in the standard version with the exception that they were surrounded by a black border. In the rules for the border version, the experimenter explained that if there is a black border on the card, the child must sort according to a particular game (e.g., ''If there is a black border, you have to play the shape game; if there is no black border, then you have to play the color game.''). The sorting dimension according to the black border was counterbalanced across all participants. Children were then administered 12 test trials, which were randomly presented to the child (with the constraint that no more than two consecutive cards of each type—border or nonborder—were presented). For each trial, the experimenter stated the rules, labeled the card according to the relevant dimension, and asked the child to sort each card facedown in the tray by asking, ''Where does this card go?'' No feedback was provided. The proportion correct was used as the dependent measure of interest. The percentage of agreement between two coders for 24% of the sample for the DCCS border version task was 99%.

Next, inhibitory control was assessed using the Day–Night Stroop-Like task, which has been been used as a measure of working memory and inhibitory control in 3.5–to 7-year-olds (Gerstadt, Hong, & Diamond, 1994) and more recently in older children aged 4 to 11 years old (Lagattutta, Sayfan, & Monsour, 2011). For this task, the child is presented with a series of cards (10 cm × 15 cm) containing two different pictures, either a yellow sun on a white background or a yellow moon and stars on a black background. The experimenter instructed the child to say ‘‘day’’ when shown the picture of the moon and stars and to say ‘‘night’’ when shown the picture of the sun. Two practice trials were administered to ensure the children comprehended the rules of the game, and children were either praised or corrected during these learning trials. Sixteen test trials were then administered, with eight sun cards and eight moon cards presented in a random order (with the constraint that cards of the same type were not presented on more than two consecutive trials). No feedback was provided during testing. A trial was considered correct if the child gave the correct verbal response as their only answer. A trial was considered incorrect if the child produced the wrong verbal response or if the child initially produced the wrong verbal response and self-corrected. The proportion correct was calculated as the measure of interest. The percentage of agreement between two coders for 20% of the sample for the day–night task was 99%.

Last, working memory was assessed using the Forward Digit Span Recall test. According to Garon, Bryson, and Smith (2008), the Forward Digit Span task can be classified as a simple working-memory task that can be administered to children 3 years and older. For this task, children were presented with a series of digits and were instructed to repeat the sequence in the same order (e.g., if a child heard the digit sequence ‘‘2 . . . 5 . . . 9,’’ they were instructed to repeat the same sequence, ‘‘2 . . . 5 . . . 9’’). Two practice trials, each containing a two-digit sequence, were given to ensure that the child understood the rules of the game. Following successful comprehension of the task rules, test trials commenced and always began with two digits. Children were required to recall the same digit sequence length for two trials (i.e., two trials using a two-digit sequence, two trials using a three-digit sequence, etc.). The experimenter lengthened the sequence by adding one extra digit to the series until the child erred on two consecutive trials. The highest span in which children could repeat the entire digit sequence in correct order was used as the variable of interest. The percentage of agreement between two coders for 31% of the sample for the Forward Digit task was 98%.

Language assessment. The Expressive Vocabulary Test (EVT) was administered to examine expressive vocabulary and word retrieval. The EVT consists of two types of items: labeling and synonyms (Williams, 1997). It has been normed for ages 2.5 through 90-plus years and is conormed with the Peabody Picture Vocabulary Test-Third Edition (Dunn & Dunn, 1997). The EVT is a nationally standardized instrument.

