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# Growth of Cognitive Skills in Preschoolers: Impact of Sleep Habits and Learning-Related Behaviors

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*Research Findings:* The present study used a longitudinal design to identify how sleep habits and learning-related behaviors impact the development of cognitive skills in preschoolers (ages 3–5). Sixty- seven children with parental report and cognitive skill assessment data were included. Scores on the Differential Ability Scales (C. Elliott, 1990) were obtained at ages 3, 4, and 5. A Sleep Questionnaire (D. Gozal, 1998) with 12 items from the Child Behavior Checklist (T. M. Achenbach & L. A. Rescorla, 2000) related to children's attention and activity levels was administered at age 3. Growth curve changes in cognitive scores were estimated using hierarchical linear modeling. Parental reports of nighttime sleep duration predicted level of cognitive skills at 3 years. The effect of sleep duration on cognitive scores was constant across age. *Practice or Policy:* Sleep and learning-related behaviors distinguish the cognitive skills children bring to preschool programs and impact gains made in skills while in preschool.

Many preschools are increasing the academic orientation of their programs in response to research evidence documenting the importance of the skills developed in the preschool period for kindergarten readiness and success in primary grades. Yet the development of cognitive skills is influenced by a variety of factors in addition to the experiences children have in preschool classrooms. In a previous study, Molfese, Beswick, Molnar, Jacobi-Vessels, and Gozal (2007) found that parental

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reports about preschool children's sleep duration and problem behaviors in attention and activity level were related to gains the children made during the school year in letter knowledge. Four-year-olds who could identify 0 to 3 letters at school entry in the fall were included in the study. Those making small gains from fall to spring (3 letter names or fewer) were characterized by shorter nighttime sleep duration and multiple behaviors that parents rated as problematic compared to those children who made larger gains from fall to spring. The purpose of the present study was to determine how sleep habits and behavior characteristics of children influence the growth of general cognitive abilities from preschool entry to kindergarten entry.

The focus on sleep and behavior characteristics of preschoolers in this study was motivated by research findings showing a link between the types of sleep problems that are relatively common among young children (e.g., insufficient sleep, nighttime awakenings, bedtime resistance) and behaviors of the children when they are awake (e.g., activity level, sleepiness, attention, temperament, and behaviors in the classroom). Bates, Viken, Alexander, Beyers, and Stockton (2002) linked disrupted sleep with measures of school adjustment in Head Start preschoolers and found that this relation held even when measures of family stress and parenting behaviors, which can also influence sleep and behaviors, were held constant. Although sleep problems and learning-related behaviors may both reflect different aspects of a common underlying construct, the purpose of including these variables in this study was to determine how they influence growth rather than concurrent measures of cognitive skills.



The importance of sleep has become a growing interest of researchers studying early learning. Although little is known about how much sleep is required by children or adults, it is known that from birth through the preschool period, children spend a significant portion of time asleep, and they require more sleep than adults do. On average, 3- to 6-year-old children sleep 10 to 12 hr during nighttime hours (Bates et al., 2002; National Sleep Foundation, 2004; Thiedke, 2001). There is evidence that young children are getting insufficient amounts of sleep as well as evidence that children whose sleep is insufficient may experience behavioral and neurocognitive sequelae (Archbold, Giordani, Ruzicka, & Chervin, 2004; Sadeh, Gruber, & Raviv, 2003; for reviews, see Bluden, Lushington, & Kennedy, 2001; O'Brien & Gozal, 2004). For example, Ali, Pitson, and Stradling (1993) studied 4- and 5-year-olds from a general clinical sample and found that teachers and parents rated children with high scores on daytime sleepiness, habitual snoring, and restless sleep as more hyperactive and inattentive than children without those characteristics.

Sleep insufficiency may arise from a child's resistance to going to bed/sleep, nighttime awakenings that require parental interactions, difficulty initiating or maintaining sleep, fears associated with sleeping, and lack of sufficient sleep time arising from the child's sleep schedule. It has been reported that 20% to 30% of preschool children are characterized by sleep problems such as these and that young children from families of low socioeconomic status and families with high stress indicators (e.g., loss, illness, relocation, emotional turmoil) have a higher reported rate of sleep problems (Sadeh et al., 2003; Stein, Mendelsohn, Obermeyer, Amromin, & Benca, 2001). Children characterized by sleep problems in the infancy/toddler period also are likely to have continuing problems in the preschool period. For example, Zuckerman, Stevenson, and Bailey (1987) reported that sleep problems identified at 8 months of age were still seen in 41% of children at 3 years of age compared to 26% of children with no sleep problems at 8 months who also evidenced sleep problems at 3 years of age. Children with continuing sleep problems are often characterized as also having behavior problems (such as tantrums) and behavior management problems compared to children without persistent sleep problems. Lam, Hiscock, and Wake (2003) studied the effects of teaching parents a behavioral sleep intervention in infancy on persistence of sleep problems at preschool age. They found that 32% of 3- to 4-year-old children who had sleep problems in infancy were reported as having a persisting sleep problem (12%) or recurring sleep problems (19%). The persistence of sleep problems was not predicted from measures obtained in infancy, but concurrent measures of sleep problems and behavior problems on the Child Behavior Checklist (CBCL; aggression and somatic scores) were correlated, as were measures of sleep problems and maternal depression and reported problems with partners in managing children's behaviors. Although the authors noted that most sleep problems in infancy do resolve, sleep problems returned in the preschool period for about 20% of children studied. Sadeh, Gruber, and Raviv (2002) reported that sleep disruption is strongly and negatively correlated with performance on measures of executive function (e.g., measures of focus and sustained attention) as well as on total problem behaviors on the CBCL in school-age children as young as second grade. These researchers linked performance on measures of neurobehavioral functioning to the impact of sleepiness and daytime alertness due to sleep problems.

