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Sleep Disturbance and Neuropsychological Function in Young Children with ADHD

Heather E. Schneider, Ph.D.¹, Janet C. Lam, M.A.^{1,2}, and E. Mark Mahone, M.D. M.H.S.^{1,2}

Department of Neuropsychology, Kennedy Krieger Institute, 1750 E. Fairmount Avenue, Baltimore, MD 21231

Department of Neurology and Developmental Medicine, Kennedy Krieger Institute, 801 N. Broadway, Baltimore, MD 21205

Abstract

Sleep disturbance, common among children with ADHD, can contribute to cognitive and behavioral dysfunction. It is therefore challenging to determine whether neurobehavioral dysfunction should be attributed to ADHD symptoms, sleep disturbance, or both. The present study examined parent-reported sleep problems (Children's Sleep Habits Questionnaire) and their relationship to neuropsychological function in 64 children, ages 4–7 years, with and without ADHD. Compared to typically developing controls, children with ADHD were reported by parents to have significantly greater sleep disturbance—including sleep onset delay, sleep anxiety, night awakenings, and daytime sleepiness—all $p < 0.01$, and significantly poorer performance on tasks of attention, executive control, processing speed, and working memory (all $p < 0.01$). Within the ADHD group, total parent-reported sleep disturbance was significantly associated with deficits in attention and executive control skills (all $p < 0.01$); however, significant group differences (relative to controls) on these measures remained ($p < 0.01$) even after controlling for total sleep disturbance. While sleep problems are common among young children with ADHD, these findings suggest that inattention and executive dysfunction appear to be attributable to symptoms of ADHD, rather than to sleep disturbance. The relationships among sleep, ADHD symptoms, and neurobehavioral function in older children may show different patterns as a function of the chronicity of disordered sleep.

Keywords

Sleep; childhood; development; assessment; neuropsychological

Introduction

Sleep problems are a prominent behavioral feature in childhood ADHD, with associations between the two ranging from 25–50% (Owens, 2005; Corkum, Tannock, & Moldofsky, 1998) to as high as 80% of children with ADHD manifesting these difficulties (Sung, Hiscock, Sciberras, & Efron, 2008). Sleep problems are prominent in childhood ADHD,

whether measured via parental report (Lycett, Sciberras, Menash, & Hiscock, 2014), actigraphy (Moreau, Rouleau, & Morin, 2013), or polysomnography (Gruber et al., 2009). Sleep problems in children with ADHD may be due to medication side effects, a primary sleep disorder that mimics ADHD symptoms, comorbid sleep problems that worsen ADHD symptoms, or sleep dysregulation problems secondary to CNS dysfunction (Owens, 2009). The relationships between sleep problems, ADHD, medication use, and psychiatric comorbidities are complex, and likely multi-directional (Hvolby, 2014). For example, meta-analytic studies suggest high rates of sleep disturbance occur in both medicated and unmedicated children with ADHD (Cohen-Zion & Alcoli-Israel, 2004). Moreover, while sleep problems and impaired daily functioning are common among children with ADHD, the overall associations between sleep problems and impaired daily functioning are similar in clinical and nonclinical children (Virring et al., 2014).

Inadequate sleep leads to symptoms that mimic those seen in ADHD (Corkum, Davidson, & MacPherson, 2011; Dahl, Pelham, & Wiersen, 1991). Among non-referred community samples, there is a consistent association between sleep problems and symptoms of ADHD (Shur-Fen, 2006). Behavioral aspects of sleep (i.e., bedtime resistance, sleep onset latency, shorter sleep duration, difficulty waking) are commonly observed among children with ADHD (Hvolby, 2014). Snoring and symptoms of obstructive sleep apnea in adolescents have been shown to be associated with a twofold increase in the odds of ADHD diagnosis and a threefold increase in odds of conduct problems (Constantin, Low, Dugas, Karp, & O'Loughlin, 2014).