RESULTS

Descriptive statistics on the dependent variables of fact recall, fact knowledge (fact recall plus recognition; Drummey & Newcombe, 2002), and source recall for both 4- and 6-year-old children are presented in Table 1. Source recognition (source recall plus recognition) was not

TABLE 1
Descriptive Statistics for the Source Memory and EF Measures as a Function of Age

	4-Year-Olds				*6-Year-Olds*			
	M	SD	*Range*	n	M	SD	*Range*	n
Fact Recall	0.40	0.19	0.10–0.80	24	0.64	0.20	0.00–0.90	26
Fact Knowledge	0.74	0.15	0.40–1.00	24	0.92	0.12	0.50–1.00	26
Source Recall	0.49	0.23	0.00–0.80	24	0.75	0.22	0.10–1.00	26
Day–Night	0.66	0.30	0.00–1.00	24	0.83	0.15	0.31–1.00	26
Forward Digit	4.23	0.75	3.00–6.00	22	5.00	0.94	4.00–7.00	26
DCCS	0.64	0.48	0.00–1.00	22	0.88	0.31	0.00–1.00	26
DCCS Border	0.54	0.12	0.42–0.90	14	0.64	0.20	0.42–1.00	23
EF Composite	–0.38	0.65	–1.85–0.93	24	0.30	0.56	–0.61–1.56	26

Note. All values represent mean proportion correct, with the exception of Forward Digit (highest span) and EF composite (z-score aggregate).

included as a dependent measure because only 12 children (24% of the sample) required a follow-up source-recognition question, meaning that most children were able to produce a response during source recall. To compare the differences in item and source memory between 4- and 6-year-old children, independent-samples t-tests were conducted. As predicted, 6-year-olds had a higher proportion of correct responses than did 4-year-olds on fact recall, $t(1, 48) = 4.47$, $p < .001$, fact knowledge, $t(1, 48) = 4.72$, $p < .001$, and source recall, $t(1, 48) = 4.16$, $p < .001$ (see Table 1). Taken together, these results indicate that 4-year-old children are worse at both recalling fact information and attributing the source of such information. When comparing the types of source-monitoring errors produced at test, children were more likely to commit intraexperimental errors ($n = 38$) compared with extraexperimental errors ($n = 15$).

Pearson correlations were calculated between the dependent measures of fact recall, fact knowledge, and source recall with EVT standard scores for each age group. As predicted, expressive language ability was correlated with fact recall (4-year-olds, $r[22] = .53$, $p = .007$; 6-year-olds,-$r[24] = .65$, $p < .001$), fact knowledge (4-year-olds, $r[22] = .51$, $p = .011$; 6-year-olds, $r[24] = .65$, $p < .001$), and source recall (4-year-olds, $r[22] = .50$, $p = .014$; 6-year-olds, $r[24] = .50$, $p = .009$).

As previously mentioned, our measures of working memory, inhibitory control, and set shifting tap into a common EF construct. Therefore, due to the conceptual relations among our EF measures, scores on the Day–Night Stroop task, the Forward Digit Span task, the standard DCCS, and the DCCS border version were aggregated into a single EF composite score. This was done by first converting the raw scores of these variables into standardized z-scores and then taking the mean of these z-scores to create a composite EF score. To retain as much data as possible, if children were missing data from one or two EF tasks, their composite score was aggregated based on data from the other available tasks. For 35 children, the EF composite score represents an aggregrate of all four EF measures. Eleven children failed to pass the learning criterion for the DCCS border version and 2 children refused to participate in the Forward Digit Span task; thus, the EF composite score for these children represents an aggregate of the remaining three EF measures. Two children failed to pass the learning criterion for both the standard and border versions of the DCCS task; thus, their EF composite score represents an aggregrate of two EF measures. Table 1 displays the means and standard deviations for each EF measure and for the composite EF score by age group.

To determine the amount of variance in children's fact recall, fact knowledge, and source recall performance explained by age, language, and EF, a series of hierarchical regressions was performed for all three dependent measures. We were particularly interested in determining whether EF would uniquely predict the variance explained in children's fact recall, fact-knowledge, and source recall performance, above and beyond the contribution of age and language.

Table 2 provides the results from the regression analyses predicting fact recall. Taken together, the variables of age, language, and EF account for 58% of the variance in children's fact recall performance. The first step in the model included age as the predictor variable. In this model, age accounted for 29% of the variance in fact recall performance (Table 2, Step 1). Model 2 included age and EVT standard scores as the first and second predictor variables, respectively. Language ability accounted for an additional 25% of the variance in fact recall performance (Table 2, Step 2). Model 3 included age, language, and EF as the first, second, and third predictor variables, respectively. Above and beyond the contributions of age and language ability, EF accounted for an additional 4% of the variance in fact recall performance (see Table 2, Step 3).