Many of the behaviors impacted by sleep problems are important for learning in the classroom. These "learning-related behaviors," which include behaviors such as listening, following directions, staying on task, self-regulation, and cooperation, are important for learning in preschool (McClelland & Morrison, 2003). McClelland, Morrison, and Holmes (2000) studied a sample of kindergarten children with poor teacher ratings on learning-related behaviors. The learning-related behaviors predicted children's kindergarten skills in various areas, including letter knowledge, vocabulary, and early reading skills, above and beyond what was predicted by child, family, and sociocultural variables. Lonigan and colleagues (1999) also found that parental reports of preschool children's impulse and attention problems were related to growth in emergent literacy skills. Based on these findings, and on our previous findings that environmental characteristics impact the growth in intelligence scores of children 3 to 6 years (Espy, Molfese, & DiLalla, 2001), we expected that general cognitive abilities also might be impacted and that children's potential ability to learn from their social and cognitive interactions may be impacted. Specifically, we expected that children entering preschool with parental reports of sleep insufficiencies and learning-related problem behaviors would have lower general cognitive abilities in preschool and kindergarten compared to children not characterized by sleep insufficiencies and problem behaviors.

The focus of this study was on children attending public preschool programs for children at risk for school achievement due to poverty. Both cognitive development and classroom behaviors of preschool children have been found to be impacted by family income and poverty status (Duncan, Brooks-Gunn, & Klebanov, 1994). Although significant gains in language, mathematics, writing, and social skills have been reported for children from low-income homes participating in preschool education programs, persistent gaps in skills have been reported at kindergarten entry (Head Start Impact Study, 2005; U.S. Department of Health and Human Services, 2001). Under study here was how the growth of cognitive skills of these at-risk children attending public preschool programs is influenced by sleep problems and learning-related behaviors, as individual variables or in combination, that may interfere with learning compared to their classmates without similar characteristics.



In the study reported here, a screening approach was used to identify children whose sleep habits and learning-related behaviors may place them at risk for learning difficulties in preschool classrooms. Parental reports can provide information to teachers that may help them in monitoring children's progress on learning objectives (Cadman, Walter, Chambers, et al., 1988; Glascoe, 2000; Lichtenstein, 1984). In the present study, parental reports of children's sleep and learning-related problem behaviors at preschool entry were studied in relation to initial status and growth in general cognitive abilities from preschool through kindergarten. To gauge general cognitive abilities, children's performance on verbal (e.g., Naming Vocabulary, Verbal Comprehension) and nonverbal/performance (e.g., Picture Similarities) was measured at 3, 4, and 5 years of age. Based on the empirical and theoretical literature, it was anticipated that children's cognitive skills development would be systematically influenced by their sleep habits and learning-related behaviors. Thus, we focused on two research questions:

1. How do cognitive skills among preschoolers at school entry vary by sleep habits and learning-related behaviors?
2. How does the growth of cognitive skills in preschoolers vary over time by sleep habits and learning-related behaviors?

## METHOD

This study was approved by the University of Louisville Institutional Review Board. Parents of participants provided informed consent for the parent–child dyad to participate in the study, and the child provided assent to participate.

## Participants

A total of 67 typically developing children (37 girls and 30 boys) with parental report and cognitive skills assessment data were included. Children participated in the study from preschool entry at age 3 until entry into kindergarten at age 5. Participants with data on the study variables were drawn from a database of 138 children (71 girls and 67 boys) participating in studies of cognitive development in children attending public preschool programs that enroll economically disadvantaged or developmentally at-risk children. These preschool programs were full day and were located in elementary schools in one school district. District-wide enrollment in these academically oriented preschool programs was 91% based on family income eligibility, and the ethnic distribution was >80% Caucasian, <10% African American, 3% Hispanic, 1% to 2% Asian, and <6% other. All families participating in the study met the definition of poverty in the district based on family income. The preschool lead teachers were female, with an average of 9.63 years of teaching experience (*SD* = 6.46, range = 3–17). At the time this study was conducted, preschool lead teachers were not required to be certified. Teachers in four classrooms had bachelor's degrees in early childhood education, and teachers in four classrooms had no college degree (<4 years of college).

The recruitment process involved contacting the parents for consent to participate, their agreement to respond to questionnaires sent to them by mail, and their agreement to allow their child to participate. Parents provided information at the time of their child's entry into the pre-kindergarten program (which was age 3–4 depending of the child's birth date and the cutoff for school entry). Mothers' education levels ranged from non-completion of high school to some college-level education, with about 62.7% of mothers having education below high school completion. Data for the other 71 children in the database were not available on the variables under study, so these children were not included in the analyses. The primary reasons for incomplete data were the following: The family did not return completed questionnaires and did not respond to follow-up requests for information, the family moved and the child was no longer in the class, or the child did not assent to participate in assessments. Those 71 children were not different from the 67 who were included in the study on average cognitive abilities scores, gender, or age. Descriptive statistics for the participants are shown in Table 1.

