

Planning in Middle Childhood: Early Predictors and Later Outcomes

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Data from 1,364 children and families who participated in the National Institute of Child Health and Human Development's Study of Early Child Care and Youth Development were analyzed to track the early correlates and later academic outcomes of planning during middle childhood. Maternal education, through its effect on parenting quality when children were 54 months old, predicts their concurrent performance on sustained attention, inhibition, and short-term verbal memory tests. This performance predicts planning in first grade, which predicts third-grade reading and mathematics attainment, but not the rate of growth in academic skills from first to fifth grades. This path was also found when the same parenting, cognitive, and academic constructs were measured at later time points.

One important distinctively human characteristic is the ability to plan rather than respond to the immediate situation without deliberation. Plans are mental representations of what we want to do and what we are emotionally committed to doing. The literature on planning has evolved from its early focus on the adult information processing skills required for planning. As research shifted to younger populations, the conceptualization of planning incorporated familial predictors (e.g., Gauvain,

2001) as well as consideration of planning as a foundation for academic achievement (e.g., Bull & Scerif, 2001). However, the research to date has not provided an overall developmental model of how family and child characteristics uniquely and simultaneously work to affect planning and how planning is linked to academic achievement over time within the same group of children (Best, Miller, & Jones, 2009).

Our research explored (a) the development of school-age children's planning, (b) social and cognitive precursors of planning, and (c) the academic consequences of planning. Previous research has focused on each of these direct links, albeit not always during the same age period that we examined (Gauvain, 2001; NICHD Early Child Care Research Network, 2003, 2009; Ruff & Rothbart,

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1996). We hypothesized that over and above the direct links previously explored, there is a mediational path from family variables (maternal education; parenting measured by the combination of the quality of the home environment and maternal sensitivity) to basic cognitive skills, to planning (a complex cognitive skill), and finally to academic performance. The longitudinal data set we used also enabled us to test the extent to which the mediational path that we were exploring was unique to a specific time period or whether it could be replicated when the web of relations under consideration was shifted to older ages.

The above hypothesized path and its replication at later time points are not necessarily causal (McCartney et al., 2010; NICHD Early Child Care Research Network, 2003), but if substantiated, they will shed further light on possible mechanisms by which family characteristics link to children’s basic cognitive skills and planning that support academic achievement. Figure 1 displays the hypothesized paths and the following sections elaborate on the hypothesized linkages under consideration.

Planning and Its Cognitive Components

Early investigators construed planning as a mental representation of the problem-solving process (e.g., Anzai & Simon, 1979; Klahr & Robinson, 1981; Kotovsky, Hayes, & Simon, 1985; Welsh, 1991). They examined this representation using tasks such as the Tower of Hanoi (TOH). These tasks consisted of constrained problem spaces that enabled them to observe how people produced the most efficient solutions (plans). Successful performance on TOH

tasks requires constructing a strategy consisting of an ordered sequence of subgoals. Implementing the strategy requires memory for the sequence (Case, 1985), focused attention, and inhibition of other competing responses (Baddeley & Hitch, 1974).

Planning, often indexed by tower tasks, has also been considered the pinnacle of executive function (EF), a set of higher order, top-down cognitive abilities (including working memory, set shifting, and inhibition) used in a coordinated, goal-directed fashion (Best et al., 2009; Gauvain, 2001; Miyake et al., 2000; Zelazo, Carter, Reznick, & Frye, 1997). Two aims of developmental research on EF have been detection of the conditions that contribute to individual differences and assessment of the contributions of EF to academic performance, especially in mathematics and reading (Best & Miller, 2010; Best et al., 2009; Bull, Espy, & Wiebe, 2008; Clark, Pritchard, & Woodward, 2010). Additionally, investigators have examined whether the network of relations among EF skills shifts with age as each of the skills develops and as the demands of academic tasks change (Best & Miller, 2010; Garon, Bryson, & Smith, 2008; Hughes, Ensor, Wilson, & Graham, 2010). However, few studies combine these aims in studying a longitudinal data set (Best et al., 2009).

Our research overlaps with the investigations of EF in targeting individual differences in tower planning and its correlates but we were also informed by the cognitive science literature (Best & Miller, 2010; Garon et al., 2008; Welsh, Friedman, & Spieker, 2006) in examining the relation between three basic cognitive skills (two of which are also considered simpler EFs) and planning. Based on task linkages reported in the EF literature, we also wanted

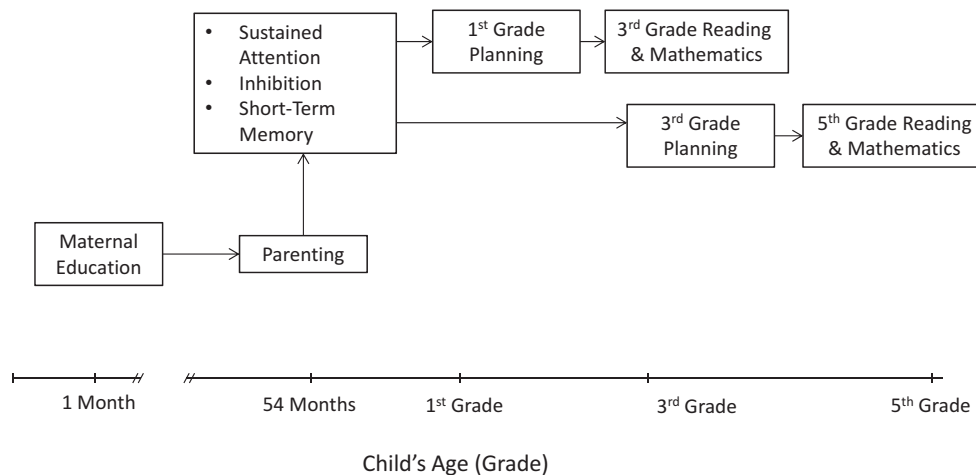


Figure 1. The hypothesized paths from family predictors to basic cognitive skills, to subsequent planning skills, and to later academic outcomes.

to find out whether the relation among the basic cognitive skills and planning shifts as the children tackle more complex tower tasks (Bull et al., 2008).