Table 3 provides the results from the regression analyses predicting fact knowledge (fact recall plus recognition). Age, language, and EF accounted for 57% of the variance in performance. In Model 1, 32% of the variance in fact knowledge was accounted for by age (Table 3, Step 1). In Model 2, language ability accounted for an additional 22% of the variance in performance (Table 3, Step 2). Although Model 3 was signficant (explaining 57% of the variance), the inclusion of EF did not contribute unique variance. However, age and language retained a significant contribution to fact-knowledge performance (see Table 3, Step 3).

Table 4 provides the results from the regression analyses predicting source recall. Taken together, age, language, and EF accounted for 51% of the variance in performance. In Model 1,

TABLE 2
Regression Analysis Investigating Age, Language, and EF as Predictors of Fact Recall

	R	R^2	$R^2\ \Delta$	F Δ	F	β	t
Dependent Variable: Fact Recall							
Step 1: Age							
Model 1							
Age	.54	.29	.29	19.94^{**}	19.94^{**}	.54	4.47^{**}
Step 2: Age and EVT							
Model 2							
Age	.74	.54	.25	25.53^{**}	27.83^{**}	.61	6.13^{**}
EVT						.50	5.05^{**}
Step 3: Age, EVT, and EF							
Model 3							
Age	.76	.58	.04	4.14^{*}	21.17^{**}	.48	4.16^{**}
EVT						.43	4.15^{**}
EF						.24	2.03^{*}

$^{*}p < .05$. $^{**}p < .01$.

TABLE 3
Regression Analysis Investigating Age, Language, and EF as Predictors of Fact Knowledge

	R	R^2	R^2 Δ	F Δ	F	β	t
Dependent Variable: Fact Knowledge							
Step 1: Age							
Model 1							
Age	.56	.32	.32	22.29*	22.29*	.56	4.72*
Step 2: Age and EVT							
Model 2							
Age	.74	.54	.22	22.93*	27.70*	.63	6.30*
EVT						.48	4.79*
Step 3: Age, EVT, and EF							
Model 3							
Age	.75	.57	.03	2.66	20.00*	.52	4.45*
EVT						.42	3.97*
EF						.20	1.63

*$p < .05$.

age accounted for 26% of the variance in performance (Table 4, Step 1). In Model 2, language ability accounted for an additional 18% of the variance in performance (Table 4, Step 2). In Model 3, EF accounted for an additional 7% of the variance in performance (see Table 4, Step 3).

Although we focused on the multifaceted nature of EF skills in early childhood by investigating a composite of its individual components (i.e., working memory, inhibitory control, and set shifting), it is important to determine whether this composite approach affords more predictive power compared with analyzing the relation between each individual EF measure and item and source memory. Thus, we also analyzed the contribution of each individual EF score on item- and source memory performance in separate regressions. For working memory, separate

TABLE 4
Regression Analysis Investigating Age, Language, and EF as Predictors of Source Recall

	R	R^2	R^2 Δ	F Δ	F	β	t
Dependent Variable: Source Recall							
Step1: Age							
Model 1							
Age	.51	.26	.26	17.26**	17.26**	.51	4.16**
Step 2: Age and EVT							
Model 2							
Age	.67	.45	.18	15.59**	19.05**	.57	5.24**
EVT						.43	3.95**
Step 3: Age, EVT, and EF							
Model 3							
Age	.72	.51	.07	6.09*	16.10**	.40	3.24**
EVT						.33	3.01**
EF						.31	2.47*

*$p < .05$. **$p < .01$.