## Measures

To obtain scores for general cognitive abilities, sleep habits, and learning-related behaviors, scores on (a) General Conceptual Ability (GCA) from the Differential Ability Scales (DAS; Elliott, 1990), (b) the Sleep Questionnaire (Gozal, 1998), and (c) selected items from the CBCL (Achenbach & Rescorla, 2000) were obtained. In addition, information from a family background questionnaire was used

TABLE 1
Sample Description

| *Family or Child Characteristic* | % | *M* | *SD* | *Range* |
|---|---|---|---|---|
| Maternal characteristics | | | | |
| Education in years | | 2.42 | 0.721 | 1–4 |
| Below high school completion (%) | 62.7 | | | |
| Some college (%) | 37.3 | | | |
| Child characteristics | | | | |
| Age in months[a] | | | | |
| 3-year-olds[b] | | 42.12 | 3.26 | 36–47 |
| 4-year-olds[c] | | 53.59 | 3.31 | 47–59 |
| 5-year-olds[d] | | 65.45 | 3.64 | 60–71 |
| Gender (% male) | 45 | | | |
| Race (% minority) | 9 | | | |
| Sleep duration (%) | | | | |
| Between 8–9 and 10–11 hr | | | | |
| Less than 8–9 hr | 59.7 | | | |
| More than 10–11 hr | 40.3 | | | |
| Between 6–7 and 8–9 hr | | | | |
| Less than 6–7 hr | 12 | | | |
| More than 8–9 hr | 88 | | | |
| Sleep problems | | 55.41 | 9.22 | 38–93 |
| Learning-related behaviors | | 28.70 | 3.28 | 21–36 |
| Cognitive ability scores | | | | |
| GCA, 3 years | | 198.29 | 42.92 | 99–277 |
| Verbal comprehension | | 81.05 | 19.46 | 39–124 |
| Picture similarities | | 53.88 | 12.86 | 18–79 |
| Naming vocabulary | | 63.36 | 0.74 | 10–108 |
| GCA, 4 years | | 254.44 | 37.35 | 174–325 |
| Verbal comprehension | | 98.03 | 18.43 | 45–100 |
| Picture similarities | | 69.59 | 11.06 | 45–100 |
| Naming vocabulary | | 86.82 | 14.37 | 57–119 |
| GCA, 5 years | | 300.82 | 42.15 | 194–338 |
| Verbal comprehension | | 116.91 | 17.11 | 74–131 |
| Picture similarities | | 78.00 | 12.68 | 45–90 |
| Naming vocabulary | | 105.91 | 15.86 | 75–125 |

*Note.* GCA = General Conceptual Ability.
[a]$N = 67$. [b]$n = 42$. [c]$n = 63$. [d]$n = 33$.

for descriptive purposes. Responses to the Sleep Questionnaire on sleep habits and learning-related behaviors were obtained at school entry at age 3.

*GCA.* Scores for the GCA were obtained using the Preschool Level of the scale for children from 3.0 through 5.11 years old. The DAS includes assessments of Verbal Abilities (Verbal Comprehension and Naming Vocabulary), Nonverbal Abilities (Block Building, Picture Similarities, Pattern Construction, and

Copying), and Early Number Concepts. Because the measures used to derive the GCA differ depending on the age range, only the common subscales of Verbal and Nonverbal Abilities across the age range were used. These consisted of Verbal Comprehension, Naming Vocabulary, and Picture Similarities, and these were used to obtain GCA scores.

GCA was measured in the fall of each year when the children were 3, 4, and 5 years old. Preschool-level test–retest reliabilities over a period averaging 30 days are reported to range from .90 to .94. The criterion-related validity of the Preschool Level of the DAS GCA was reported against the Stanford-Binet: Fourth Edition Composite (Thorndike, Hagen, & Sattler, 1986), with which it correlated .77; and against the Wechsler Preschool and Primary Scale of Intelligence (Wechsler, 1989), with which it correlated .89 (Elliott, 1990, DAS Examiner's Manual).



*Sleep Questionnaire.* The Sleep Questionnaire (Gozal, 1998) contains a series of parental report questions pertaining to sleep habits, childhood illnesses, and behavior problems. This instrument has been extensively validated with a low-income population in the same school district from which the current sample was drawn (Montgomery-Downs, O'Brien, Holbrook, & Gozal, 2004) and who had educational characteristics similar to those of the families sampled in the current study. For the purposes of the present study, only selected questions from the full questionnaire that was administered were used; these are described below.

Items on the Sleep Questionnaire asked parents to report on how long their child slept at night on average (4–5 hr, 6–7 hr, 8–9 hr, 10–11 hr, more than 11 hr) and if their child had sleep problems (response options ranging from 0 to 5). Sleep duration was dummy-coded as 6–7 hr or less (= 0) and 8–9 hr or more (= 1). In addition, for an in-depth analysis, sleep duration was additionally dummy-coded as less than 8–9 hr (= 0) or more than 10 hr (= 1). This was done to find out if there were significant differences in impacts on the cognitive development of preschoolers for sleep durations of less than 6–7 hr, less than 8–9 hr, and more than 10 hr. Each sleep problem question included a 5-point scale (never, rarely, occasionally, frequently, and almost always). Sleep problems were measured using the summed scores for the sleep problem questions (e.g., "Does your child struggle to breathe while asleep?" "Do your child's lips ever turn blue or purple while asleep?"). Scoring was based on the described sleep problems: *never* = 1 point, *rarely* = 2, *occasionally* = 3, *frequently* = 4, and *almost always* = 5.

*CBCL.* Also included on the Sleep Questionnaire were 12 questions from the CBCL (Achenbach & Rescorla, 2000) that asked parents to report about their child's behaviors. The reason for selecting just a few items from this widely used scale with well-established psychometric properties (reliability across 8 days = .90 for Total Problems; convergent validity with other preschool behavior checklists, range = .46–.77; Achenbach & Rescorla, 2000) was twofold: to enable a small number of items to be used that focused on behaviors that have been found in previous research to be correlates of sleep problems (Sadeh et al., 2003) and/or reflected learning-related behaviors described by others (McClelland & Morrison, 2003, McClelland et al., 2000). The 12 selected questions asked about the child's concentration, hyperactivity, confused behaviors, involvement with others, predictability of behaviors, frustration tolerance, cooperation, and energy level. Each question included a 3-point scale (very true, somewhat or sometimes true, and not true). Scoring was based on the described behaviors being *very true* = 2 points, *somewhat or sometimes true* = 1, and *not true* = 0. In Table 1, means and standard deviations on this measure for the sample are shown.