Links Between Family Characteristics, Parental Behaviors, and Cognitive and Academic Outcomes

Our mediational path begins with maternal education as a family characteristic affecting children's cognitive and achievement outcomes. Maternal education levels are strongly and positively associated with the family's investment in teaching and in resources that promote learning (e.g., educational materials, visits to libraries and museums, high-quality child care; Bradley et al., 1989; Shonkoff & Phillips, 2000). In turn, research suggests that home environments in which parents invest in promoting learning appear to bolster basic cognitive and EF skills (Bernier, Carlson, & Whipple, 2010; Gauvain, 2001; NICHD Early Child Care Research Network, 2003, 2005). Additionally, sensitive, cognitively stimulating parenting mediates between distal characteristics of the child-rearing environment (socioeconomic class, income, maternal education) and a variety of young children's developmental outcomes. More specifically, the evidence supports our proposal that a cognitively enriching environment provides the path through which higher maternal education is associated with better basic cognitive, EF, and achievement outcomes (Adi-Japha & Klein, 2009; Crosnoe, Leventhal, Wirth, Pierce, Pianta, & NICHD Early Child Care Research Network, 2010; Downer & Pianta, 2006; Lugo-Gil & Tamis-LeMonda, 2008; NICHD Early Child Care Research Network, 2003, 2005; Rhoades, Greenberg, Lanza, & Blair, 2011).

Links Between Planning and Academic Skills

Evidence suggests that planning is associated with better performance on standardized mathematics and reading tests in the early grades (Bull & Scerif, 2001; Bull et al., 2008; Clark et al., 2010; Espy et al., 2004; NICHD Early Child Care Research Network, 2003; Van der Sluis, de Jong, & van der Leij, 2007). This is not surprising. Arithmetic requires recursive operations in tasks such as multidigit addition and long division. Similarly, reading or solving mathematics word problems require comprehending the sequence of events or actions described by the text. Our analyses tracked the links between the development of planning and academic achievement across the elementary school years. We also explored an

indirect path, in which basic cognitive skills contribute to academic achievement through their link to planning.

Predicting a Network of Links and Paths

Based on theory and empirical research (described above), we predicted that better short-term memory, sustained attention, and ability to inhibit responding to nontarget stimuli would be associated with better later planning performance. We further predicted that better planning ability would be associated with better academic achievement. Going beyond currently available research, we predicted that there would be a path leading from (a) maternal education as measured in children's early infancy to (b) observations of parenting behaviors and home environments when children were 54 months of age to (c) concurrent measures of children's performance on tasks that require basic cognitive skills (i.e., sustained attention, inhibition of responses to nontarget stimuli, verbal short-term memory) and, from these basic skills, to (d) children's planning at first grade, and, finally, from planning to (e) reading and mathematics achievement at third grade (see Figure 1). Partially based on the NICHD Early Child Care Research Network (2003, 2009) and on Fraley, Roisman, and Haltigan (2013), we also hypothesized that these paths would be evident at other ages (see Figure 1). Even though there is no clear guidance from either theory or empirical studies regarding the possibility that those endowed with more enriched environments and higher cognitive skills have an opportunity to accrue skill at a faster rate, we also hypothesized that parental education level, early parenting and children's early levels of cognitive skills will be linked to steeper developmental changes in planning and that these developmental changes in planning will be linked to steeper growth in reading and mathematics skills.

Method

Sample

The sample recruited in 1991 into the NICHD Study of Early Child Care and Youth Development contained 1,364 families with healthy newborns (705 boys and 659 girls) from 10 sites from across the United States. As can be seen in Table 1, the majority of the sample was European Americans, and the mean of maternal education when the

Table 1
Descriptive Statistics for Study Variables

	N	M (SD) or %
Gender (female)	659	48.31%
Ethnicity (European Americans)	1,023	75.00%
(African Americans)	157	11.51%
(Hispanic)	90	6.60%
(Other)	76	5.57%
Crystallized intelligence	1,060	100.24 (15.02)
Mother education	1,362	14.23 (2.51)
HOME 54 months	1,045	45.99 (5.45)
HOME Gr. 1 (imputed and standardized)	1,131	-0.02 (0.92)
Maternal sensitivity 54 months	1,040	16.87 (3.02)
Maternal sensitivity in Gr. 1	1,104	16.94 (2.90)
Sustained attention (omission errors) 54 months	1,002	9.13 (7.59)
Inhibition (commission errors) 54 months	1,002	14.19 (21.30)
Short-term memory 54 months	1,054	91.74 (18.48)
Sustained attention (omission errors) Gr. 1	996	2.36 (3.92)
Inhibition (commission errors) Gr. 1	995	6.11 (10.64)
Short-term memory Gr. 1	1,018	98.51 (14.94)
Planning (TOH) in Gr. 1	989	14.37 (6.77)
Planning (TOH) in Gr. 3	1,003	23.18 (7.70)
Planning (TOH) in Gr. 5	991	28.89 (7.62)
Reading* in Gr. 1	1,024	452.58 (24.00)
Reading* in Gr. 3	1,011	494.58 (15.75)
Reading* in Gr. 5	993	507.61 (14.12)
Mathematics* in Gr. 1	1,022	470.03 (15.53)
Mathematics* in Gr. 3	1,012	493.49 (12.76)
Mathematics* in Gr. 5	993	510.53 (13.04)

Note. *Woodcock Johnson-Revised W Scores.

children were 1 month old was 2 years above high school graduation. The mean household income at recruitment was \$ 37,781.28. Based on U.S. Census Tract data, on most demographic variables, the study sample reflects the population of families with young infants residing in the communities from which research participants were recruited. However, parents in the study had higher than average education levels for their census tracts. At the same time, families were more likely to be on public assistance and had slightly lower household incomes than the average for their census tracts (NICHD Early Child Care Research Network, 2001).