regressions were performed for fact recall, fact knowledge, and source recall with age, language, and Forward Digit Span performance entered, respectively. Age and language were significant predictors across all dependent measures, so we will focus on the contribution of the individual EF measure. Working memory did not uniquely predict variance in fact recall, $R^2\ \Delta = .009$, $F\Delta = 0.940$, $p = .337$; fact knowledge, $R^2\ \Delta = .006$, $F\Delta = 0.559$, $p = .459$; or source recall, $R^2\ \Delta = .000$, $F\Delta = 0.002$, $p = .965$. For inhibitory control, Day–Night Stroop task performance was entered as the third step after controlling for age and language. Inhibitory control did not uniquely predict variance in fact recall, $R^2\ \Delta = .014$, $F\Delta = 1.45$, $p = .234$, or fact knowledge, $R^2\ \Delta = .005$, $F\Delta = 0.457$, $p = .503$. However, for source recall, inhibitory control uniquely predicted the variance in performance, $R^2\ \Delta = .057$, $F\Delta = 5.253$, $p = .027$. Lastly, for set shifting, DCCS standard performance and DCCS border performance were entered as the third and fourth steps in the regression equation, respectively. These set-shifting measures were not unique predictors of fact recall, $R^2\ \Delta = .069$, $F\Delta = 2.374$, $p = .109$; fact knowledge, $R^2\ \Delta = .018$, $F\Delta = 0.529$, $p = .594$, or source recall, $R^2\ \Delta = .032$, $F\Delta = 1.236$, $p = .304$.

DISCUSSION

The purpose of our study was to explore source memory development in early childhood, specifically focusing on a cross-sectional comparison of source-monitoring ability among children aged 4 to 6 years old. Previous investigations examining the developmental trend of source memory have noted significant improvements in source-monitoring ability between these two ages in early childhood (Drummey & Newcombe, 2002; Lindsay et al., 1991). We were also interested in exploring whether the variation in children's performance on tasks that recruit the use of more episodic traces (such as fact recall and source recall) could be uniquely predicted by children's EF, above and beyond the variation that would be accounted for by age and language ability.

Our results replicated the findings of Drummey and Newcombe (2002); 4-year-old children performed worse than 6-year-old children on measures of fact recall, fact knowledge, and source recall. It is important to mention, however, that in our sample, children's proportion of correct responses on fact recall, fact knowledge, and source recall were higher than those reported by Drummey and Newcombe. The reason for this discrepancy can be attributed to the fact that the Drummey and Newcombe source memory protocol implemented a 1-week delay between encoding and testing phases. It could be possible that this 1-week delay between testing periods accounted for a higher occurrence of source memory errors because it allowed for greater interference or intrusion between multiple sources. When analyzing the nature of source memory errors in the present study, children were more likely to commit intraexperimental errors by misattributing the sources within the experiment (confusing experiment and puppet sources) and were much less likely to attribute the facts to an outside source, such as a parent or teacher. Despite these discrepancies brought by using a shorter delay period, the overall pattern of findings and general direction of results matches those observed by Drummey and Newcombe.

Our next aim was to explore the role of other cognitive processes, namely EF, in supporting episodic memory performance. Given that age-related differences in children's fact recall, fact knowledge, and source recall performance were observed in our sample, we predicted that age would significantly predict performance on all three dependent measures. We also hypothesized that children's language ability would be related to all three dependent measures of interest, as the source memory task used in our study is highly dependent on children's ability to produce a verbal response. Above and beyond these contributions of age and language, however, we predicted that children's EF would uniquely explain the variation in performance on tasks relevant to episodic memory ability, specifically predicting performance on fact recall and source recall.

Age, language ability, and EF accounted for 58% of the variance in children's fact recall performance and 51% of the variance in children's source recall performance. For both fact recall and source recall, the majority of this variance was captured by age and language. However, EF still captured a unique proportion of the residual variance in fact recall and source recall. In contrast, only age and language ability uniquely predicted children's fact knowledge. Thus, for children's fact knowledge, which contained more responses based on forced-choice recognition questions, EF was not associated with performance.