### Procedure

At the start of school in the fall, parents of children participating in preschool programs at four schools were sent a letter requesting their child's participation in the study. Those families returning consent letters (92% of the total sample) were sent packets with family background and sleep questionnaires to complete and return by mail. Forty-nine percent of the total sample returned complete packets of questionnaires and had children who participated in the behavioral assessments across three measurement points; this comprised the research sample. All the questionnaires included in the packets have been used successfully in our previous research with samples having the same demographic characteristics (Molfese, Molfese, Modglin, Walker, & Neamon, 2004; Montgomery-Downs, Jones, Molfese, & Gozal, 2003). The packets were only sent to families at enrollment due to funding limitations. The DAS was administered between October and November. Each child was tested individually by trained researchers at school in a room near the child's classroom. Children received a gift bag and stickers for their participation.

### Analysis

Using hierarchical linear modeling (HLM; Raudenbush & Bryk, 2002), we estimated growth curves based on standardized scores for the outcome measure. HLM is recognized as a standard program for estimating multilevel models (Raudenbush & Bryk, 2002; Raudenbush, Bryk, Cheong, & Congdon, 2000). In growth curve modeling, longitudinal observations are nested within individuals. Level 1 (within-person) variables are scores within individuals on an outcome variable at different points in time. Level 2 (between-person) variables are characteristics of individuals that may affect an individual's change in the outcome variable over time. The first step in the growth curve modeling in this study was to specify the within-person model to determine the growth pattern in the GCA scores. To estimate the parameters of the within-person model, individual growth curves were calculated by regressing the GCA scores on age. The analyses showed that the growth pattern followed a linear function. Figure 1 presents the linear growth on the outcome (GCA).

After the within-person model was specified, we used individual-level characteristics to model the coefficients. To see which between-person characteristics helped to explain variation in the growth curve coefficients, we included three composite variables based upon the literature review and the research questions: children's sleep habits (sleep duration and sleep problems) and learning-related behaviors. Time 1 (age 3) was recoded to 0, Time 2 (age 4) to 1, and Time 3 (age 5) to 2 so that the intercept in HLM represented the cognitive skills for the first year of preschool. In addition, aspects of individual characteristics such as gender (0 = male, 1 = female), race (0 = minority, 1 = White), and the continuous measure for the child's age at Time 0 were included in the analysis.

With growth modeling, we can estimate models that fit data structures. In our study, in which each child had his or her unique data collection schedule and some of the children had some missing data, the number of time points varied across children from one to three time points, and the spacing of the follow-up waves in months was not exactly the same. With HLM, we could reasonably estimate a growth curve even when individuals' data were missing at any of the time points. Furthermore, another advantage of using HLM in growth curve modeling is that the observations do not have to be conducted at the same time across individuals (Raudenbush & Bryk, 2002). For the centering point decision, age was centered at Time 0 (age 3) since the data collection began at age 3, the information obtained at age 3 was used, and all the participating children had data at Time 0 (Raudenbush & Bryk, 2002).



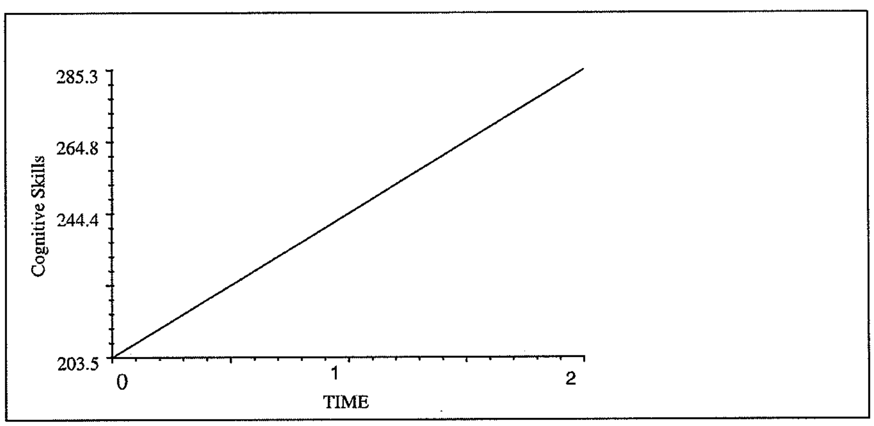


FIGURE 1 Growth of composite General Conceptual Ability scores derived from Naming Vocabulary, Verbal Comprehension, and Picture Similarities over time.