Our analyses focused on data collected when the children were newborns, 54 months of age, in first grade (ages 6–7), third grade (ages 9–10), and fifth grade (ages 11–12). Subject retention was high compared to other large-sample, multisite longitudinal studies. Seventy-three percent of the sample had TOH, reading, and mathematics performance data

at fifth grade, the last assessment point for our study. The number of observations per assessment appears in Table 1.

Assessments and Measures

Control Variables

Child gender, ethnicity, and performance on a test of crystallized intelligence served as control variables. The percentages of children in the different gender and ethnic groups are reported in Table 1. Crystallized intelligence, demonstrated largely through one's vocabulary and general knowledge, was measured at 54 months with the Woodcock-Johnson Psycho-Educational Battery-Revised (WJ-R) Picture Vocabulary subtest (Woodcock & Johnson, 1989–1990). This test correlates with the Peabody Picture Vocabulary Test ($r = .69$).

Social Environment Predictors

We assessed distal and proximal measures of each child's social environment. These were (a) number of years of maternal education as self-reported when the child was 1 month old, and (b) parenting quality.

Parenting. The parenting quality measure was obtained when children were 54 months old (and in the follow-up analyses at first grade) based on composites of maternal sensitivity and the total Home Observation for Measurement of the Environment (HOME; Caldwell & Bradley, 1984). For each measure, we first calculated the mean of the within-sample standardized scores and then averaged the two scores to form the parenting quality composite. Table 1 provides descriptive statistics about maternal education and parenting quality.

HOME. HOME provides information about aspects of home experience that ecological-developmental theory suggests should be related to child outcomes (Bronfenbrenner, 1999). HOME assesses the overall quality of the physical and social resources available to the child from objects, events, and transactions occurring in the family surroundings. The HOME score is derived from ratings of direct observations, a semistructured interview with the mother, and her responses to questionnaire items. All observers attended centralized training sessions prior to collecting the data and were required to maintain reliability by matching a master coder on 90% of items. Cronbach's alpha for the total score was 0.82.

For the 54-month HOME data, we used the Early Childhood HOME (Caldwell & Bradley, 1984). It contains 57 items. The alpha for the total score was 0.82 (alphas for subscales ranged from 0.26 to 0.57). Interobserver agreement was > 90%. Because HOME data were not collected when the children were in first grade, in the follow-up analyses we imputed the first-grade HOME score from the 54-month and third-grade total HOME scores based on the Middle Childhood HOME with 59 items. Scores were standardized before averaging.

Maternal sensitivity. The mother's sensitivity to the child when they interact with each other in challenging and pleasurable tasks has been found to be consistently and strongly associated with child social and cognitive outcomes (Bernier et al., 2010; NICHD Early Child Care Research Network, 2003, 2005). Maternal sensitivity was rated by coders from a 15-min videotaped semistructured mother-child play procedure that occurred in the laboratory. When the children were 54 months of age, mother and child interacted during two tasks involving planning (completing mazes on an Etch-A-Sketch apparatus and building a block tower) that were too difficult for the child to carry out independently and required the parent's instruction and assistance. A third activity, involving hand puppets, was included to encourage play between mother and child. The mother-child interaction when the children were in first grade involved the same framework but different tasks. First graders and their mothers were presented with a more difficult Etch-A-Sketch task, they were also asked to insert different-shaped parquet pattern blocks in three geometric cutout frames, and they played a competitive card game.

The mother-child interactions were rated from videotapes of each of the tasks described above by coders who were highly trained and certified to use a well-specified global rating system based on Allen, Hauser, Bell, McElhaney, and Tate (1996) and modified for the purpose of the NICHD Study of Early Child Care and Youth Development. The coders were unacquainted with the family or the child's nonmaternal care history. At each age, the maternal sensitivity score was the sum of three 7-point ratings of the mother-child interaction: supportive presence, hostility (reverse scored), and respect for autonomy. Cronbach's alphas for the sensitivity composites were 0.84. Intraclass correlations were used to calculate intercoder reliability on the composite score. Coefficients averaged across pairs of raters were 0.88. For more detailed

descriptions of the interaction tasks, their respective rating scales, and the reliability procedures, see the entries for "mother-child interaction" in the Phase II Instrument Document at <http://www.icpsr.umich.edu/icpsrweb/ICPSR/>.

Basic Cognitive Skills

At 54 months of age and at first grade the children were assessed on three basic cognitive skills: sustained attention, inhibition, and verbal memory. Table 1 presents descriptive statistics about performance on these assessments.

Sustained attention and inhibition. Sustained attention and inhibition (the ability to withhold responses to prepotent stimuli) were assessed with the Continuous Performance Task (CPT; Rosvold, Mirsky, Sarason, Bransome, & Beck, 1956). The CPT requires the child to recognize and respond promptly and accurately to a target stimulus that is embedded in a sequence of foils. At 54 months of age children saw computer-generated dot matrix pictures on the screen in 10 blocks of 22 sequences for a total of 220 presentations of stimuli. Each stimulus was presented for 500 ms with an interstimulus interval of 1,500 ms. The target stimulus (a chair) was randomly presented twice within each block. Children had to press a button as soon as they saw the chair. The duration of the task was approximately 7 min 20 s. At first grade the stimuli were presented in 30 blocks with 10 stimuli per block. The stimulus duration was 200 ms, and the interstimulus interval was 1,500 ms. The target stimulus was an X and was randomly presented twice within each block. The test took approximately 8 min 30 s.

Sustained attention was indexed by the number of errors of omission (i.e., failures to press the button when the target stimulus appeared). Inhibition was reflected in the number of errors of commission (i.e., button-press responses to nontarget stimuli). Measures of sustained attention and inhibition derived from the CPT have adequate test-retest reliability ($r_s = .65-.74$; Halperin, Sharma, Greenblatt, & Schwartz, 1991). The two measures show low correlation with each other ($r = .24$). Children's performance on the CPT has high construct validity as a measure of attention (Halperin et al., 1991) and adequate predictive validity to attention problems in children with attention deficit hyperactivity disorder or mental retardation (Barkley, 1994; Barkley, Grodzinsky, & DuPaul, 1992).