Our findings suggest a link between episodic memory and EF. Being able to correctly monitor the origin of information and being able to link content information to the correct context requires conscious working memory-dependent strategies. To elaborate, Davidson and Glisky (2002) posit that EF may be linked to contextual memory by supporting integration of item and source information during encoding. In the present investigation, it may be the case that children with better EF skills are more efficient at spontaneously integrating item and source information together during encoding, resulting in a better bound representation of the event. To elaborate, research investigations have established that *binding,* which refers to the process that encodes the relations among separate stimuli into a cohesive unit, is important for retaining the contextual details of a memory episode (Chalfonte & Johnson, 1996; Sluzenski, Newcombe, & Kovacs, 2006). When binding processes are disrupted during encoding, source memory becomes compromised. For example, Mather et al. (2006) found that using emotionally arousing content disrupted binding processes in adults, resulting in poorer source memory for item–location pairs during high-arousal trials. Failures in feature binding may result in incomplete episodic memory representations. Thus, the development of binding processes may play a role in supporting source-monitoring ability.

EF may also support episodic memory by guiding retrieval processes. Children with better EF skills may be more efficient at engaging in search and monitoring processes at test, and may be better at retrieving the correct pair of item and source information or more efficient at making a decision regarding whether the match that is retrieved is correct or not. Conversely, better EF skills are also related to the ability to avoid making source memory errors. Ruffman et al. (2001) found that *avoiding* making false-alarm errors (i.e., incorrectly attributing a new item as old) benefited from greater inhibitory control. The relation to inhibitory control makes sense, given that source monitoring requires the individual to correctly distinguish and inhibit feelings of familiarity generated from the experimental context in favor of the relevant aspects of the memory episode. Therefore, these component search and decision processes are likely to depend on EF (Davidson & Glisky, 2002).

In contrast, children's fact-knowledge performance was not associated with EF. As previously mentioned, fact knowledge contained children's recognition-memory responses. Compared with recall and source memory, recognition-memory judgments may be less cognitively taxing because the demands for this type of judgment rely on recognizing the content of an item (e.g., the fact that was previously heard) in the midst of having available cues (e.g., recognizing the answer to a fact by discriminating it from multiple choices). Therefore, recognition-memory judgments can be made in the absence of contextual information and recollection, and can be based on familiarity (Glisky et al., 2001), thus limiting the engagement of executive control processes. We find it important to note, however, that these results should be interpreted with caution, given that 6-year-old children's fact-knowledge performance was close to ceiling levels, thus restricting the amount of meaningful variance.

Recall memory, on the other hand, requires participants to freely reproduce previously studied information in the absence of perceptually available cues and places a greater demand on postretrieval processes (Cabeza et al., 1997; Haist, Shimamura, & Squire, 1992). In adults aged 18 to 90 years old, McCabe, Roediger, McDaniel, Balota, and Hambrick (2010) found that working-memory capacity and EF predicted episodic memory as assessed by immediate free recall of verbal information. Similarly, source memory judgments are almost always more demanding than item recognition judgments because they not only require the retrieval of content item information, but also require the successful matching, or binding, of item–source pairs rather than the retrieval of item information alone (Glisky et al., 2001). For example, source memory judgments require binding the fact that you learned that butterflies taste with their feet to the contextual details of which specific individual—either the puppet or the experimenter—taught you this piece of information. From this perspective, it is reasonable to conclude that EF may be more closely related to fact recall and source recall ability and less associated with memory judgments based on recognition-memory processing.

We propose that future developmental investigations should explore how EF supports the development of episodic memory. Successful recollection of contextual details relies on shifting attention to relevant features, integrating information during encoding, searching and reactivating information from a memory trace, and evaluative decision-making processes at test. All the processing involved in searching and monitoring the origin of information may be dependent on EF and offer one potential explanation as to why difficulties in source monitoring are evident early in development.