In children ultimately diagnosed with ADHD, sleep disturbance and overall shorter sleep duration appear to predate the onset of clinical symptoms of the disorder. Scott and colleagues also found that age-specific reduction in sleep duration of > 1 SD across a one-year time interval in preschoolers was a significant predictor of ADHD diagnosis. This difference was largely related to a later bedtime and more nighttime waking (Scott et al., 2013). Among preschool children, sleep-related breathing problems have been shown to be more associated with hyperactive-impulsive symptoms of ADHD, rather than inattention (Ren & Qiu, 2014). Preschool children with sleep-disordered breathing also show impairment on parent ratings of behavior problems, including oppositional behavior (Jackman et al., 2012). These types of findings in young children have prompted researchers to recommend baseline assessment of sleep problems during initial evaluation of childhood ADHD (Sadeh, Pergamin, & Bar-Haim, 2006), and continued assessment of sleep disturbance as part of ongoing ADHD treatment (Cortese et al., 2013).

Poor sleep patterns can also affect performance on cognitive tasks (Gruber et al., 2009). Lam and colleagues found that typically developing preschool children who napped more also slept less at night, and that reduced consolidated nighttime sleep was associated with increased difficulties on performance-based tasks of attention (Lam, Mahone, Mason, & Scharf, 2011a). Among school-aged children, reduced overall sleep duration (measured via actigraphy) is associated with lower performance on neuropsychological tests of attention (Moreau et al., 2013). These associations are not surprising, given that brain regions involved in the regulation of arousal and sensitive to sleep deprivation, such as dorsolateral and

ventrolateral prefrontal and dorsalanterior cingulate cortices, are also implicated in ADHD pathophysiology (Owens et al., 2012).

In summary, there is consistent evidence of an association between symptoms of ADHD and sleep disturbance in children. Sleep disturbance and ADHD are also associated with neuropsychological dysfunction. In young children presenting with symptoms of ADHD, it remains unclear to what extent sleep problems may contribute to onset of (or exacerbation of) behavioral and cognitive sequelae often attributed to ADHD. The purpose of the present study was to examine the relationships between sleep disturbance, behavioral function, and neuropsychological test performance among young children with and without ADHD. We hypothesized that children with ADHD would have greater sleep disturbance than age-matched peers without ADHD. We further hypothesized that the severity of sleep problems would predict both ADHD symptoms and neuropsychological function.

METHODS

Study Procedures

Approval was granted for this study from the Johns Hopkins Medicine Institution Review Board. Participants were recruited from advertisements in the community, pediatricians' offices, and local daycare centers to participate in a study of child development. After description of the study, parents of participants signed written consent and participants provided verbal assent. Participants were initially screened via telephone interview with a parent to determine eligibility. Once enrolled, participants completed a comprehensive neuropsychological assessment battery that included measures of attention, memory, language, visual, and motor skills. Parents (and teachers, if available) also completed behavior rating scales at the time of neuropsychological testing.

Participants

Inclusion and Exclusion Procedures—Participants were excluded if they had any of the following, established via review of medical/developmental history, and/or by study screening assessment: 1) diagnosis of Intellectual Disability or Autism Spectrum Disorder; 2) known visual impairment; 3) treatment of any psychiatric disorder (other than ADHD) with psychotropic medications [for those with diagnosis of ADHD, treatment with stimulants was allowed, whereas children treated with other psychotropic medications were excluded]; 4) any history of DSM-IV Axis I diagnosis other than Oppositional Defiant Disorder or Adjustment Disorder; 5) neurological disorder (e.g., epilepsy, cerebral palsy, traumatic brain injury, tic disorder); 6) documented hearing loss ≥ 25 dB loss in either ear; 7) evidence of physical, sexual, or emotional abuse; 8) Full Scale IQ scores (FSIQ; either by previous assessment or by study screening assessment) less than 80. In addition, children were excluded if there was a history of a Developmental Language Disorder (DLD) determined during the initial phone screen, based on prior assessment (completed within one year of the current assessment), or determined during screening visit.