Short-term memory. Short-term memory was assessed with a subtest from the WJ-R Memory for

Sentences, which measures the ability to remember and repeat phrases and sentences of varying lengths presented with a tape recorder. In our analyses we used the children's *W* scores. McGrew, Werder, and Woodcock (1991) reported that split-half internal consistency at ages 4–7 years is 0.86–0.94.

Planning. Planning was assessed at first, third, and fifth grades using the TOH task. Performance on the task varies across age (Klahr & Robinson, 1981; Welsh, 1991), cognitive ability (Welsh, Pennington, Ozonoff, Rouse, & McCabe, 1990), and neurological status (Denckla, 1994; Welsh, Pennington, & Groisser, 1991) but there are few large-scale studies of test–retest reliability. The task requires the child to think ahead and develop a sequence of moves to transform an initial configuration of rings on the child's set of pegs into the pattern shown on the experimenter's set of pegs (goal state). The child is asked to reach the goal in the minimum number of moves (equal or less than 20) while obeying rules requiring that only one ring is moved at a time and that no ring rests on a smaller ring. Each child worked on a maximum of six puzzles. Puzzles were presented in an ascending sequence of difficulty. The easiest puzzle had three rings and could be solved in 4 moves. The most difficult puzzle had four rings and could be solved in 15 moves. If children reproduced the goal state in more than the optimal number of moves, they were encouraged to try to solve the task in fewer moves. After two consecutive optimal solutions of a given puzzle, a more difficult puzzle was presented. Failure to produce an optimal solution to a given puzzle, led to termination of the entire task.

The planning score for each puzzle was based on the number of trials required to achieve two successive optimal solutions (Borys, Spitz, & Dorans, 1982). Six points were awarded for optimal solutions produced on Trials 1 and 2, 5 points for optimal solutions produced on Trials 2 and 3, and so on. First graders could work on as many as the first six puzzles. Pilot work suggested that they would fail on the seventh puzzle. Therefore, they were awarded a score of 0 for it. Third and fifth graders started with the second puzzle because pilot work suggested that they would perform perfectly on the first puzzle. Therefore, they were awarded a score of 6 for it. The mean total performance score by grade appears in Table 1 and detailed information for each task and grade level appears in Table S1 in the online Supporting Information.

Our measure of planning consisted of the trajectory of TOH performance from first through fifth grades. TOH performance trajectories were

modeled using a growth model with three parameters. The intercept, β_0 , represented the individual's planning at first grade; β_1 represented the individual's linear slope over the period from first to fifth grades. Both varied across children. We accounted for the nonlinear growth curve by introducing an estimated middle time point fixed parameter, which was estimated at the sample level and therefore did not vary among individuals. The time for first grade was coded as 0 and the time for fifth grade was coded as 1, leaving the sample estimated middle time point parameter, λ_{TOH} , to represent the percent of the total first-to-fifth-grade growth accomplished by third grade. This growth model allows us to model the general increase in planning, which includes a slowing of growth between third and fifth grades relative to the growth between first and third grades. The growth model equation is: Tower of Hanoi score_{*ij*} = β_{0i} + β_{1i} (Time_{*k*}) + β_2 (Time_{*k2*}), where *i* indexes individuals and *k* indexes time points.

Academic Outcomes

Reading. To obtain children's reading level, we used *W* scores derived from subtests of the WJ–R (Woodcock & Johnson, 1989–1990; Woodcock & Mather, 1989). The Letter Word Identification (LWI) subtest was used in first grade. Both the LWI and the Passage Comprehension subtests were used in third and fifth grades, and the *W* scores were combined to create a composite reading score. Table 1 provides descriptive statistics on children's reading performance by grade.

In the LWI subtest, the first five items assess ability to match a pictographic presentation of a word with an actual picture of the object. The remaining items require identification of isolated letters and words that appear in large type. The internal consistency reliability for 9-year-olds is $r = .94$, $SEM = 4.8$ (Woodcock & Mather, 1989, p. 100).

In the Passage Comprehension test, the first four items are presented in multiple-choice format, requiring the child to point to the picture represented by a phrase. The remaining items require the child to read a short passage and identify a missing key word that makes sense in the context of the passage. Passage Comprehension internal consistency reliability for 9-year-olds is $r = .88$, $SEM = 5.8$ (Woodcock & Mather, 1989, p. 100).

Similar to the case of planning, reading performance was evaluated with a three-parameter model. The only differences were that (a) the

intercept term, β_0 , was set to the reading achievement in third grade, and (b) the free time point sample parameter, λ Reading, which was incorporated to accommodate nonlinearity in the reading achievement growth, was placed at fifth grade (making it the percentage of first-to-third-grade growth accomplished between third and fifth grades). As in the planning model, β_1 remains the linear change in reading performance across the three grades. These parameters form the basis of a linear growth model: Reading score $_{ij} = \beta_{0i} + \beta_{1i}$ (Time $_k$).

Mathematics. Like reading performance, mathematics performance was assessed with subtests of the WJ-R. The Calculation subtest was used for first graders. Both the Calculation and Applied Problems subtests were used for third and fifth graders. The W scores were combined to create a composite mathematics score. Table 1 provides descriptive statistics on children's mathematics performance by grade.

The Calculation subtest measures the child's skill in performing addition, subtraction, multiplication, division, and combinations of these basic operations, as well as more advanced operations. Internal consistency reliability data for 9-year-olds is $r = .89$, $SEM = 4.4$ (Woodcock & Mather, 1989, p. 100).

The Applied Problems subtest requires the child to analyze and solve mathematics problems. Solving the problem requires listening to the problem, recognizing the procedure to be followed, and then performing relatively simple calculations. Many of the problems include extraneous information and the child must select not only the appropriate mathematical operations to use, but also which numbers to include in the calculation. The internal consistency reliability for 9-year-olds is $r = .90$, $SEM = 5.0$ (Woodcock & Mather, 1989).

