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ARTICLE

Elicited Imitation Performance at 20 Months Predicts Memory Abilities in School-Aged Children

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During the first decade of life, there are marked improvements in mnemonic abilities. An important question from both a theoretical and applied perspective is the extent of continuity in the nature of memory during this period. The present longitudinal investigation examined declarative memory during the transition from toddlerhood to school age using both experimental and standardized assessments. Results indicate significant associations between immediate nonverbal recall at 20 months (measured by elicited imitation) and immediate verbal and nonverbal memory (measured by standardized and laboratory-based tasks) at 6 years in typically developing children. Regression models revealed this association was specific, as measures of language abilities and temperament were not predictive of later memory performance. These findings suggest both continuity and specificity within the declarative memory system during the first years of life. Theoretical and applied implications of these findings are discussed.

Since the 1980s, researchers have utilized nonverbal imitation-based paradigms to characterize the development of memory processes during infancy and toddlerhood. In these paradigms, an adult researcher demonstrates a sequence of novel actions using props, and the participant is

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invited to imitate the actions modeled by the researcher either immediately (elicited imitation), after a prescribed delay (deferred imitation), or both. Successful imitation is taken as behavioral evidence of memory for the action sequence. This technique is generally accepted as a nonverbal analogue to declarative memory report (Bauer, 2006; Bauer, DeBoer, & Lukowski, 2007; Carver & Bauer, 2001; McDonough, Mandler, McKee, & Squire, 1995). However, to date, longitudinal relations between elicited imitation performance and memory abilities at school age have not been documented. Thus, it remains unknown whether performance on behavioral imitation tasks early in life is related to memory abilities later in life. The present study was designed to address this question.

The relation between early and later memory performance is important for at least two reasons. First, issues of continuity/discontinuity are core in developmental science. In the domain of memory, it has been suggested that because of phenomena such as infantile amnesia (i.e., the lack of personally relevant episodic memories from the first 2 years of life), memory early in life is qualitatively different from memory later in life (e.g., Neisser, 1962; K. Nelson, 1992; Pillemer, 1998; Pillemer & White, 1989; Wheeler, 2000; see C. A. Nelson, 1995, for elaboration). However, empirical research has produced compelling data that young children are able to verbally report on events they experienced prior to the onset of language (Bauer, Kroupina, Schwade, Dropik, & Wewerka, 1998; Bauer & Wewerka, 1995, 1997; Morris & Baker-Ward, 2007). Importantly, this subsequent verbal recall has been shown to be unrelated to the child's language abilities at the time of the event, which suggests that a memory encoded without the benefit of language can be accessible to verbal report later in life (Cheatham & Bauer, 2005; but see Cleveland & Reese, 2008, and Simcock & Hayne, 2002, 2003, for evidence that language at encoding does play a role in young children's verbal memory). Although the transition to verbal memory is fragile and evidence from other studies suggests this process is easily disrupted (Morris & Baker-Ward, 2007), these findings imply some continuity between early and later memory processes (Bauer, 2005; Howe & Courage, 1997; C. A. Nelson).

Second, children's memory abilities are related to their school success and general cognitive development. For example, memory abilities are associated with reading abilities in children (Schneider & Näslund, 1993) and in adolescents with and without learning difficulties (Mirandola, Del Prete, Ghetti, & Cornoldi, 2011). Thus, from an applied perspective, understanding of relations between early and later memory abilities is important, particularly because research consistently shows that the key to altering the course of development lies in implementing intervention strategies as early as possible (Ramey & Ramey, 1998). If early and later memory processes are *un*related, a lower limit would exist as to how early deficits could be identified and interventions initiated in children at risk for memory impairment. Conversely, continuity between early nonverbal mnemonic abilities and later abilities would motivate earlier intervention.

The elicited/deferred imitation paradigm has been used extensively to characterize the course of typical memory development from infancy through toddlerhood. Beginning as early as the 6th month of life, infants are able to recall individual actions for 24 hours (Barr, Dowden, & Hayne, 1996; Collie & Hayne, 1999), albeit only after six exposures. By 9 months of age, infants can recall actions for up to 5 weeks (Carver & Bauer, 1999, 2001). Ten-month-olds recall after delays of 3 months (Carver & Bauer, 2001; Mandler & McDonough, 1995), 14-month-olds recall after delays of 4 months (Meltzoff, 1995), and 16-month-olds recall after delays of 6 months (Bauer, Wenner, Dropik, & Wewerka, 2000). Ordered recall is exhibited more reliably after 13 months of age, although individual differences in ordered recall are dependent on both the length of delay and degree of cognitive challenge (Bauer et al., 2000). The number of exposures necessary for successful ordered recall drops to one by 14 months of age (Meltzoff, 1995). Together these studies map the development of a memory system that early on requires repeated exposures and shorter delays for successful recall. As development progresses, the system becomes more established and ordered recall becomes less challenging. Thus, the declarative memory system begins to be evidenced at 6 months of age, and by 20 months, recall abilities as tested by this paradigm are robust and reliable (see Bauer, 2007, for a review).