## RESULTS

The outcome measure was GCA scores. These scores can be created using different approaches. Standardized scores are frequently used to describe intellectual abilities for comparisons across groups. Standardized scores can be created from raw scores using the DAS conceptual ability score metric (Elliott, 1990). Raw scores or calculated ability scores can also be used to investigate individual differences in cognitive growth (Espy et al., 2001). These ability (raw) scores can be calculated by taking the sum of the scores on individual items on the Verbal and Nonverbal Abilities Subscales (Naming Vocabulary, Verbal Comprehension, and Picture Similarities) to create a composite GCA. In the analyses, we used both standardized scores and ability scores of the GCA composite measure; however, the results and the patterns of the growth were similar. This is shown in Table 2, which presents the results of the conditional models for standardized and ability scores as a function of sleep habits and



TABLE 2
Results of the Conditional Models for Composite GCA Ability (Raw) and Standardized Scores

| *Variable* | *Coefficient* | *SE* | *t Ratio* | *df* | *p* |
|---|---|---|---|---|---|
| Composite GCA ability scores | | | | | |
| Effects for intercept | | | | | |
| Intercept | 211.040 | 16.058 | 13.143 | 63 | .000 |
| Nighttime sleep[a] | 35.531 | 17.025 | 2.087 | 63 | .041 |
| Sleep problem | −0.804 | 0.471 | −1.706 | 63 | .092 |
| Learning-related behavior | 3.477 | 1.692 | 2.184 | 63 | .033 |
| Effects for slope | | | | | |
| Intercept | 15.781 | 27.369 | 0.577 | 63 | .566 |
| Nighttime sleep[a] | 25.464 | 28.439 | 0.895 | 63 | .374 |
| Sleep problem | 0.198 | 0.476 | 0.416 | 63 | .678 |
| Learning-related behavior | −0.192 | 1.250 | −0.154 | 63 | .879 |
| Composite standardized scores | | | | | |
| Effects for intercept | | | | | |
| Intercept | −0.397 | 0.235 | −1.692 | 63 | .095 |
| Nighttime sleep[a] | 0.519 | 0.249 | 2.087 | 63 | .041 |
| Sleep problem | −0.108 | 0.064 | −1.706 | 63 | .092 |
| Learning-related behavior | 0.167 | 0.076 | 2.183 | 63 | .033 |
| Effects for slope | | | | | |
| Intercept | 0.231 | 0.400 | 0.577 | 63 | .566 |
| Nighttime sleep[a] | 0.372 | 0.416 | 0.896 | 63 | .374 |
| Sleep problem | 0.027 | 0.064 | 0.415 | 63 | .679 |
| Learning-related behavior | −0.009 | 0.060 | −0.156 | 63 | .877 |

*Note.* GCA = General Conceptual Ability.
[a]Nighttime represents 8 hr or more sleep at age 3.

learning-related behaviors. Further results of the analyses are reported here using ability scores.

To answer the research questions concerning cognitive skills among preschoolers at school entry and growth over time by sleep habits and learning-related behaviors, we first specified the within-person model with no predictors. The reliabilities of the intercept (GCA scores at age 3) and the linear growth term were 0.597 and 0.540, respectively. Raudenbush et al. (2000) indicated that any coefficient that has reliability in HLM analysis below 0.1 is problematic. Thus, we had sufficient reliability to apply the analyses. The analyses revealed that preschoolers' scores at the first year of preschool significantly varied between individuals ($p < .0001$), and the slope (their growth) significantly varied between individuals ($p < .0001$). The fixed-effects result with robust standard errors showed that, on average, preschoolers had a score of 241.73 on the GCA measure in the first year of preschool. With each year, their GCA increased, on average, by scores of 40.89 points. Results for the unconditional model are presented in Table 3.

Once a within-person model was specified, the research question that asked how the growth of cognitive skills in preschoolers varies over time by sleep habits and learning-related behaviors was addressed. We used individual-level characteristics to model the intercept and the slopes. In modeling the intercept, we were interested in testing which characteristics of individual children affected where they started out on GCA. In modeling the slopes, we were interested in testing which characteristics of individual children put them on different growth trajectories. In these analyses, we used the same predictors (gender, race, sleep duration, sleep problems, and learning-related behaviors) for the intercept and slopes. The Level 2 coefficients modeling the intercept showed that children were not different in their cognitive ability at age 3 by gender or race, and there were no significant between-person variables. Therefore, gender and race were deleted from further inclusion in the conditional analyses to estimate the remaining effects more precisely.

The Level 2 coefficients modeling the intercept showed that when we used sleep duration, sleep problems, and learning-related behaviors as predictors, children had a score of 211.04 on GCA at age 3. The positive coefficient related to the linear term indicated that, on average, children's GCA scores increased at a stable rate over time. In terms of the linear term in the model, children who had 8 hr or

TABLE 3
Results of the Unconditional Model

| *Outcome* | *Coefficient* | *SE* | *t Ratio* | *df* | *p* |
|---|---|---|---|---|---|
| Composite General Conceptual Ability Scores | | | | | |
| Average initial status | 241.733 | 5.58 | 43.286 | 66 | .000 |
| Average year growth rate | 40.885 | 7.436 | 5.544 | 66 | .000 |

more of sleep had significantly higher GCA scores than those children with 7 hr or less of sleep by 35.53 points ($p < .05$) at age 3. This result is graphically illustrated in Figure 2. The level of sleep problems also had an effect on GCA scores, but the effect was not significant. Children with fewer behavior problems had significantly higher GCA scores by 3.48 points ($p < .05$) at age 3. This result is graphically illustrated in Figure 3. This conditional model using sleep duration, sleep