Diagnostic methods for the ADHD and control groups were adapted from the NIH Preschoolers with Attention-deficit/Hyperactivity Disorder Treatment (PATS) Study

(Kollins et al., 2006; Posner et al., 2007). For 4-year olds, diagnosis of ADHD was made using parent interview on the Diagnostic Interview Schedule for Children-Young Child (YC-DISC) (Lucas, Fisher, & Luby, 1998; Lucas, Fisher, & Luby, 2008). The YC-DISC is a highly structured diagnostic instrument that includes computer-assisted administration and assesses common psychiatric disorders, as defined by DSM-IV, that present in young children. The following YC-DISC modules were administered: ADHD, Social Phobia, Generalized Anxiety Disorder, Separation Anxiety, Depression, Oppositional Defiant Disorder, and Conduct Disorder. For children who were 5 years of age or older, diagnosis was based on the Diagnostic Interview for Children and Adolescents, Fourth Edition (DICA-IV; Reich, Welner, & Herjanic, 1997). To be included in the ADHD group, symptoms must have been present for at least 6 months and cross-situational impairment (defined as parent report of problems at home and with peers or school) was required. Additionally, children in the ADHD group were required to have T-scores ≥ 65 on one or both of the DSM-IV ADHD Scales (Scales L and M) of the Conners' Parent Scales-Revised (Conners, 1997).

Once children met general entry criteria, they were included in the control group only if they did not meet categorical diagnostic criteria for ADHD on the YC-DISC or DICA-IV. Additionally, children in the control group were required to have T-scores ≥ 60 on the DSM-IV ADHD Scales (Scales L and M) of the Conners' Parent Scales-Revised. Socioeconomic status (SES) for the study participants was determined using the Hollingshead Index four-factor index (Hollingshead, 1975).

Study Measures

Children's Sleep Habits Questionnaire(CSHQ) (Owens et al., 2000)—The CSHQ is a 33-item sleep questionnaire administered to a parent to assess their child's sleep. Each item is rated on a 3-point Likert scale (3-Usually, 2-Sometimes, or 1-Rarely) which assesses Bedtime Resistance, Sleep Onset Delay, Sleep Duration, Sleep Anxiety, Night Wakenings, Parasomnias, Sleep Disordered Breathing, and Daytime Sleepiness.

Clinical Evaluation of Language Functions-Preschool-2 (CELF-P-2) (Wiig, Secord, & Semel, 2004)—The CELF-P-2 is an individually administered, norm-referenced test developed to identify and diagnose language and communication disorders in preschool children. Participants scoring < -1.5 SD on either the Receptive Language or Expressive Language Index of the CELF-P-2, or < -1.0 SD on *both* indices, were excluded.

Wechsler Preschool and Primary Scale of Intelligence-Third Edition(WPPSI-III) (Wechsler, 2002)—The WPPSI-III was used to assess IQ in our sample for each participant. Children with WPPSI-III FSIQ < 80 were excluded. The WPPSI-III Verbal IQ (VIQ) was used as an estimate of the intellectual ability for participants. VIQ was selected due to potential group differences in processing speed that could be reflected in the FSIQ. The WPPSI-III Processing Speed Index (PSI) was also used to examine associations with sleep disturbance and neuropsychological performance.

Conners' Rating Scales-Revised-Long Form (CPRS-R and CTRS-R) (Conners, 1997)—Dimensional ratings of ADHD symptom severity were obtained using the DSM-IV

oriented scales from the CPRS-R and CTRS-R, including Scale L (DSM-IV Inattentive) and Scale M (DSM-IV Hyperactive/Impulsive).

Auditory Continuous Performance Task-Preschool (ACPT-P; Mahone et al., 2001)—This measure is a computerized, go/no-go task. Two presented auditory stimuli (dog bark, bell) are used as target and non-target respectively. Duration of each stimulus is 690 msec., and inter-stimulus interval was fixed at 5000 msec. A total of 15 targets and 15 non-targets are arranged randomly so that the child is presented 4 targets and 11 non-targets in the first half of the test, and 11 targets and 4 non-targets in the second half of the test. The total time of the test is approximately 3 minutes. Variables of interest include mean reaction time for correct responses and coefficient of variability.

Auditory Working Memory, Woodcock Johnson III (WJ-III-AWM; Woodcock, McGrew, & Mather, 2001)—This is a measure of short-term auditory memory span and auditory (verbal) working memory. The child is asked to listen to a series that contains digits and words such as “dog,” “1,” “shoe,” “8,” and attempts to reorder the words, repeating the objects first and the numbers second. The task requires the child to hold the information in immediate awareness and manipulate it by dividing the words into two groups.