The elicited/deferred imitation paradigm has also been used to identify differences in memory abilities in infants and toddlers at risk for impairment due to a variety of conditions (each with their own distinct underlying mechanisms/pathophysiology), including preterm birth, prenatal iron deficiency, maltreatment, and institutional rearing (see Bauer, 2010, for recent review). These studies suggest that compared with standardized measures (e.g., Bayley Scales of Infant Development; Bayley, 1993), behavioral imitation paradigms provide increased specificity regarding the nature of cognitive impairments early in life (e.g., DeBoer, Wewerka, Bauer, Georgieff, & Nelson, 2005) and can identify at-risk children when standardized assessments fail to do so (e.g., Cheatham, Bauer, & Georgieff, 2006). Such specific, early identification is an essential first step toward early intervention when chances are better that developmental trajectories can be altered (Ramey & Ramey, 1998). Although these findings from applied settings are promising, their impact remains limited because these samples have not been followed longitudinally into the school-aged years, and thus, long-term outcomes remain unknown.

One previous study has examined associations between deferred imitation at 9 months and general cognitive abilities at 4 years in a typically developing sample (Strid, Tius, Smith, Meltzoff, & Heimann, 2006). This study reported a marginal correlation between 10-minute deferred imitation of single actions and overall performance on the McCarthy Scales of Children's Abilities (collapsed across Verbal, Perceptual, Quantitative, Motor, and Memory subscales). This finding suggests early memory abilities may be related to later global cognitive ability, but no relation was observed for the Memory subscale alone (which measured immediate recall of words, numbers, pictures, and tonal sequences). The Memory subscale on the McCarthy Scales differs substantially from the deferred imitation paradigm administered, which required infants to behaviorally recall single actions performed on objects (e.g., pressing a button on a box to produce a beeping sound). Thus, although it is possible that early memory abilities were not related to later memory abilities (despite being related to global cognitive ability), it is also possible that the lack of association between imitation performance and later memory measures was due to differences in: 1) the format of the assessments (behavioral vs. verbal recall); 2) the content of the to-be-remembered information (visual/motor vs. verbal/auditory); 3) the delay over which the information needed to be retained (10 minutes vs. immediate); 4) the young age of infants when the imitation task was administered (i.e., at 9 months there is very high variability in infants' elicited imitation performance; see Bauer, 2006, 2007), or 5) a combination of these and other factors.

In the current study, we examined associations between imitation of action sequences at 20 months (when performance is reliable and robust) and a battery of memory measures at 6 years of age in typically developing children. Specifically, the follow-up memory measures included a task that is very similar to the imitation paradigm (referred to as a ''non-standardized/laboratory-based imitation sequencing task'') as well as a commercially available and standardized memory assessment (Children's Memory Scale [CMS]; Cohen, 1997), which provides indices of immediate and delayed recall for both verbal and visual stimuli. We hypothesized that imitation performance at 20 months of age would predict performance on both laboratory-based and standardized memory measures at 6 years of age. An exploratory question was whether imitation performance (i.e., a behavioral measure of memory for action sequences) would predict memory for verbal, visual, or both types of stimuli.

Finally, to address the specificity of these associations, we also examined whether other cognitive abilities (i.e., language) and social factors (i.e., temperament) as measured at 20 months would predict later memory abilities. We hypothesized they would not.

METHOD

Participants

Seventy-five participants were initially recruited from a list of families who indicated interest in participating in research; 36 (17 female, 19 male) were available for the follow-up assessment 5 years later.[1] The sample was recruited from middle- to upper middle-class suburbs surrounding a large Midwestern university in the United States. Participants reported the following racial decent: 86% Caucasian, 5% Asian/Caucasian, 3% African American/Caucasian, 3% American Indian/Alaskan Native & Caucasian, and 3% Undisclosed. Data from one male were not included due to a diagnosis of autism spectrum disorder. Mean age of the children at Wave 1 was 1 year, 8 months ($SD = 0.89$ months), and at Wave 2, it was 6 years, 7 months ($SD = 2.69$ months). In accordance with the American Psychological Association's guidelines for ethical treatment of human participants, parents provided written informed consent for their children to participate, and all procedures were approved prior to the start of the investigation by the university's institutional review board.

Materials

Twenty-month assessment. At 20 months of age, children were tested on eight four-step sequences, the temporal orders of which were constrained by enabling relations. Enabling relations exist when certain actions must be completed sequentially for the desired end-state to be realized (e.g., Bauer, 1992; Bauer & Mandler, 1989; Wenner & Bauer, 1999). To increase the generalizability of the findings, half of the sequences were demonstrated three times and half were demonstrated only once (exposure sessions were 1 week apart). To assess abilities in another cognitive domain (i.e., language), parents completed the MacArthur-Bates Communicative Development Inventory for Toddlers (CDI; Fenson et al., 1994) by indicating the words their children produced. Responses to these questionnaires yielded a total score that was converted to a standardized percentile score based on age and gender. To assess other social characteristics of the child (i.e., temperament), parents completed the Toddler Behavior Assessment Questionnaire

[1]To determine if there were differences in memory performance between the toddlers who were available for follow-up and those who were not, one-way analyses of variance were conducted on variables indicative of memory performance. No significant differences in memory performance were identified (all $ps > .54$).