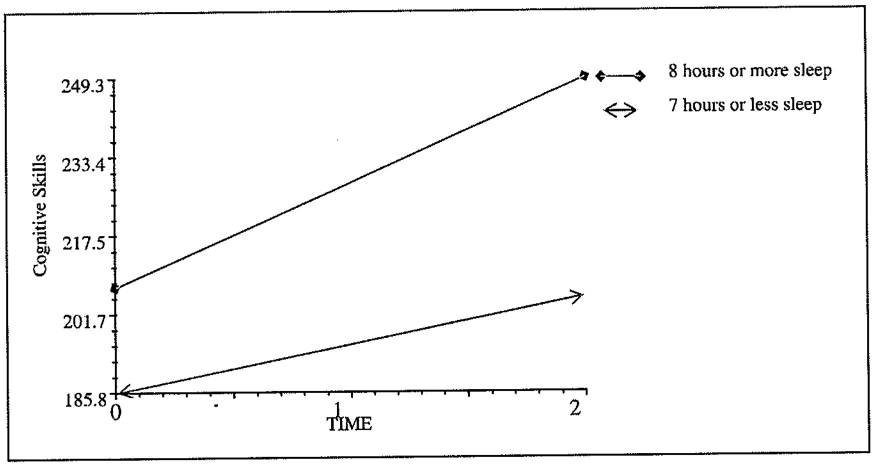


FIGURE 2 Growth trajectory of cognitive skills as a function of 8 hr or more sleep.

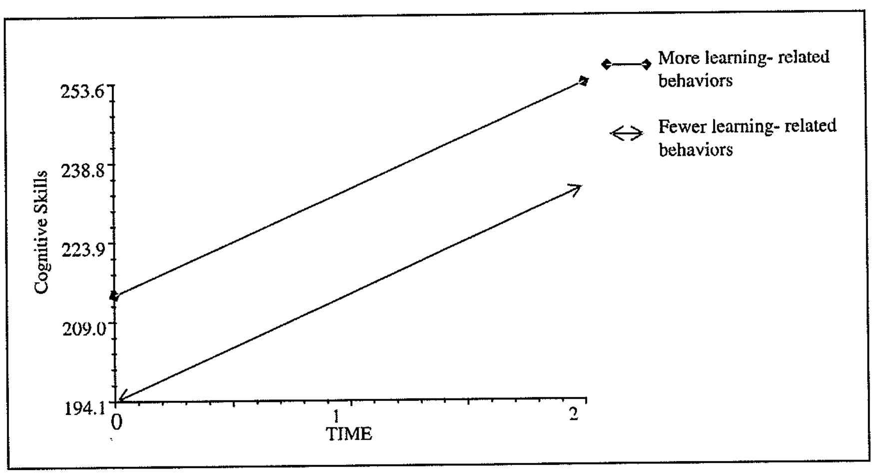


FIGURE 3 Growth trajectory of cognitive skills as a function of learning-related behaviors. Stronger learning-related behavior indicates +2.296 from a mean of 0 (75th percentile) and weaker learning-related behavior indicates −2.705 from a mean of 0 (25th percentile) of participants' learning-related behaviors scores.

problems, and learning-related behavior as children's characteristics accounted for 25.30% of the explainable variability in the growth model of cognitive abilities. Sleep problems was deleted from further inclusion in the conditional analyses to estimate the remaining effects more precisely.

Therefore, the Level 2 coefficients modeling the intercept showed that, on average, those children who had more than 8 hr of sleep and stronger learning-related behavior performed better as 3-year-olds than did those who had 7 hr or less of sleep and weak learning-related behaviors. Growth of GCA scores also reflected cognitive skill gains in linear growth terms for children in relation to sleep habits and learning-related behaviors. That is, given the linear growth pattern on the outcomes in the analyses, those who slept more than 8 hr and had strong learning-related behaviors on average increased their cognitive skills constantly over time. At age 5, the GCA scores of children who scored high at age 3 were still high. This result is graphically illustrated in Figure 4.

To further examine differences among children, we conducted several supplementary analyses in which only sleep duration and learning-related behaviors were used as predictors since sleep problems was not found to be a significant predictor. These were done to isolate the effect of the three combined predictors (sleep duration, learning-related behaviors, and sleep problems) from that of each predictor

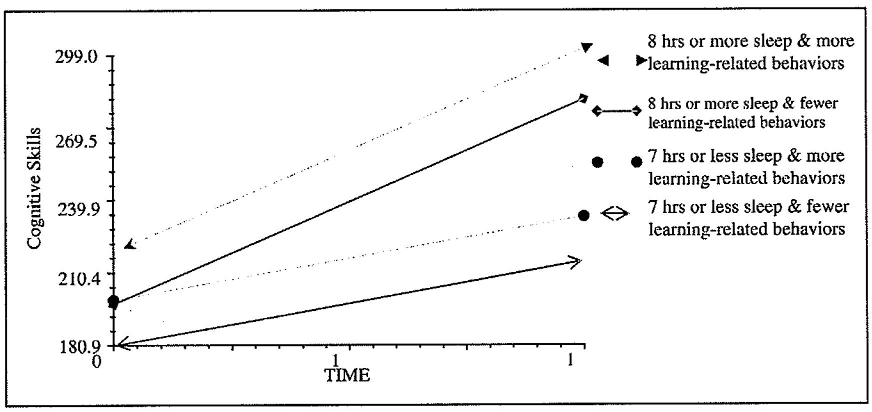


FIGURE 4 Growth trajectory of cognitive skills as a function of hours of sleep and learning-related behaviors. Note that 8 hr or more sleep & more learning-related behaviors indicates more than 8 hr of nighttime sleep and +2.295 from a mean of 0 (75th percentile) of participants' leaning-related behavior scores; 8 hr or more sleep & fewer learning-related behaviors indicates more than 8 hr of nighttime sleep and –2.705 from a mean of 0 (25th percentile) of participants' learning-related behaviors; 7 hr or less sleep & more learning-related behaviors indicates less than 7 hr of nighttime sleep and +2.295 from a mean of 0 (75th percentile) of participants' learning-related behavior scores; 7 hr or less sleep & fewer learning-related behaviors indicates less than 7 hr of nighttime sleep and –2.705 from a mean of 0 (25th percentile) of participants' learning-related behavior scores.

and from that of the two combined predictors (sleep duration and learning-related behaviors). We reasoned that if the results from those individual predictors and the two predictors versus all three combined predictors did not change much, this would be evidence of the effect of each predictor on cognitive skills. There was a slight change in the regression weight for the difference from combined model to models with individual predictors and two predictors, yet the same patterns of results were obtained whether predictors were combined, used individually, or used as a set of two predictors for GCA cognitive skills. As addressed previously, the result of each analysis is shown in Tables 2 and 4 and in Figures 2, 3, and 4.