Future investigations should explore the role of neural maturation in supporting source-memory development. Both the hippocampus and prefrontal cortex regions of the brain are involved in episodic memory (see Raj & Bell, 2010, for a review). EF processes, in particular, follow a protracted course of development and have been linked to prefrontal brain areas, which also exhibit delayed maturation through childhood and young adulthood (Casey, Giedd, & Thomas, 2000; Chugani, 1994, 1998; Chugani & Phelps, 1986; Diamond, 2002; Huttenlocher, 1979; Jernigan et al., 1991; Sowell et al., 2003). Developmental studies using functional neuroimaging methodology (e.g., functional magnetic resonance imaging) have documented activation of prefrontal cortex brain regions during tasks of episodic memory. Specifically, Ofen et al. (2007) examined recollection and familiarity-based processing in 8- to 24-year-olds and found that reliance on recollection-based processing increased with age and was associated with age-related increases in activation of dorsolateral prefrontal cortex regions. Thus, it is likely that developmental improvements in episodic memory are linked to maturation of the prefrontal cortex areas that support EF abilities.

Interestingly, Drummey and Newcombe (2002) examined whether frontal-lobe functioning was related to source monitoring and found inconclusive results. Certain frontal-lobe functioning tasks, such as the WCST, were related to source memory errors but only within a subsample of

4-year-old children. When comparing the entire sample of 4-year-olds, the authors found no correlation between prefrontal measures (WCST and Day–Night Stroop task) and source memory. As noted by the authors, this lack of an association may be related to a problem in measurement of tasks designed to tap into frontal-lobe functioning. It may be the case that the present study found a link to prefrontal-dependent EF measures and episodic memory because we used a comprehensive composite of EF that included the abilities of working memory, inhibitory control, and set shifting into one factor. Relying on a single task as an indicator of EF is problematic as no task can be process-pure and this approach discounts the multifaceted nature of EF. Indeed, our results suggest that a composite measure of EF has greater explanatory power compared with separately analyzing each individual EF measure.

Although the results of our study provide promising insight into source memory development in early childhood, several caveats should be noted. First, the generalizability of these findings is rather restricted, as most participants were European Caucasian and had older and well-educated parents. Therefore, the homogeneity of the participant population is one limitation that restricts the application of these results to this particular demographic population. In addition, our study design was administered in such a way that children's EF skills were assessed prior to the source memory test phase, and it is possible that our order of task administration influenced the observed age differences in memory performance. To clarify, it may be that the benefits of engaging in these executive processes prior to the source memory test phase could have differentially transferred to older children, who could better take advantage of working-memory and response inhibition skills during source retrieval. Although it is beyond the scope of the present article, this raises the possibility that engaging in EF tasks could transfer to other cognitive domains, such as episodic memory. Ranganath, Flegal, and Kelly (2011) discuss the possibility that cognitive ability training on executive skills, such as working memory, may serve as a successful intervention for improving episodic memory. Unfortunately, as the authors note, very little empirical evidence exists to support these claims.

Another limitation of this study is that statements about the development of source monitoring ability in early childhood must be interpreted with caution, because the data within our study are cross-sectional. To fully understand the developmental trends that occur in source-monitoring ability during the early childhood period, it is necessary for future investigations to employ a longitudinal technique. Although a shift in source-monitoring ability was evident between 4 and 6 years of age in the present study, performance was far from ceiling levels. Thus, it may be the case that more time is needed before adult levels of performance are achieved. Given that both source-monitoring skills (Chastelaine et al., 2007; Ghetti, DeMaster, Yonelinas, & Bunge, 2010) and EF skills (Best, Miller, & Jones, 2009; Garon et al., 2008) continue to develop from childhood to adolescence, our restricted focus on early childhood is another limitation to this study. However, using our present sample, we are currently conducting a longitudinal follow-up source memory and EF assessment at 6 and 8 years old and plan to examine the development of source memory skills in late childhood and adolescence in future investigations.