(TBAQ; Goldsmith, 1996) by indicating how often their child behaved in certain ways during the past month in a variety of situations (using a 7-point scale ranging from 1 = *never* to 4 = *about half the time* to 7 = *always*, with the opportunity to indicate that the situation did not apply). Responses to these items result in five independent dimensions of temperament: 1) Activity Level, 2) tendency to express Pleasure, 3) Social Fearfulness, 4) Anger Proneness, and 5) Interest/Persistence.

Six-year assessment. At age 6 years, a non-standardized/laboratory-based imitation sequencing task was administered. This provided a behavioral measure of memory abilities using a modified version (no learning trials) of the nine-item picture-sequencing task (see Weintraub et al., 2013; Bauer, Leventon, & Varga, 2012; Zelazo & Bauer, in press, for a similar paradigm) that was designed to be as similar as possible to the traditional elicited imitation paradigm used with toddlers, yet age-appropriate for school-aged children. In short, nine pictures of objects associated with a common theme (e.g., playing at the park) were laid out on a table one at a time with verbal narration (e.g., ‘‘catch the butterfly,’’ ‘‘throw the Frisbee,’’ ‘‘feed the duck’’). Each sequence was shown only once. Relations between items in the sequence were arbitrary. Following presentation of the pictures, the experimenter collected, shuffled, and re-presented them to the children in a 3×3 grid. Children were asked to reconstruct the sequence. In addition, the CMS (Cohen, 1997) was used as a standardized measure of memory abilities. The CMS is an individually administered, comprehensive assessment instrument designed to evaluate learning and memory functioning in children ages 5 through 16 years. It assesses functioning across three domains: Auditory/Verbal Learning and Memory (i.e., stories and word pairs), Visual/Nonverbal Learning and Memory (i.e., dot locations and faces), and Attention/Concentration (i.e., digit span, speed and accuracy of familiar sequences). From these subtests, the following index scores are derived: 1) General Memory Score; 2) Immediate and Delayed Verbal Memory Score; 3) Immediate and Delayed Visual Memory Score; 4) Delayed Recognition Memory Score; 5) Concentration Score; and 6) Learning Score. Children were also tested on two tests from the Woodcock-Johnson III (WJ-III; Woodcock, McGrew, & Mather, 2001) to assess processing abilities: Pair Cancellation and Visual Matching, both of which require children to search for certain items in an array emphasizing both speed and accuracy but do not involve memory per se. Because our focus was on predicting memory, language and temperament were not assessed at 6 years.

Procedure

Children were tested individually in a laboratory setting at both 20 months and 6 years of age. At Wave 1, all children participated in the elicited imitation paradigm (for similar protocol, see Bauer et al., 2000). Consistent with previous research, each of the eight test sequences consisted of: 1) a baseline measure (to control for general problem-solving skills and fortuitous production of the actions), 2) demonstration (i.e., modeling) of the event sequences with verbal labeling by the experimenter, and 3) immediate imitation with a verbal prompt. Following established procedures (Bauer et al., 2000), two dependent measures indicative of memory were derived: 1) production of individual target actions (max = 4), and 2) production of pairs of target actions in the correct temporal order (max = 3). Sessions were videotaped for later coding.

At Wave 2, children returned to the laboratory and completed the modified nine-item picture-sequencing paradigm (Weintraub et al., 2013; Bauer, Leventon, & Varga, 2012; Zelazo & Bauer, in press), the CMS (Cohen, 1997), and the two WJ-III tests (Woodcock et al., 2001). Administration of the nine-item picture-sequencing task was as similar as possible to that of the elicited imitation paradigm at Wave 1. That is, the experimenter first modeled the event sequence for the child with verbal labeling, and the child was subsequently given the opportunity to reproduce the sequence immediately or after a 10-minute delay. Production of two adjacent items in consecutive order served as the dependent measure of memory. Administration of the standardized assessments followed published guidelines, and dependent measures consisted of scaled scores.

Data coding and reduction. Videotapes of imitation sessions were coded by experienced coders who were unaware of the design and hypotheses of the study. Before coding study tapes, coders were required to achieve more than 90% reliability with master codes on three training tapes. Frequent reliability checks were made to ensure that any coder drift was detected and remedied immediately. Reliability was assessed on 25% of the sample with an average interrater reliability of 89.36% (range = 81.82%–97.30%).

RESULTS

Prior to analyses, all data were checked for inconsistencies, extreme values, and violation of assumptions. Data were normally distributed and values were within the range expected.

Twenty-Month Assessment

No differences were found between scores on events to which the toddlers were exposed once and those to which the toddlers were exposed three times. Thus, data were collapsed, and all analyses were performed on scores averaged across the entire session.

At 20 months of age, children's immediate recall of individual target actions was significantly greater than baseline performance, $t(34) = 22.89$, $p < .001$, as was their production of pairs of