Spatial Working Memory (SWM; CANTAB®; CeNeS Cognition, 1996)—This self-ordered pointing task utilizes a touch-screen monitor. Children were shown colored boxes on a computer screen and instructed to search through an array of boxes looking for a blue token in order to “collect” enough blue tokens to fill up a container on the right side of the screen. Participants were told that once a blue token had been found within a particular box, that box would never be used again to hide a token. Participants completed four test trials with four, six, and eight boxes. “Between-search errors” were defined as returning to a box in which a token had already been found.

Stop Signal Response Time Task (SST; CANTAB®; CeNeS Cognition, 1996)—SST is a classic stop signal response inhibition test, which uses staircase functions to generate an estimate of stop signal reaction time. This test gives a measure of the child’s ability to inhibit a prepotent response. The Direction Errors variable is a measure of the number of times the participant presses the incorrect button following stimulus presentation.

Statue (NEPSY-II; Korkman, Kirk, & Kemp, 2007)—The Statue test is a measure of inhibition and motor persistence in which the child is asked to maintain a body position with eyes closed during a 75-second period, while inhibiting the impulse to respond to sound distracters.

Conflicting Motor Response Test—This test was adapted from the Luria-Christensen Battery (Christensen, 1975) and has been used to examine motor response inhibition deficits in children (Mahone et al., 2006). Participants were told, “If I show you my finger, you show me your fist. If I show you my fist, you show me your finger.” Examiners presented each of two gestures 12 times (a total of 24) in pseudorandom sequence, at a rate of one per second. Number of correct responses were recorded (range = 0-24).

Physical and Neurologic Assessment of Subtle Signs (PANESS) (Denckla, 1985)—The PANESS is a motor examination standardized for age, sex, and handedness. Detailed information on administration and scoring is outlined in Larson et al. (2007). Total Overflow and Total Timed scores were used in analyses. Overflow is defined as co-movement of body parts not specifically needed to efficiently complete a task.

Behavior Assessment System for Children-2 (BASC-2; Reynolds & Kamphaus, 2004)—The BASC-2 is a comprehensive set of rating scales that can be completed by parents and teachers regarding an individual's behaviors, emotions, and adaptive skills, which helps in making differential diagnoses of specific categories of disorders, such as those identified in the DSM-IV-TR. Parents of children ages 4-5 completed the preschool version of the BASC-2 (PRS-P), while parents of children ages 6-7 completed the child version of the form (PRS-C). Summary scores from both measures were combined for data analyses.

Behavior Rating Inventory of Executive Function (BRIEF) and Behavior Rating Inventory of Executive Function-Preschool Version (BRIEF-P; Gioia et al., 2000, 2003)—The BRIEF is a questionnaire/rating scale that enables professionals to assess executive function behaviors in the home and school environments. Parents of children ages 4-5 completed the BRIEF-P, while parents of children ages 6-7 completed the BRIEF. Summary scores from both measures were combined for data analyses.

Data Analyses

Data from all questionnaires and performance measures were taken from the same visit from which the CSHQ data were collected. Data were initially examined for normality and transformations made as appropriate. ANCOVAs were used to compare the groups on parent reported sleep problems and on all performance measures. Pearson correlations were conducted to investigate the potential association of sleep disturbance with neuropsychological performance and parent and teacher reported behavior. Within the ADHD group, nonparametric tests (Mann-Whitney U) were used to examine reported sleep differences between children prescribed stimulant medication ($n = 6$) and those who were not ($n = 27$). Stimulant medication use was used as a covariate for group comparisons of parent rating data for both sleep and behavior problems. Conversely, medication use was not used as a covariate for examining group differences for performance-based testing, as medication was restricted on the day of testing. The CHSQ Total Sleep Problems score was also used as a covariate in group comparisons of cognitive tests and parent ratings of behavior problems. Given the number of group comparisons for parent rating and performance-based measures, a more conservative alpha level ($p = .01$) was employed in determining statistical significance for group comparisons.