The mathematics data were initially modeled with the same formal growth model as used for modeling the reading data: Mathematics score $_{ij} = \beta_{0i} + \beta_{1i}$ (Time $_k$). Because the linear slope did not vary significantly among the children, we made this an estimate that was fixed between children.

Analytical Methods

Our analytical goals were (a) to test a model that describes a path from social environment-family predictors to concurrent basic cognitive skills, and to subsequent planning skills, and, finally, to later academic outcomes and (b) to test the model again with data obtained at later time points in the same

longitudinal data set. The hypothesized paths are presented in Figure 1. The simple sample correlations among the variables used in the primary analyses are presented in Table S2 in the online Supporting Information.

The full structural equation model fit and tested in this study is the following. The reading intercept and slope latent variables were estimated using the reading measures at first, third, and fifth grades using a latent curve model, and the same is true for the two planning latent variables. The mathematics random intercept was estimated the same way, but the mathematics slope was fixed. The two reading latent variables were each correlated with the mathematics intercept. All these random latent variables were adjusted for (had regression paths from) each of the eight covariates: maternal education, parenting, sustained attention, inhibition, short-term memory, child's ethnicity (non-European Americans), child's gender (female), and child's crystallized intelligence. Maternal education had a regression path to parenting and was correlated with ethnicity and gender. Parenting had regression paths to sustained attention, inhibition and short-term memory, and was correlated with ethnicity and crystallized intelligence. Ethnicity had regression paths to sustained attention, inhibition and short-term memory, and was correlated with gender and crystallized intelligence. The child's gender had regression paths to sustained attention, inhibition and short-term memory, and was correlated with crystallized intelligence. Finally, sustained attention, inhibition, short-term memory, and crystallized intelligence were all completely correlated with each other pairwise.

First, we fit three measurement models with growth curve models (GCMs) to determine the best models for individual trajectories of change over time for planning, reading, and mathematics. Second, we used a structural equation model that incorporated the variables under investigation to test the hypothesized path from maternal education to parenting quality at age 54 months to the children's concurrent basic cognitive skills as predictors of the latent growth parameters of the trajectories of planning and, finally, to the intercepts of reading and mathematics GCMs and the slope of the reading GCM. The structural model among the parameters of the three GCMs was specified as follows: The reading intercept and slope and the mathematics intercept were all regressed on the planning intercept (set at first grade) and the reading slope was regressed on the planning intercept and slope. Gender, ethnic-

ity, the three cognitive skills, and a child measure of crystallized intelligence were all used as covariates for all regressions involving planning, reading achievement, and mathematics achievement latent growth curve parameters.

The model was estimated using the full information maximum likelihood estimator in MPlus 6.0 (Muthén & Muthén, 2007). This widely used method of estimation allows the inclusion of information from all cases, including those with some missing values (Arbuckle, 1996; Schafer & Graham, 2002), which enabled the incorporation of data from the full sample of 1,364 children. All standard errors were estimated using bootstrap estimation, with 5,000 bootstrap draws. In the model estimation, we included statistical tests of several indirect effects of interest, based on bootstrap standard errors. These latter tests enabled us to test our hypothesis regarding the mediational structure among the predictors of planning, as well as the full indirect paths of interest between maternal education and the reading and mathematics GCM intercepts, via parenting, the three basic cognitive skills, and the planning intercept.

Overall, the estimated model specified in the analysis plan had reasonably good fit. The comparative fit index (CFI; 0.984) and the Tucker–Lewis index (TLI; 0.965) both had values > 0.95, which represents good fit. The root mean square error of approximation (RMSEA; 0.038, 90% CI [0.032,

0.044]) had a value of < 0.05, which represents excellent fit, and the test of close fit (MacCallum, Browne, & Sugawara, 1996) is met ($p = .999$). The standardized root mean square residual was 0.138, indicating some lack of good fit as it is not < 0.08. Not surprisingly, given the complexity of the model, sample size, and degrees of freedom, the model does not fit according to the $\chi^2(23) = 180.695, p < .0001$.

Results

From the Social Environment Through Basic Cognitive Skills to Planning

Primary Analyses

Table 2 contains basic information on the GCM for planning and the regression of this model’s parameters on the set of predecessors and control variables described above. The planning measurement model showed that the trajectory of planning had a mean intercept (Estimate β_0 at first grade) of 7.84 (out of a maximum possible score of 42) across the sample. The mean linear slope was Estimate $\beta_1 = 13.85$. The estimated time point representing the proportion of total growth in planning accomplished by third grade was 0.60, leaving about 40% of the growth to occur between third and fifth grades. Child environment (represented by mother

Table 2
Direct and Indirect Predictors of Planning

	Planning intercept			Planning slope		
	Estimate	SE	Stdzd Est	Estimate	SE	Stdzd Est
Fixed	7.84***	2.11	1.97	13.85***	3.01	4.42
Random	10.25***	1.88	.65	8.90**	3.20	.91
Maternal education	.08	.09	.05	.03	.12	.02
Female	.84	.42	.21	-.71	.54	-.23
Non-European Americans	-.69	.50	-.07	-.22	.71	-.03
Parenting quality	.48	.31	.10	.85*	.43	.23
Sustained attention (omission errors)	-.13***	.03	-.24	-.01	.04	-.01
Inhibition (commission errors)	-.03**	.01	-.13	.00	.01	.00
Memory.Short.Term	.05***	.01	.22	-.01	.02	-.03
Crystallized intelligence	.02	.02	.08	.01	.02	.06
Indirect eff. from Mat.Ed. ^a	.15***	.03	.10	-.00	.03	.00
Mat.Ed.->Parenting-Att.Om.Err->	.06***	.02	.04	.00	.02	.00
Mat.Ed.->Parenting->Inhibit.Com.Err->	.03*	.01	.02	-.00	.02	.00
Mat.Ed.->Parenting->Mem.Srt.Trm->	.06***	.02	.04	-.00	.02	-.01

Note. Stdzd Est = standardized estimate; Mat.Ed. = maternal education; Att.Om.Err = sustained attention (omission errors); Inhibit.Com.Err = inhibition commission errors; Mem.Srt.Trm = short-term memory.