TABLE 1
Descriptive Statistics for Measures at 20 Months of Age

Assessment	*Mean*	*SD*	*Minimum*	*Maximum*
Memory (Elicited imitation)				
Baseline				
Target actions	0.78	0.29	0.13	1.5
Pairs of target actions	0.12	0.12	0	0.5
Imitation				
Target actions	3.05	0.65	1.38	4
Pairs of target actions	1.79	0.55	0.5	2.63
Language (MacArthur-Bates CDI)				
Standardized percentile	55.03	34.19	5	100
Temperament (TBAQ)				
Activity Level	4.04	0.58	3	5
Pleasure	5.30	0.62	4	7
Social Fearfulness	3.93	0.88	2	5
Interest/Persistence	4.20	0.80	3	6
Anger Proneness	3.78	0.75	2	5

actions in the correct temporal order, $t(34) = 18.49$, $p < .001$, indicating robust recall for the sequences (Table 1). Scores on the MacArthur-Bates Vocabulary Scales and TBAQ were typical for this age group (Table 1). At the 20-month assessment, both the number of actions and pairs of actions produced in the correct temporal order, but not the number of actions produced at baseline, were correlated with ratings of Activity Level from the TBAQ, $r(33) = .40$, $p < .05$, $r(33) = .41$, $p < .05$, respectively. This is consistent with previous research indicating that characteristically high activity levels may be beneficial in behavioral imitation tasks (see Bauer, Burch, & Kleinknecht, 2002). No other temperament measures or language measures were correlated with performance on the elicited imitation task at 20 months (*r*s ranged between .05 and .30).

Six-Year Assessment

Descriptive statistics regarding performance on the tasks at 6 years (CMS, WJ-III, and the nine-item picture-sequencing task) are included in Table 2. The sum of scaled scores from the CMS fell within the typical range for this age group. None of the children's general memory index scores suggested memory impairment (Cohen, 1997). Measures of memory and speed of processing at 6 years were related to each other. Specifically, the General Memory Score from the CMS was significantly correlated with performance on both Pair Cancellation, $r(33) = .44$, $p < .01$, and Visual Matching, $r(33) = .57$, $p < .001$, tasks from the WJ-III. Performance on the nine-item picture-sequencing task was not correlated with the CMS or WJ-III.

Associations Between Memory Performance at 20 Months and 6 Years of Age

Correlational analyses were conducted between the dependent measures of memory performance at 20 months of age and measures of memory at 6 years. As indicated in Table 3, immediate

TABLE 2
Descriptive Statistics for Cognitive Measures at 6 Years of Age

Task	*Mean*	*SD*	*Minimum*	*Maximum*
CMS Sum of Scaled Scores				
General Memory	97.31	16.09	55	134
Visual Memory–Immediate	22.69	4.52	13	32
Visual Memory–Delayed	23.31	3.47	13	30
Verbal Memory–Immediate	25.83	5.46	13	38
Verbal Memory–Delayed	25.49	5.99	10	36
Delayed Recognition Memory	24.23	3.90	16	31
Attention/Concentration	22.29	4.55	14	30
Learning	24.11	4.85	14	34
Woodcock-Johnson III				
Pair Cancellation	32.09	9.33	19	53
Visual Matching	21.94	5.84	9	33
Nine-Item Picture Sequencing				
Adjacent Pairs–Immediate	4.17	2.22	1	8
Adjacent Pairs–Delay	3.11	1.91	0	8

TABLE 3
Correlations Between Elicited Imitation Performance at 20 Months of Age and Measures at 6 Years

	Tasks at 20 Months							
	Memory (elicited imitation)		*Language*			*Temperament*		
Task at 6 years	*Target actions*	*Ordered actions*	*MacArthur-Bates*	*Activity level*	*Pleasure*	*Social Fearfulness*	*Interest/ Persistence*	*Anger Proneness*
CMS								
General Memory	.39*	**.40***	.11	–.06	.11	–.29	.32	–.003
Visual Memory–Immediate	**.44****	**.47****	.15	.05	.15	–.24	.24	–.11
Visual Memory–Delayed	.10	.15	.03	–.16	–.10	.02	.18	–.09
Verbal Memory–Immediate	**.42***	**.42***	.05	.02	.15	**–.38***	**.38***	.14
Verbal Memory–Delayed	.28	.26	.12	–.12	.10	–.26	.22	.000
Delayed Recognition Memory	.24	.23	–.04	–.19	**.35***	–.17	.23	.08
Attention/Concentration	**.48****	**.47****	**.35***	–.09	.15	–.002	.27	–.23
Learning	**.42***	**.42***	**.34***	.01	.03	–.24	.27	–.31
Woodcock-Johnson III								
Pair Cancellation	**.46****	**.49****	.13	.27	.15	–.21	.19	.12
Visual Matching	**.52****	**.54****	–.03	.20	.24	–.12	.16	.08
Nine-Step Picture Sequencing								
Adjacent Pairs–Immediate	**.35***	**.41***	.29	.16	.20	–.12	.01	–.18
Adjacent Pairs–Delay	.06	.02	.21	.11	–.12	–.09	–.13	–.11

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

imitation of individual actions and pairs of actions in the correct temporal order at 20 months of age were significantly related to the following measures on the CMS: General Memory score, Immediate Visual and Verbal scores, Attention/Concentration scores, and Learning score. Performance on the elicited imitation task was also significantly related to Pair Cancellation (WJ-III), Visual Matching (WJ-III), and immediate recall of pairs of actions on the nine-item picture-sequencing task.