A further investigation into differences between 10 hr and more of sleep versus 8–9 hr or less of sleep revealed an important finding. Children with more than 10 hr of sleep had higher GCA scores at age 3 compared to children with 8–9 hr or less of sleep (233.91 vs. 203.92, respectively). With each year, children's cognitive skill scores significantly and constantly increased for both groups with similar changes in GCA growth. Growth of GCA was linear and positive in slope for both groups. The results are shown in Table 5 and Figure 5.



## DISCUSSION

Preschool proficiencies have been found to significantly impact subsequent school performance (Denton & West, 2002). Reports of persistent gaps in school readi-

TABLE 4
Results of Supplementary Analyses

| | *Model 1* | | *Model 2* | | *Model 3* | | *Model 4* | |
|---|---|---|---|---|---|---|---|---|
| *Effect* | *Coefficient* | *SE* | *Coefficient* | *SE* | *Coefficient* | *SE* | *Coefficient* | *SE* |
| Intercept | 241.81** | 5.10 | 203.92** | 16.20 | 242.13** | 5.31 | 242.46** | 5.33 |
| Nighttime sleep | 39.76* | 17.88 | 42.62* | 17.18 | | | | |
| Sleep problems | | | | | | | −1.12 | 0.59 |
| Learning-related behavior | 3.65* | 1.63 | | | 3.89* | 1.64 | | |
| Slope | 38.56** | 7.42 | 19.40** | 21.72 | 39.87** | 7.46 | 40.26** | 7.54 |
| Nighttime sleep | 24.45 | 27.47 | 22.76 | 26.23 | | | | |
| Sleep problems | | | | | | | −0.01 | 0.47 |
| Learning-related behavior | −0.05 | 1.22 | | | −0.109 | 1.13 | | |

*Note.* Model 1: sleep duration and learning-related behaviors as predictor variables (grand-mean centered, as they were continuous variables). Model 2: nighttime sleep only as a predictor variable (un-centered, as it was a categorical variable). Model 3: sleep problems only as a predictor variable (grand-mean centered, as it was a continuous variable). Model 4: learning-related behaviors only as a predictor variable (grand-mean centered, as it was a continuous variable).

*$p < .05$. **$p < .0001$.

TABLE 5
Results of Sleep Duration (10 hr or More vs. 9 hr or Less) for GCA Scores

| *Variable* | *Coefficient* | *SE* | *t Ratio* | *df* | *p* |
|---|---|---|---|---|---|
| Composite GCA scores | | | | | |
| Intercept | 203.92 | 17.775 | 11.473 | 65 | .000 |
| Nighttime sleep (9 hr or less) | 42.615 | 18.619 | 2.289 | 65 | .025 |
| Slope | | | | | |
| Intercept | 19.404 | 25.102 | 0.773 | 65 | .442 |
| Nighttime sleep (9 hr or less) | 22.757 | 26.227 | 0.868 | 65 | .389 |
| Composite GCA scores | | | | | |
| Intercept | 233.913 | 7.166 | 32.64 | 65 | .000 |
| Nighttime sleep (10 hr or more) | 19.706 | 11.090 | 1.777 | 65 | .080 |
| Slope | | | | | |
| Intercept | 33.011 | 11.441 | 2.885 | 65 | .006 |
| Nighttime sleep (10 hr or more) | 19.514 | 12.664 | 1.541 | 65 | .128 |

*Note.* GCA = General Conceptual Ability.

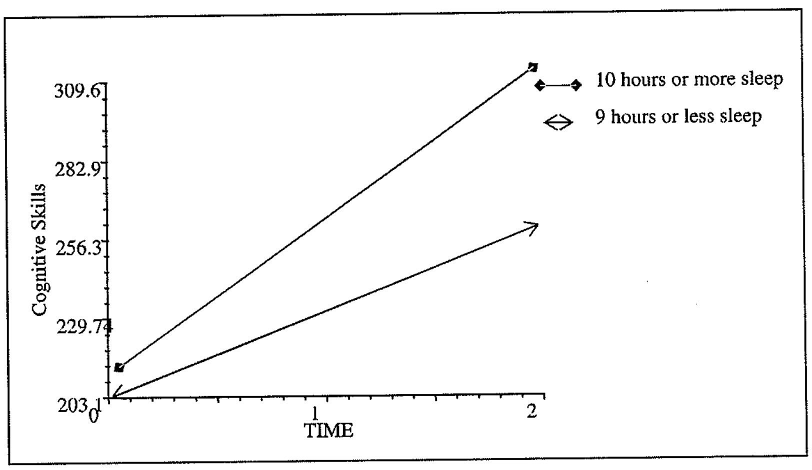


FIGURE 5 Growth trajectory of cognitive skills as a function of 10 hr or more sleep.

ness skills at kindergarten entry that characterize children from low-income homes are giving rise to research seeking to better understand why some but not all children benefit from participation in academically oriented public preschool programs. In the present study, sleep habits and learning-related behaviors that have been found to influence preschool children's behaviors and cognitive skills were investigated for their impact on growth of cognitive skills. We used a longitudinal design to study the hypothesized impact of sleep habits and learning-related behaviors on the growth of cognitive skills during the preschool years (ages 3–5). At preschool entry, 3-year-olds with various characteristics related to sleep duration, sleep problems, and learning-related behaviors were identified from parental reports and their general cognitive abilities measured over a 3-year period. In addition, child characteristics, such as gender and race, were examined. We were particularly interested in investigating the types of characteristics of children that have been found to influence early cognitive skills and that can be ascertained using parental report methods.