^aMaternal education, to parenting, to each of the three cognitive skills, to planning intercept or slope.

* $p < .05$. ** $p < .01$. *** $p \leq .001$.

education and parenting) and child basic cognitive skills were included as antecedent correlates of the trajectory parameters of planning, while controlling for child gender, ethnicity, and crystallized intelligence. Our hypothesized mediation model assumed a path from maternal education to parenting quality prior to entry to school (at 54 months of age); and from parenting quality to the concurrent sustained attention, inhibition, and short-term memory variables; and from those basic cognitive skills to the trajectories of planning. We estimated direct and mediated effects.

The results of the planning analyses shown in Table 2 support the direct associations for some of the hypothesized antecedent correlates. The direct paths from the basic cognitive measures to the planning trajectory intercept indicated that higher initial planning scores were associated with greater sustained attention (fewer errors of omission; Estimate $\beta_0 = -0.13$), higher inhibition (fewer errors of commission; Estimate $\beta_0 = -0.03$), and higher scores on the short-term memory task (Estimate $\beta_0 = 0.05$). Standardized coefficients for these three predictors, shown in column 3, are -0.24 , -0.13 , and 0.22 , respectively. The measure of crystallized intelligence based on a picture vocabulary test was not a significant predictor of planning.

As can be seen in Table S3 in the online Supporting Information, no significant relation was found between maternal education and any of the basic cognitive skills measured (sustained attention, inhibition, short-term memory). Parenting quality was significantly linked to these skills (with the standardized estimates = -0.31 , -0.28 , and 0.32 , respectively) and the effects of maternal education on these basic cognitive skills were indirect through parenting quality (standardized estimates = -0.16 , -0.14 , and 0.16 , respectively). Likewise, while no significant direct relation was found between maternal education and the planning trajectory (i.e., intercept and slope) or between parenting quality and the planning intercept, Table 2 shows a composite indirect effect of maternal education on the planning intercept. This estimate is for the path through parenting and further through each of the three basic cognitive skills (total indirect effect: Estimate $\beta = 0.15$, $p < .001$). The comparable indirect path to the planning slope was not significant.

Parenting quality had a direct effect on the slope, indicating that children gained additional planning skills over time when the parenting quality they experienced was rated as more positive (Estimate $\beta_1 = 0.85$, standardized coefficient = 0.23). A change of 1 *SD* in the ratings of the parenting environment

was associated with a change of about 0.25 *SD* in planning gains.

Follow-Up Analyses

To find out whether the findings described above are specific to the ages in which constructs were measured, we used the same analytical models to examine the same constructs at different time points. Parenting and basic cognitive skills were assessed at first grade and the planning intercept was set at third grade. Table S4 in the online Supporting Information shows these findings. The follow-up analyses revealed that parenting quality and the basic cognitive skills (sustained attention, inhibition, and short-term memory) are significantly linked to the planning intercept (Estimate $\beta_0 = 1.01$, $\beta_0 = -0.18$, $\beta_0 = -0.05$, and $\beta_0 = 0.06$, respectively) and that the effect of maternal education on the planning intercept is partially mediated by a path through parenting quality, and then through the basic cognitive skills (Estimate $\beta_0 = 0.14$). We also found a statistically significant link between parenting quality and the slope of planning (Estimate $\beta_1 = 0.52$; standardized coefficient = 0.17). In addition, in the follow-up analyses we found an effect of sustained attention (errors of omission) on the slope of planning (Estimate $\beta_1 = -0.15$; standardized coefficient = -0.23). Moreover, we found a significant indirect effect from maternal education—through parenting quality and then through the three cognitive skills—on the planning intercept ($\beta_0 = 0.14$) and, within it, a statistically significant path from maternal education to parenting to sustained attention to the planning slope ($\beta_1 = 0.04$; standardized coefficient = 0.34). A change of 1 *SD* in the latter path was associated with 0.34 *SD* change in planning gains.

From the Planning Trajectory to the Trajectories of Reading and Mathematics

Primary Analyses

As can be seen in Table 3, the measurement models of reading and mathematics showed variation in their predicted random intercepts (β_0 set at third grade) and in the reading slope. Reading had a predicted mean intercept of 434.12. The predicted average slope was 39.80. The estimated time point for fifth grade was 0.31, indicating that growth slowed significantly in the third-to-fifth-grade timeframe relative to the earlier period. Mathematics scores had a mean predicted intercept of 447.80. The

Table 3
Mediated Predictors of Reading and Mathematics Achievement

	Reading intercept			Reading slope			Mathematics intercept		
	Est	SE	Stdzd Est	Est	SE	Stdzd Est	Est	SE	Stdzd Est
Fixed	434.12***	5.50	29.28	39.80***	11.29	4.03	447.80***	4.83	38.37
Random	126.00***	8.61	.57	87.53***	16.76	.90	60.68***	6.01	.45
Maternal education	.75***	.21	.13	-.08	.30	-.02	.57**	1.18	.12
Female	.39	.86	.01	-.77	1.69	-.04	-2.40**	.76	-.10
Non-European Americans	-.56	1.17	-.02	-.95	1.71	-.04	-.47	1.03	-.01
Parenting quality	2.32***	.71	.13	-1.47	1.21	-.13	1.83**	.62	.13
Sustained attention (omission errors)	.02	.07	.01	.08	.13	.06	-.01	.07	-.00
Inhibition (commission errors)	.02	.03	.02	-.01	.04	-.01	.01	.02	.02
Memory.Short.Term	.09**	.03	.12	.03	.05	.05	.06*	.03	.10
Crystallized intelligence	.27***	.04	.27	.03	.05	.05	.13***	.03	.17
Indirect eff. from Mat. Ed ^a	.15***	.04	.03	-.11	.11	.03	.21***	.05	.04
Mat.Ed.->Parntg->Att.Om.Err->P Incpt	.06**	.02	.01	-.04	.05	-.01	.02***	.01	.02
Mat.Ed.->Parntg->Inhibit.Com.Err->P Incpt	.03*	.01	.01	-.02	.03	-.01	.08*	.03	.01
Mat.Ed.->Parntg->Mem.Srt.Trm->P Incpt	.06*	.02	.01	-.04	.05	-.01	.08*	.03	.02
Planning intercept	.97***	.21	.26	-.70	.71	-.28	1.39***	.21	.47
Planning slope	—	—	—	.54	.98	.17			