To address the specificity of these relations, we examined associations between language and temperament at 20 months, which were hypothesized to be unrelated to memory at 6 years of age. When correlational analyses were conducted between these measures at 20 months and measures at 6 years, the only significant relations to emerge were between: 1) Language and Attention/Concentration, 2) Language and Learning, 3) Social Fearfulness and Verbal Immediate Memory, 4) Interest/Persistence and Verbal Immediate Memory, and 6) Pleasure and Delayed Recognition Memory (see Table 3). Because multiple measures were related to performance on the CMS (i.e., elicited imitation and temperament), we sought to address which measure accounted for the most variance in CMS performance. To this end, we conducted a series of stepwise linear regression analyses using measures of elicited imitation, language, and temperament at 20 months of age to predict standardized performance on the CMS. Only target actions were included in the regression models, because they were highly correlated with pairs of actions in the correct temporal order, $r = .96$, $p < .001$. As summarized in Table 4, only elicited imitation performance entered into the models and significantly predicted later memory

TABLE 4
Stepwise Regressions Conducted on the Dependent Variables From the CMS, in Turn

Dependent variable	*B*	*SE (B)*	*β*	R^2
General Memory				
Step 1				
Elicited Imitation	9.61	3.96	.39	.15*
Visual Immediate Memory				
Step 1				
Elicited Imitation	3.04	1.09	.44	.19**
Verbal Immediate Memory				
Step 1				
Elicited Imitation	3.49	1.33	.42	.17**
Attention/Concentration				
Step 1				
Elicited Imitation	3.38	1.01	.48	.23**
Step 2				
Elicited Imitation	4.28	1.11	.61	.33**
Activity Level	–2.57	1.23	–.33	
Learning				
Step 1				
Elicited Imitation	3.16	1.17	.43	.18**
Step 2				
Elicited Imitation	3.3	1.11	.44	.29**
Anger Proneness	–2.18	0.97	–.34	

*$p \leq .05$. **$p \leq .01$.

Note. Potential predictors were the following measures from 20 months: elicited imitation (target actions), language (standardized percentile on the MacArthur-Bates CDI), and temperament (TBAQ Scales of Activity Level, Pleasure, Social Fear, Interest/Persistence, Anger Proneness).

performance on the CMS General Memory Scale and the CMS subscales: Visual Immediate Memory and Verbal Immediate Memory. Elicited imitation performance at 20 months of age accounted for 15% of the variance in the General Memory scores, 18% of the variance in Visual Immediate Memory scores, and 19% of the variance in Verbal Immediate Memory scores. For the Attention and Concentration subscale, both elicited imitation and the temperament scale Activity Level entered into the model and accounted for 37% and 11%, respectively, of the variance in attention and concentration. Finally, elicited imitation performance and the temperament scale Anger Proneness accounted for 19% and 12% of the variance in Learning Scores, respectively. In sum, after controlling for language abilities, performance on elicited imitation explains between 15% and 37% of the variance in later memory.

DISCUSSION

Findings from this study revealed longitudinal associations between elicited imitation performance and both immediate verbal and nonverbal memory measures across 5 years of life. The contribution of this investigation to research on memory development is twofold. First, it addresses in a controlled laboratory environment whether early memory performance is related to later memory performance. It adds to the small, yet influential, corpus of longitudinal studies in cognitive development that span infancy to school age and nonverbal to verbal measures (e.g., Harley & Reese, 1999; Rose, Feldman, & Jankowski, 2005; Rose, Feldman, Jankowski, & Van Rossem, 2005). Second, it establishes the utility of infant memory assessment via elicited imitation in predicting later school-aged memory abilities.

The current study extends previous research (i.e., Strid, et al., 2006) by examining the utility of toddlers' performance on multistep elicited imitation tasks as a predictor of their memory abilities after entering formal schooling. In addition, it shows that elicited imitation performance is predictive of both visual and verbal memory, when similar delays are imposed. Specifically, our measure of immediate recall at 20 months was related to immediate recall of both verbal and visual material at 6 years, but was not related to memory across a 30- to 45-minute delay (on standardized or laboratory-based measures). The fact that immediate imitation predicts immediate but not delayed memory measures at 6 years is not surprising, given that recall immediately and after a delay make different demands on the individual and, especially, on the infant. However, the fact that there are different demands does not mean that different types of memory are being measured. All imitation (using this task, at least) is elicited. The field has adopted the convention of saying that immediate recall is ''elicited'' imitation and delayed recall is ''deferred,'' but of course, deferred imitation is also elicited. Thus, the tests simply make different demands on the same memory system. Future studies should aim to address the predictive utility of deferred imitation in predicting later delayed recall abilities, when task demands are similar.

Our findings provide important evidence relevant to the theoretical debate regarding the nature of early memory development. Continuity and specificity within the declarative memory system are not predicted by developmental theories in general, but by theories that postulate similar mechanisms for the formation, maintenance, and retrieval of memories both early and later in life (see C. A. Nelson, 1995, for elaboration). From a cognitive neuroscience perspective, performance on the elicited imitation task has been shown to rely more heavily on memory structures in the medial temporal lobe (i.e., hippocampus) in comparison with regions in the frontal lobe (e.g., McDonough et al., 1995). These same structures are argued to underlie declarative memory abilities in infants, children, and adults (Bachevalier & Vargha-Khadem, 2005; Bauer, 2005; C. A. Nelson; Ghetti, DeMaster, Yonelinas, & Bunge, 2010). Our behavioral results are consistent with neuroimaging studies that suggest there are not qualitative changes in neural regions underlying successful memory performance but a refinement of structures and increases in functional connectivity within these and supporting regions (such as the prefrontal cortex; e.g., Casey, Giedd, & Thomas, 2000; Menon, Boyett-Anderson, & Reiss, 2005; Ofen et al., 2007). Memory at 20 months predicted several measures at 6 years (i.e., verbal memory, visual memory, attention/concentration, and learning); however, these were also predicted by measures of temperament at 20 months. In contrast, memory at 20 months was the *only* unique predictor of later memory, suggesting continuity within the declarative memory system over time. Regression analyses revealed that even after controlling for language abilities, variance in memory abilities at 6 years of age can be explained by memory abilities as a toddler. Depending on the subscale analyzed, performance on the elicited imitation task explained 15% to 37% of the variance in memory performance at 6 years of age. Interestingly, when the temperament scale Activity Level was controlled, the variance in Attention/Concentration scores on the CMS for which imitation scores accounted jumped to 37%. Attention/Concentration was the only construct for which Activity Level was a predictor. These regression analyses suggest that future research is needed to further elucidate these relations.