The results support hypothesized relations between measures of sleep habits as reported by parents and cognitive skills at preschool entry at age 3. Children who were reported to have 8 hr or more of nighttime sleep had significantly higher cognitive scores than did children with 7 hr or less of sleep. It also was found that children with more than 10 hr of sleep showed a pattern of higher cognitive skills at school entry than did children with 9 hr or less of sleep. It is important to note that greater amounts of sleep did not significantly predict individual variability in the growth rate (e.g., children with more sleep did not have steeper growth curves), but children with more sleep did have significantly higher GCA scores at age 3, and these scores showed constant growth over time, resulting in children with more sleep having higher GCA scores at age 5. One interpretation of this finding is that for 3-year-old children, having at least 8 hr of sleep might be desirable and more than 10 hr of sleep optimal for the development of cognitive skills.



These sleep findings are relevant to those reported by Bates et al. (2002) in a study of Head Start preschool children. In that study, the average amount of reported nighttime sleep was more than 10 hr. In the present study, children's amount of nighttime sleep was generally lower. Sixty percent of the children were reported to be getting less than 8–9 hr, and 12% of the sample was getting less than 6–7 hr of nighttime sleep. However, correlations between nighttime sleep duration and children's school behaviors as reported by teachers and parents in the Bates et al. study, and correlations between nighttime sleep duration and the development of cognitive skills in the present study, show that getting more sleep is related to more positive child measures.

The present study also found that children with stronger learning-related behaviors at age 3 had significantly higher cognitive scores at the outset and over time. These findings from the behavioral measures and those from the sleep measures point to the roles played by behavioral and physiological mechanisms that support the attention skills needed for learning in general and may also be attributable to learning in preschool programs. Those children who are tired, inattentive, and restless, because of either sleep habits or the presence of less developed learning-related behaviors or both, may be less able to participate in the learning opportunities available in their preschool classrooms that are intended to facilitate the development of cognitive skills.

Growth of GCA scores reflected cognitive skill gains in linear growth for children in relation to sleep habits, learning-related social skills, and combinations of both variables. Children who enter preschool with good sleep habits, strong learning-related behaviors, or both show growth in cognitive skills, and they achieve more gains in cognitive scores than do children with poorer sleep habits, poorer learning-related behaviors, or both. By 5 years of age, the cognitive scores of these children are still higher than those of children with poorer sleep habits and learning-related behaviors. Sleep and learning behaviors distinguish the cognitive skills children bring to preschool programs and impact gains they make in skills while in preschool.

This study is among the few reports linking sleep and other behaviors of preschool children to measures of cognitive skills. One other is our earlier report (Molfese et al., 2007), which found that parental reports about their preschool children's sleep and problem behaviors are related to preschool children's letter knowledge, an emergent literacy skill that is highly predictive of conventional reading skills at school age (Shanahan et al., 2004). Findings from sleep studies reported for older children support a link between sleep problems (e.g., sleep apnea, symptoms of obstructive sleep disorders [snoring, breathing difficulties]) and poor academic performance (Gozal, 1998; Gozal & Pope, 2001). Although the sleep problems reported in these studies are far more serious than those reported in the current study, they do provide a consistency of findings that sleep disruptions impact the development of cognitive skills, including academic skills, of preschool- and school-age children. For older children, researchers have reported that treatment of sleep problems (such as tonsillectomy/adenoidectomy to remediate obstructive sleep disorders) improved academic performance (Gozal, 1998; Guilleminault, Winkle, Korobkin, & Simmons, 1982). Interventions for less serious sleep disruptions, such as behavior-based interventions targeting nighttime awakenings and resistance to going to bed (e.g., Eckerberg, 2004; Lam et al., 2003; Ramchandani, Wiggs, Webb, & Stores, 2000), might be effectively used by parents of preschoolers to improve poor sleep habits and possibly also to improve daytime behaviors and, thereby, the growth of cognitive skills.

Knowing about children's sleep and behavior characteristics at preschool entry may be helpful to teachers in conceptualizing how children's learning may be impacted during the school year and in providing information for parents and pediatricians about how current and future learning may be impacted. Furthermore, parental involvement in preschool activities, through volunteering, parent–teacher conferences, and parent–teacher associations, offers opportunities for discussions of behavioral interventions for use by parents targeting children's sleep and daytime behaviors, both at school and at home. Changes in parenting practices related to good sleep habits and encouragement of positive learning-related behaviors at home as well as in the classroom may have long-term effects on children's learning and may result in greater parental attention to these important components of childrearing.

The information acquired from this study should be expanded beyond the characteristics of the specific sample and duration of this study. The differences between 9 hr or less and 10 hr or more of sleep on children's cognitive skills development warrant an in-depth exploration with a bigger sample. Future longitudinal studies should examine children's growth trajectories into early elementary school as well as the growth patterns of children prior to age 3 in relation to sleep habits and behavioral characteristics. These studies may help us to identify precursors of cognitive development difficulties in young children, as well as opportunities to study the effects of changes in parenting practices related to sleep and behavior on the growth of cognitive skills.



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