RESULTS

Sample Demographics

Demographic information about the study sample is included in Table 1. The study sample included 64 children ages 4-7 years ($M = 5.52$, $SD = .95$), which included 31 typically

developing children (18 boys, 13 girls) and 33 children with ADHD (23 boys, 10 girls). There was a significant difference in VIQ between the two groups, favoring the control group; however, the mean for both groups was within the high average range. There were no significant differences in age, SES, or sex distribution [$\chi^2_{(n=64)}=0.94$; $p = 0.436$] between the ADHD and control groups. Within the ADHD group, 6 of the children were prescribed stimulant medication; however, none of these participants took their medication on the day of performance-based testing.

Sleep Disturbance

Within the ADHD group, there were few differences (Mann-Whitney U) in sleep disturbance between medicated and non-medicated participants. More specifically, significant differences were observed on only one individual scale—sleep anxiety ($p = .011$)—as well as the Total CSHQ score ($p = .010$). Of note, in both cases, parents of children who were prescribed medication reported observing *fewer* sleep problems than parents of children who were not prescribed medication. Subsequent group analyses (ADHD vs. control) for sleep and behavior problems revealed nearly identical patterns of results, regardless of whether or not the potential effects of medication use were considered as a covariate.

Results of parent reports of sleep difficulties, controlling for medication use, are listed in Table 2. There was a significant group difference in the total parent reported sleep problems, such that children with ADHD were reported to display greater sleep disturbance (Total CSHQ score) than typically developing children ($p < 0.001$). Additionally, group differences were present on four of the eight CSHQ subscales, i.e., all except bedtime resistance, sleep duration, parasomnias, and sleep disordered breathing (Table 2). The largest group differences were reported in the areas of sleep anxiety, night awakenings, and daytime sleepiness.

Performance Measures

Results of performance-based measures are listed in Table 3. Medications were not administered on the day of evaluation; thus, medication use was not added as a covariate for group analysis of performance measures. There were significant group differences observed on most of the measures administered, including: WPPSI-III Processing Speed Index, WJ-III Auditory Working Memory, CANTAB SWM Between Errors, CANTAB Stop Signal Task Directional Errors, NEPSY-2 Statue, Conflicting Motor, PANESS Total Overflow, and PANESS Gaits & Stations. In all cases, controls performed significantly better than children with ADHD. Additionally, after covarying for parent report of Total Sleep Disturbance on the CSHQ, all previously observed group differences on performance-based neuropsychological tests remained, with similar effect size (Table 3), with the exception of the Conflicting Motor Response Test, which approached significance ($p = 0.02$).

Behavioral Ratings

Group differences on behavior rating scales are listed in Table 4. Medication use and CSHQ Total score were included as covariates. As expected, children with ADHD were reported to

have significantly greater problems than controls for both parent and teacher ratings on the Conners' Inattention and Hyperactivity scales and the BRIEF Global Executive Composite (GEC). Conversely, there were no significant group differences in parent ratings or teacher ratings of Anxiety, or on parent ratings of Depression on the BASC-2. Although significant differences between groups occurred on teacher-rated Depression on the BASC-2, the mean scores for both groups were well within normal limits.

Because the control group was not rated to display clinically significant behavioral problems in any area, correlations between Total Sleep Problems and behavior problems were only conducted for the ADHD group. Among children with ADHD, significant associations were observed between parent-reported total sleep disturbance and parent- and teacher-reported inattention, parent-reported hyperactive-impulsive behavior, and parent-reported depression, but not parent- or teacher-reported anxiety or teacher-reported depression (Table 5).

Associations between Sleep Problems and Neuropsychological Test Performance

Within the ADHD group, there were no significant correlations between parent reported sleep problems and performance on any of the neuropsychological tests (Table 6).

DISCUSSION

Preschool and early elementary school age children with ADHD manifest greater evidence of sleep disturbance than age- and sex-matched typically developing children without ADHD. This finding is consistent with the relationships between sleep and ADHD observed in older school-aged children (Hvolby, 2014) and adolescents (Constantin et al., 2014). In our sample of young children with ADHD, parent ratings of the level of sleep disturbance were directly (and significantly) associated with ratings of ADHD symptomatology, highlighting the interrelatedness of sleep and daytime behavior, and suggesting a potential causal relationship, or, more likely, the dependence of both sleep integrity and ADHD on delayed maturation of shared neural circuitry.