Measures of memory, language, and temperament at 20 months of age were related to Attention/Concentration scores and Learning scores at 6 years of age (in both correlation and regression analyses). These associations suggest that attention, concentration, and learning are multiply determined and that elicited imitation performance is not the only indicator of future problems or successes in these domains. For instance, Activity Level at 20 months was negatively associated with Attention/Concentration scores, suggesting that perhaps being very physically active (as opposed to sitting still and focusing on a task) early in development may be detrimental to one's similar ability to pay attention and concentrate in early childhood.

The present investigation is the first to suggest that memory variability identified using the elicited imitation paradigm early in life is predictive of individual differences in memory years later. This predictive utility suggests the use of the elicited imitation paradigm is a viable option for early identification of memory difficulties in at-risk populations (e.g., Cheatham et al., 2006; DeBoer et al., 2005; de Haan, Bauer, Georgeiff, & Nelson, 1999; Kroupina, Bauer, Gunnar, & Johnson, 2010; Riggins, Miller, Bauer, Georgeiff, & Nelson, 2009; Rose, Feldman, Jankowski, & Van Rossem, 2005). Early identification of impairment is important because problems identified later in development are more difficult to remediate, with the likely result that the child will continue to fail and perhaps withdraw from school. The earlier an intervention is begun, the higher the likelihood of success (Ramey & Ramey, 1998). Moreover, assessment of memory functions is an important component of neuropsychological, psychological, and psychoeducational evaluations as deficits in memory functioning have been associated with a number of acquired and developmental disorders of childhood (Drozdick, Holdnack, Rolfhus, & Weiss, 2008). It is critical that practitioners are able to make distinctions between global versus specific cognitive impairments. Thus, the implications of this work are far-reaching.

There are a few notable limitations of the current study. First, these results are based on a limited sample, both in terms of size and diversity. Related to this, attrition rates were high due to the length of the delay between assessments; only 48% of the original sample was available for follow-up. Second, there was a limit to the variables that were obtained at the 20-month assessment that may be predictive of later memory performance. Future studies should examine additional variables of interest, such as deferred imitation and/or speed of processing. Third, although memory abilities in school-aged children can be statistically explained by memory abilities as a toddler, we report correlations across time, not causal relations. There are numerous causal mechanisms that could lead to this correlation. This is certainly a question that deserves more attention in future research.

In closing, this report establishes elicited imitation methodology as a predictor of school-aged abilities when utilized at 20 months of age. These results not only speak to the domain specificity of relations between early measures and later measures of abilities, but they also lend credibility to recent studies using elicited imitation to identify early children at risk for memory impairment.

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REFERENCES

Bachevalier, J., & Vargha-Khadem, F. (2005). The primate hippocampus: Ontogeny, early insult, and memory. *Current Opinions in Neurobiology*, *15*, 168–174.

Barr, R., Dowden, A., & Hayne, H. (1996). Developmental changes in deferred imitation by 6- to 24-month-old infants. *Infant Behavior & Development*, *19*, 159–170.

Bauer, P. J. (1992). Holding it all together: How enabling relations facilitate young children's event recall. *Cognitive Development*, *7*, 1–28.

Bauer, P. J. (2005). New developments in the study of infant memory. In D. M. Teti (Ed.), *Handbook of research methods in developmental psychology* (pp. 467–488). Oxford, UK: Blackwell Publishers.

Bauer, P. J. (2006). Event memory. In D. Kuhn, R. S. Siegler (Vol. Eds.), W. Damon & R. M. Lerner (Eds.), *Handbook of child psychology: Vol. 2. Cognition, perception, and language* (6th ed., pp. 373–425). Hoboken, NJ: John Wiley & Sons, Inc.

Bauer, P. J. (2007). *Remembering the times of our lives: Memory in infancy and beyond*. Mahwah, NJ: Lawrence Erlbaum Associates.

Bauer, P. J. (2010). *Advances in child development and behavior: Vol. 38. Varieties of early experience: Implications for the development of declarative memory in infancy*. London, UK: Elsevier.

Bauer, P. J., Burch, M., & Kleinknecht, E. E. (2002). Developments in early recall memory: The mean the variablity behind it. In H. W. Reese and R. Kail (Eds.), *Advances in Child Development and Behavior*. Academic Press.