Note. stdzd est = standardized estimate; Mat.Ed. = maternal education; Prntg = parenting; Att.Om.Err = sustained attention (omission errors); Inhibit.Com.Err = inhibition commission errors; Mem.Srt.Trm = short-term memory; P Incpt = planning intercept.

^aMaternal education, to parenting, to each of the three cognitive skills, to planning intercept to reading and mathematics intercept and to reading slope.

* $p < .05$. ** $p < .01$. *** $p \leq .001$.

estimated fixed slope was 23.60. We fixed this after preliminary estimates for the mathematics growth model indicated this measure did not display significant individual differences in the linear slopes. Finally, the estimated time point for fifth grade was 0.73, indicating slower growth between third and fifth grades than between first and third, but not as dramatic a slowdown as we found in reading.

In addition, the analyses revealed statistically significant indirect paths from maternal education—through parenting quality, each of the basic cognitive skills, and planning—to the reading and mathematics intercepts. The total indirect effects were $\beta_0 = 0.15$ and $\beta_0 = 0.21$ for the reading and mathematics outcomes, respectively. The bottom two rows of Table 3 show the unique contributions of the planning trajectories to the reading and mathematics trajectories. The analyses revealed statistically significant effects of the planning intercept on the reading and mathematics intercepts. That is, children with higher first-grade planning scores had higher third-grade reading scores (Estimate $\beta_0 = 0.97$) and mathematics scores (Estimate $\beta_0 = 1.39$). An increment of 1 SD in the planning intercept was associated with increments of 0.26 and 0.47 SD on the reading and mathematics intercepts, respectively. However, the planning random intercept and

slope did not significantly predict the random slope of reading. Because the slope for mathematics was fixed, we had no information about how a change in planning would predict a change in mathematics.

Table 3 also shows the effects of all of the other variables in the model on reading and mathematics trajectories. These other variables were included as control variables when estimating the effects of planning trajectories on reading and mathematics.

Follow-Up Analyses

Using the same analysis model, but with the parenting and cognitive skills variables measured in first grade and the reading and mathematics intercept fixed at fifth grade, we explored the relation between planning as measured at third grade and achievement (reading and mathematics) at fifth grade. Table S5 in the online Supporting Information shows our findings. The analyses revealed statistically significant effects of the planning intercept on the reading and mathematics intercepts. That is, children with higher third-grade planning scores had higher fifth-grade reading scores (Estimate $\beta_0 = 0.43$) and mathematics scores (Estimate $\beta_0 = 0.84$). An increment of 1 SD in the planning intercept scores

was associated with increments of 0.16 and 0.37 *SD* on the reading and mathematics intercepts, respectively. However, the planning intercept and slope did not significantly predict the slope of reading. As in the preceding analyses (in which parenting and basic cognitive skills were assessed when the children were 54 months of age), the follow-up analyses revealed statistically significant indirect paths from maternal education—through parenting, each of the basic cognitive skills, and planning—to the reading and mathematics intercepts. The total indirect effects were Estimate $\beta_0 = 0.06$ and $\beta_0 = 0.12$ for reading and mathematics outcomes, respectively.

Discussion

This study explored hypothesized mechanisms that support the development of planning during middle childhood and the role of planning in reading and mathematics achievement during the same developmental period. As predicted, children with better basic cognitive skills—short-term memory, ability to sustain attention and inhibit responding to nontarget stimuli—at 54 months of age were also better planners in subsequent years. Children's level of planning ability was not affected directly either by maternal education level or by a combination of the quality of the home environment and mothers' sensitivity (here combined and labeled "parenting"). Instead, these two predictors had their impact indirectly. Maternal education affected parenting, which in turn affected children's basic cognitive skills, which in turn affected planning level. Also as predicted, better parenting when the children were 4½ years old and in first grade was associated with faster improvement in planning over the period studied. Furthermore, at first grade, maternal education, through parenting and the three basic cognitive skills, predicted faster improvement in planning over time. The findings suggest the need to explore in detail which specific aspects of the family home and maternal sensitivity (together labeled "parenting") affect planning and the rate of its development. Such knowledge will guide the development of optimal interventions for increasing children's skills in a domain central to EF. While in this study we did not compare the role of parenting with the role of other environments such as those of child care or school, an earlier study by the NICHD Early Child Care Research Network (2005, Table 6 and follow-up analyses) suggests that within this sample of about a thousand children born in 1991, it is parenting rather

than the other social environments that affected planning in first grade.

As predicted, individual differences in planning were linked to later performance on reading and mathematics tests but contrary to predictions, planning was not linked to the pace of age-related changes in academic achievement. Considering that most of the growth in planning, reading, and mathematics occurred between first and third grades, it is possible that other analytical methods more sensitive to nonlinear individual growth would be able to support the latter prediction.