In addition to the increased sleep problems observed in our sample of young children with ADHD, these children also displayed a broad range of performance-based neuropsychological deficits, relative to controls, including impairment in areas of function potentially affected by daytime sleepiness (e.g., processing speed, working memory, motor control, attention). This pattern of ADHD-related neuropsychological deficits is well documented in both preschool (Rajendran et al., 2014) and school-aged children (Huang-Pollock, Karalunas, Tam, & Moore, 2012; O'Brien, Dowell, Mostofsky, Denckla, & Mahone, 2010); however, the relationship between sleep and neuropsychological dysfunction remains unclear. For example, among preschool children referred for sleep concerns (i.e., not for ADHD), severity of sleep problems was associated with greater behavioral disturbance, but not with cognitive deficits. Moreover, the group of preschoolers with primary sleep problems manifested few performance-based neuropsychological deficits (Jackman et al., 2012). In contrast, our sample of young children with ADHD manifested prominent performance-based neuropsychological deficits, suggesting that the early neurobiological factors contributing to the onset of ADHD may also contribute to the onset of neurocognitive deficits.

In our sample, despite the higher rate of parent-reported sleep disturbance in children with ADHD and the association between sleep disturbance and ADHD symptoms, sleep problems were not associated with neuropsychological performance on direct assessment. Moreover, after controlling for total sleep disturbance, nearly all of the group differences in neuropsychological test performance differences remained. Taken together, these findings suggest that the reduced neuropsychological test performance in children with ADHD appears more strongly associated with ADHD symptomatology (inattention and/or hyperactivity-impulsivity) than with sleep disturbance. In other words, within in our highly screened sample of young children with ADHD, the present findings argue against the idea that there is a subgroup of young children who appear to have ADHD but actually exhibit behavior that is primarily associated with a sleep disorder. The relationships among sleep, ADHD symptoms, and neurobehavioral function in older children may show different patterns, however, as a function of the chronicity of disordered sleep or the increase in stimulant medication use.

The relative strength of the associations between parent-rated sleep problems and parent-rated behavior problems (i.e., ADHD symptoms, executive dysfunction, internalizing symptoms), contrasted with the relative absence of associations between parent-reported sleep problems and neuropsychological performance, suggests that some of the findings may be driven by commonalities in method variance within parent ratings. Additionally, it is established that parents of young children tend to overestimate sleep problems when parent report is compared to an objective measure, such as actigraphy (Lam, Mahone, Mason, & Scharf, 2011b; Goodlin-Jones, Waters, & Anders, 2009). As such, parent ratings of sleep patterns in young children may not be the most accurate way to assess the types (and timing) of sleep disturbance seen in children, and future studies using actigraphy, and perhaps polysomnography, may show different patterns of association with neurocognitive function. Alternatively, it may be that these associations may not manifest in the preschool years and may emerge only after sustained periods of sleep disruption.

It is also of note that while most components of sleep disturbance (as measured by the CSHQ) were reportedly disrupted in our sample of children with ADHD, issues with bedtime resistance and sleep disordered breathing were not reported as different, as compared to typically developing controls. This finding is in contrast to reports of such problems in older children with ADHD (Hvolby, 2014), and may be a function of reduced sensitivity of the CSHQ in younger children, or possibly the nature of our ADHD sample, which was highly screened for most comorbidities, including anxiety and conduct disorders. Future studies investigating associations between sleep problems and ADHD symptoms in young children are needed using larger samples in which the range of comorbidities observed in ADHD can be considered.

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Table 1

Participant Demographics

	Control <i>n</i> = 31		ADHD <i>n</i> = 33			
	Mean	SD	Mean	SD	<i>p</i>	η^2
Age	5.68	0.98	5.37	0.90	0.190	.028
SES	59.98	7.69	57.45	10.39	0.275	.019
CPRS-R DSM-IV Total T	50.35	11.43	74.48	10.04	<0.001	.732
VIQ	117.97	10.84	110.03	9.62	0.003	.134

Note: SES = Socioeconomic status, measured via Hollingshead Index; CPRS = Conners' Parent Rating Scale; VIQ = Verbal IQ from Wechsler Preschool and Primary Scale of Intelligence, Third Edition