Bauer, P. J., DeBoer, T., & Lukowski, A. F. (2007). In the language of multiple memory systems, defining and describing developments in long-term explicit memory. In L. M. Oakes & P. J. Bauer (Eds.), *Short- and long-term memory in infancy and early childhood: Taking the first steps towards remembering* (pp. 240–270). New York, NY: Oxford University Press.

Bauer, P. J., Kroupina, M. G., Schwade, J. A., Dropik, P. L., & Wewerka, S. S. (1998). If memory serves, will language? Later verbal accessibility of early memories. *Development & Psychopathology*, *10*, 655–679.

Bauer, P. J., Leventon, J. S., & Varga, N. L. (2012). Neuropsychological assessment of memory in preschoolers. *Neuropsychology Review*, *22*(4), 414–424. doi:10.1007/s11065-012-9219-9.

Bauer, P. J., & Mandler, J. M. (1989). One thing follows another: Effects of temporal structure on 1- to 2-year-olds' recall of events. *Developmental Psychology*, *25*, 197–206.

Bauer, P. J., Wenner, J. A., Dropik, P. L., & Wewerka, S. S. (2000). Parameters of remembering and forgetting in the transition from infancy to early childhood. *Monographs of the Society for Research in Child Development*, *65*(4, Serial No. 263).

Bauer, P. J., & Wewerka, S. S. (1995). One- to two-year-olds' recall of events: The more expressed, the more impressed. *Journal of Experimental Child Psychology*, *59*, 475–496.

Bauer, P. J., & Wewerka, S. S. (1997). Saying is revealing: Verbal expression of event memory in the transition from infancy to early childhood. In P. W. van den Broek & P. J. Bauer (Eds.), *Developmental spans in event comprehension and representation: Bridging fictional and actual events* (pp. 139–168). Mahwah, NJ: Lawrence Erlbaum Associates, Inc.

Bayley, N. (1993). *Bayley Scales of Infant Development-II*. New York, NY: Psychological Testing Corporation.

Carver, L. J., & Bauer, P. J. (1999). When the event is more than the sum of its parts: 9-month-olds' long-term ordered recall. *Memory*, *7*, 147–174.

Carver, L. J., & Bauer, P. J. (2001). The dawning of a past: The emergence of long-term explicit memory in infancy. *Journal of Experimental Psychology: General*, *130*, 726–745.

Casey, B. J., Giedd, J. N., & Thomas, K. M. (2000). Structural and functional brain development and its relation to cognitive development. *Biological Psychology*, *54*, 241–257.

Cheatham, C. L., & Bauer, P. J. (2005). Construction of a more coherent story: Prior verbal recall predicts later verbal accessibility of early memories. *Memory*, *13*, 516–532.

Cheatham, C. L., Bauer, P. J., & Georgieff, M. K. (2006). Predicting individual differences in recall by infants born preterm and full term. *Infancy*, *10*, 17–42.

Cleveland, E. S., & Reese, E. (2008). Children remember early childhood: Long-term recall across the offset of childhood amnesia. *Applied Cognitive Psychology*, *22*, 127–142. doi:10.1002/acp.1359

Cohen, M. J. (1997). *Children's Memory Scale*. San Antonio, TX: Psychological Corporation.

Collie, R., & Hayne, H. (1999). Deferred imitation by 6- and 9-month-old infants: More evidence for declarative memory. *Developmental Psychobiology*, *35*, 83–90.

DeBoer, T., Wewerka, S., Bauer, P. J., Georgieff, M. K., & Nelson, C. A. (2005). Explicit memory performance in infants of diabetic mothers at 1 year of age. *Developmental Medicine & Child Neurology*, *47*, 525–531.

de Haan, M., Bauer, P. J., Georgieff, M. K., & Nelson, C. A. (2000). Explicit memory in low-risk infants aged 19 months born between 27 and 42 weeks of gestation. *Developmental Medicine & Child Neurology*, *42*, 304–312.

Drozdick, L. W., Holdnack, J., Rolfhus, E., & Weiss, L. (2008). *WISC-IV Technical Report #5: WISC-IV and Children's Memory Scale*. Pearson Education Inc.

Fenson, L., Dale, P. S., Reznick, J. S., Bates, E., Thal, D. J., & Pethick, S. J. (1994). Variability in early communicative development. *Monographs of the Society for Research in Child Development*, *59*(5, Serial No. 242).

Ghetti, S., DeMaster, D. M., Yonelinas, A. P., & Bunge, S. A. (2010). Developmental differences in medial temporal lobe function during memory encoding. *Journal of Neuroscience*, *30*, 9548–9556.

Goldsmith, H. H. (1996). Studying temperament via construction of the Toddler Behavior Assessment Questionnaire. *Child Development*, *67*, 218–235.

Harley, K., & Reese, E. (1999). Origins of autobiographical memory. *Developmental Psychology*, *35*, 1338–1348.

Howe, M. L., & Courage, M. L. (1997). The emergence and early development of autobiographical memory. *Psychological Review*, *104*, 499–523.

Kroupina, M. G., Bauer, P. J., Gunnar, M. R., & Johnson, D. E. (2010). Institutional care as a risk for declarative memory. In P. J. Bauer (Ed.), *Advances in child development and behavior: Vol. 38. Varieties of early experience: Implications for the development of declarative memory in infancy* (pp. 137–159). London, UK: Elsevier.