The highlight of this longitudinal study is the discovery of a mediational path that led from maternal education through parenting, through children's attention, inhibition, and verbal memory, to later planning, and from planning to still later academic performance. These findings were replicated when assessments of focal points in the path were anchored at later ages than in the original analysis. Our findings, in conjunction with earlier findings (NICHD Early Child Care Research Network, 2005), suggest that the continuity of the long-term effects of parenting in the first 4½ years of life is indirect when the outcome is planning. Parenting influences other earlier emerging processes that may be fundamental to the later emergence of planning. In their 2005 paper, the authors demonstrated that early parenting in the first 3 years of life is linked to attention, inhibition, and short-term memory at first grade but not to planning at first grade. But later parenting at 54 months and at first grade is linked to the above basic cognitive skills and to planning performance in first grade. This seeming discontinuity in parenting effects on planning is found even though the correlation between early and later parenting is high ($r = .72$). Therefore, the findings from the 2005 study and from this one suggest that continuity in the effects of parenting manifests itself indirectly. Our observed parenting effects on planning build on the earlier effects of parenting on basic cognitive skills. The findings about the indirect links extend the conceptualization and evidence reported by Fraley et al. (2013) who have demonstrated the direct short- and long-term effects of maternal sensitivity (a component of our parenting measure) on children's academic and social outcomes. Had they included basic cognitive skills in their model, they might have found the same indirect effects.

Our mediational analyses also revealed the differential routes by which maternal education impacts developmental outcomes. Maternal education is not linked directly to planning but indirectly through parenting and the three basic cognitive

skills. In contrast, there is both a direct link and an indirect link between maternal education and the reading and mathematics achievement outcomes.

The indirect pathways set the stage for consideration of a broad array of potential interventions. While our findings are correlational and cannot imply causal relations between the constructs under investigation, the study strongly suggests the possibility that interventions aimed at boosting children's cognitive and academic success may be particularly successful if they focus on the home environments that parents create, and on parenting behaviors that target emerging cognitive skills. This idea is supported by correlational research published over the past 50 years (Fraley et al., 2013; Shonkoff & Phillips, 2000). It is also supported by the results of rigorous early childhood interventions that have focused on parents as agents of change in their children's development (Karoly, Kilburn, & Cannon, 2005). Furthermore, our findings suggest the merit of focusing interventions directly on children and their cognitive skills, as has already been done in many cases (Campbell, Ramey, Pungello, Sparling, & Miller-Johnson, 2002; Diamond & Lee, 2011).

Our findings were based on data from a large longitudinal study incorporating many constructs and on analyses revealing the complex relations among them. However, the study has limitations that suggest further lines of research. The limitations pertain to the representativeness of the sample, the choice of constructs to incorporate into the paths to be examined, the concurrent assessment of parenting and basic cognitive skills, and the choice of specific measures.

The study sample was not nationally representative. Although one nationally representative study confirms linkages between planning and academic outcomes, the generalizability of the findings needs further investigation (Best, Miller, & Naglieri, 2011). Likewise, our sample was not sufficiently diverse economically and ethnically and included a relatively high mean level of maternal education, which may limit what we can say about the effects of maternal education in the population at large. It is noteworthy that despite this limitation, maternal education proved a direct predictor of children's academic performance in reading and mathematics. It is not unreasonable to infer that in a fully representative sampling design, the indirect links from maternal education to children's cognitive functioning would be as strong or stronger. Although the data set incorporated aspects of the home environment, an area that needs further examination is the role of personal characteristics such as perceived

control, and personal and cultural beliefs about the importance of planning (Diamond & Lee, 2011; Friedman & Scholnick, 1997).

Another limitation of the study is that it ignores the role of shared characteristics and environment between children and their parents (Keating, 2011). The direct and indirect links between maternal education and children's cognitive and academic outcomes could be partially due to such factors.

Measures of parenting and the basic cognitive skills used in the mediational model were assessed when the children were 54 months. It might be fruitful to incorporate parenting data from the first 36 months of the children's lives even though other results from the NICHD Study of Early Child Care and Youth Development (NICHD Early Child Care Research Network, 2003) suggest that our findings would have been very similar regardless of the timing at which parenting was assessed. The NICHD Early Child Care Research Network (2003, 2009) papers show that the effect of early parenting (measured at 6, 15, 24, 36, and 54 months of life, rather than only at 54 months of age, as was the case in our study) on 54-month and first-grade WJ-R achievement measures is mediated by Continuous Performance Task attention and inhibition measured at 54 months of age.

The construct validity of the tasks used to test our hypotheses should be considered. For example, the TOH planning strategies resemble the use of computational algorithms. The TOH structure is ideal for examining precursors to arithmetic. There are other more naturalistic planning tasks, such as those simulating scheduling errands and grocery shopping (Gauvain & Rogoff, 1989). There are other tower tasks such as the Tower of London. Performance on these tasks may not be highly correlated; different tasks may draw on other cognitive skills and they may be influenced by child or family characteristics that this study has not focused on (Bull, Espy, & Senn, 2004; Welsh, Satterlee-Cartmell, & Stine, 1999). Hence, we cannot discern whether a general planning ability is a correlate of academic performance or whether some specific feature of TOH performance, such as recursive subgoaling, accounts for the overlap between TOH performance and academic ability in our study.

Another example of a potential measurement issue was the use of the CPT to tap both sustained attention and inhibition. In our analyses, the impact of each was assessed independently from the impact of the other, but the impacts of these two constructs might have been different if separate instruments had been used for each construct.

Finally, the fact that our mediational hypotheses were supported by the data does not rule out the possibility of evaluating other paths.

Our research represents a broad, integrative look at the mechanisms of development for a key construct—planning. The unique properties of the NICHD Study of Early Child Care and Youth Development that include detailed observational and test data collected longitudinally from over a thousand families across the United States enabled us to take a wide-angle view. We found out how maternal education and parenting uniquely and simultaneously contribute to children's basic cognitive skills and how those skills uniquely and together affect a key EF skill, planning, which in turn affects academic performance.

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Supporting Information

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

Table S1. Means and (Standard Deviations) of Planning Scores by Task by Grade Level and Across Tasks

Table S2. Zero-Order Correlations Among Measures

Table S3. Links Between Maternal Education and Basic Cognitive Skills Mediated by Parenting

Table S4. Follow-Up Predictors of Planning

Table S5. Follow-Up Predictors of Reading and Mathematics