It should be noted that the relationship between source memory and age is quite complex and the development of source memory skills is not necessarily linear (Roberts, 2002). In some situations, young preschool-aged children can demonstrate competence on external source-monitoring judgments (e.g., distinguishing between memories of self-performed vs. other-performed actions) but experience difficulty with internal source monitoring (e.g., distinguishing between memories of imagined self-generated actions and performed actions; Foley & Johnson, 1985; Welch-Ross, 1995). Children's source-monitoring skills are also affected by the nature of the task. For example, when tested nonverbally, 3- and 4-year-old children are able to discriminate between memories of performed versus imagined actions (Roberts & Blades, 1995) and children make fewer source errors when allowed to freely recall events compared with answering individual questions (Roberts & Blades, 1998, 1999). Thus, although the present investigation found age-related differences on a free verbal recall test of external source memory, it is possible that these findings may be task-specific and may not generalize to other tests of source memory. Taken together, these research investigations seem to suggest that source memory should not be conceptualized as a single skill that can be acquired abruptly at one specific period in development. Rather, it is more appropriate to view source memory development as gradual and situation-specific (Lindsay, 2002; Roberts).

In trying to obtain a complete picture of the developmental changes and variability in children's source monitoring, a number of other factors may be involved. For instance, age-related changes may be due to increases in children's use of retrieval strategies and reasoning processes when trying to complete a source memory judgment. The development of mnemonic strategies and metamemory operations may also contribute to improvements in episodic memory (Ghetti, Lyons, Lazzarin, & Cornoldi, 2008; Ghetti, Papini, & Angelini, 2006). Language has also been found to facilitate the encoding and expression of memories. As children's own productive language skills increase, they are better able to describe past events (Simcock & Hayne, 2002, 2003). More elaborate verbal cues provided by adults in an imitation paradigm facilitate memory performance after long delays (Hayne & Herbert, 2004), and the narrative styles exhibited by parents influence children's verbal reports about past events (Nelson, 1993; Nelson & Fivush, 2004). Although we attempted to control for children's verbal ability in the present investigation, we acknowledge that children's expressive vocabulary also accounted for a significant proportion of the variance in children's fact and source-recall memory (25% and 18%, respectively). Thus, children's early language abilities may influence the organization and elaboration of episodic memory. Future investigations should seek to incorporate both verbal and nonverbal indexes of episodic memory (Hayne & Imuta, 2011) to understand how language may facilitate early episodic memory development.

Developmental differences in children's source memory may also be linked to immature development of medial-temporal and frontal-lobe brain structures, as previous investigations have found that both the hippocampus and the prefrontal cortex regions of the brain are important for the functioning of episodic memories (Raj & Bell, 2010). It is important to note, however, that some developmental researchers have discounted the role that neural maturation plays in explaining age-related variance in memory and metamemory processes (i.e., knowledge, control, and monitoring of memory functioning). Ceci, Fitneva, and Williams (2010) argue that changes in representational abilities are the primary contributing factor to growth in memory and metamemory performance, rather than prefrontal cortex maturation. We acknowledge that without the incorporation of functional neuroimaging techniques, our interpretations about the role of neural maturation should be met with caution. As noted by Newcombe et al. (2007), researchers have yet to determine the level of maturation needed to support episodic memory processes. Future investigations should explore the role of these cognitive and brain-behavior processes to obtain a more complete picture about the emergence of such an important memory system responsible for connecting separate events into a cohesive whole and establishing a unique sense of autobiography to events from our past.

ACKNOWLEDGMENTS

The research reported here represents a portion of the first author's master's thesis research. She would like to thank her thesis committee members (Kirby Deater-Deckard and Kee Jeong Kim) for their input on this project. We are grateful to the families for their participation. We wish to thank Annie Cardell, Anjolii Diaz, Katherine Morasch, and Lena Polejaeva for help with data collection and Candace Hummer and Tara Rupard for assistance with coding.

This research was supported by Grant HD049878 from the Eunice Kennedy Shriver National Institute of Child Health and Human Development (NICHD). The content of this manuscript is solely the responsibility of the authors and does not necessarily represent the official views of the NICHD or the National Institutes of Health.

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