Mandler, J. M., & McDonough, L. (1995). Long-term recall of event sequences in infancy. *Journal of Experimental Child Psychology*, *59*, 457–474.

McDonough, L., Mandler, J. M., McKee, R. D., & Squire, L. R. (1995). The deferred imitation task as a nonverbal measure of declarative memory. *Proceedings of the National Academy of Science*, *92*, 7580–7584.

Meltzoff, A. N. (1995). What infant memory tells us about infantile amnesia: Long-term recall and deferred imitation. *Journal of Experimental Child Psychology*, *59*, 497–515.

Menon, V., Boyett-Anderson, J. M., & Reiss, A. L. (2005). Maturation of medial temporal lobe response and connectivity during memory encoding. *Cognitive Brain Research*, *25*, 379–385.

Mirandola, C., Del Prete, F., Ghetti, S., & Cornoldi, C. (2011). Recollection but not familiarity differentiates memory for text in students with and without learning difficulties. *Learning and Individual Differences*, *21*, 206–209. doi:10.1016/j.lindif.2010.12.001

Morris, G., & Baker-Ward, L. (2007). Fragile but real: Children's capacity to use newly acquired words to convey preverbal memories. *Child Development*, *78*, 448–458. doi:10.1111/j.1467–8624.2007.01008.x

Neisser, U. (1962). Cultural and cognitive discontinuity. In T. E. Gladwin & W. Sturtevant (Eds.), *Anthropology and human behavior* (pp. 54–71). Washington, DC: Anthropological Society of Washington.

Nelson, C. A. (1995). The ontogeny of human memory: A cognitive neuroscience perspective. *Developmental Psychology*, *31*, 723–738.

Nelson, K. (1992). Emergence of autobiographical memory at age 4. *Human Development*, *35*, 172–177.

Ofen, N., Kao, Y.-C., Sokol-Hessner, P., Kim, H., Whitfield-Gabrieli, S., & Gabrieli, J. D. E. (2007). Development of the declarative memory system in the human brain. *Nature Neuroscience*, *10*, 1198–1205.

Pillemer, D. B. (1998). *Momentous events, vivid memories*. Cambridge, MA: Harvard University Press.

Pillemer, D. B. & White, S. H. (1989). Childhood events recalled by children and adults. In H. W. Reese (Ed.), *Advances in child development and behavior* (Vol. 21, pp. 297–340). San Diego, CA: Academic Press.

Ramey, C. T., & Ramey, S. L. (1998). Early intervention and early experience. *American Psychologist*, *53*, 109–120.

Riggins, T., Miller, N. C., Bauer, P. J., Georgieff, M. K., & Nelson, C. A. (2009). Consequences of low neonatal iron status due to maternal diabetes mellitus on explicit memory performance in childhood. *Developmental Neuropsychology*, *34*, 762–779.

Rose, S. A., Feldman, J. F., & Jankowski, J. J. (2005). Recall memory in the first three years of life: A longitudinal study of preterms and full-terms. *Developmental Medicine and Child Neurology*, *47*, 653–659.

Rose, S. A., Feldman, J. F., Jankowski, J. J., & Van Rossem, R. (2005). Pathways from prematurity and infant abilities to later cognition. *Child Development*, *76*, 1172–1184.

Schneider, W., & Näslund, J. C. (1993). The impact of early metalinguistic competencies and memory capacity on reading and spelling in elementary school: Results of the Munich Longitudinal Study on the Genesis of Individual Competencies (LOGIC). *European Journal of Psychology of Education*, *8*, 273–287. doi:10.1007/BF03174082

Simcock, G., & Hayne, H. (2002). Breaking the barrier? Children fail to translate their preverbal memories into language. *Psychological Science*, *13*, 225–231.

Simcock, G., & Hayne, H. (2003). Age-related changes in verbal and nonverbal memory during early childhood. *Developmental Psychology*, *39*, 805–814.

Strid, K., Tius, T., Smith, L., Meltzoff, A. N., & Heimann, M. (2006). Infant recall memory and communication predicts later cognitive development. *Infant Behavior & Development*, *29*, 545–553.

Weintraub, S., Dikmen, S. S., Heaton, R. K., Tulsky, D. S., Zelazo, P. D., Bauer, P. J., . . . Gershon, R. C. (2013). NIH Toolbox for the assessment of behavioral and neurological function: Cognition domain instruments. *Neurology*.

Wenner, J. A., & Bauer, P. J. (1999). Bringing order to the arbitrary: One- to two-year-olds' recall of event sequences. *Infant Behavior & Development*, *22*, 585–590.

Wheeler, M. A. (2000). Episodic memory and autonoetic awareness. In E. Tulving & F. I. M. Craik (Eds.), *The Oxford handbook of memory* (pp. 597–608). New York, NY: Oxford University Press.

Woodcock, R. W., McGrew, K. S., & Mather, N. (2001). *Woodcock-Johnson III Tests of Cognitive Abilities*. Itasca, IL: Riverside Publishing.

Zelazo, P. D., & Bauer, P. J. (Eds.), (in press). National Institutes of Health Toolbox–Cognition Battery (NIH Toolbox CB): Validation for Children Between 3 and 15 Years. Monographs of the Society for Research in Child Development.