Table 2

Group Differences in Parent-Reported Sleep Problems

	Control <i>n</i> = 31		ADHD <i>n</i> = 33			
	Mean	SD	Mean	SD	<i>p</i>	η^2
Sleep Duration	3.45	1.028	4.24	1.70	.067	.054
Sleep Anxiety	4.97	1.43	6.00	2.40	.004	.127
Night Wakenings	3.65	1.36	4.70	1.86	.007	.115
Daytime Sleepiness	10.39	2.25	12.09	3.46	.005	.124
Bedtime Resistance	9.07	10.78	8.82	3.04	.954	.000
Sleep Onset Delay	1.23	0.43	1.52	0.67	.014	.094
Parasomnias	8.32	1.89	9.21	2.10	.036	.070
Sleep Disordered Breathing	3.10	0.30	3.15	0.80	.300	.018
TOTAL	39.74	5.34	46.61	9.93	.001	.223

Note: Analyses included stimulant medication use as a covariate.

Table 3

Group Differences in Performance on Neuropsychological Measures

	Control <i>n</i> = 31		ADHD <i>n</i> = 33		Without Sleep as Covariate		With Sleep as Covariate [*]	
	Mean	SD	Mean	SD	<i>p</i>	η^2	<i>p</i>	η^2
ACPT-P Mean Reaction Time ⁺	473.92	332.91	715.76	554.72	0.041	0.067	0.028	0.078
ACPT-P Variability ⁺	0.82	0.43	0.89	0.46	0.525	0.007	0.744	0.002
WPPSI-III PSI	107.00	15.68	90.84	13.96	0.001	0.234	0.001	0.179
Auditory Working Memory	116.39	14.01	105.42	13.63	0.004	0.139	0.006	0.129
CANTAB SWM ⁺	23.00	8.93	30.45	6.48	0.001	0.192	0.002	0.146
CANTAB SSRT ⁺	2.45	2.96	6.48	7.44	0.007	0.113	0.004	0.127
NEPSY Statue (raw scores)	21.74	8.37	14.85	8.80	0.002	0.142	0.012	0.099
Conflicting Motor Response	15.42	4.25	12.52	4.26	0.008	0.107	0.022	0.082
PANESS Total Overflow ⁺	9.32	4.98	13.07	5.69	0.008	0.113	0.006	0.122
PANESS Total Timed ⁺	19.48	9.62	24.74	11.16	0.109	0.063	0.075	0.079
PANESS Gaits & Stations ⁺	9.23	4.72	13.42	5.77	0.003	0.141	0.007	0.117

Note:

⁺ Lower score reflects better performance on these variables. ACPT-P = Auditory Continuous Performance Test for Preschoolers; WPPSI = Wechsler Preschool and Primary Scales of Intelligence; SWM = Spatial Working Memory; SSRT = Stop Signal Reaction Test; PANESS = Physical and Neurological Assessment of Subtle Signs;

* CSHQ Total Score used as covariate

Table 4

Group Differences in Behavioral Ratings

	Control <i>n</i> = 31		ADHD <i>n</i> = 33			
	Mean	SD	Mean	SD	<i>p</i>	η^2
CPRS-R DSM-IV Inattentive	49.81	11.18	72.55	10.33	.0001	.389
CPRS-R DSM-IV Hyperactive/Impulsive	50.94	11.40	72.61	10.97	.0001	.297
CTRS-R DSM-IV Inattentive	49.29	8.28	67.48	14.12	.0010	.271
CTRS-R DSM-IV Hyperactive/Impulsive	49.90	7.32	65.68	13.95	.0001	.342
BRIEF-P Parent GEC	44.94	12.28	73.39	13.91	.0001	.345
BRIEF-P Teacher GEC	51.30	12.34	66.91	12.96	.0001	.365
BASC-2 Parent Anxiety	45.13	8.83	52.91	12.14	.7410	.003
BASC-2 Parent Depression	47.39	9.01	60.33	15.34	.0770	.084
BASC-2 Teacher Anxiety	30.65	22.00	37.15	22.66	.3100	.029
BASC-2 Teacher Depression	46.76	6.69	56.04	10.55	.0100	.071

Note. Group comparisons are performed using medication use and CSHQ Totalscores as covariates; CPRS = Conners' Parent Rating Scale; CTRS = Conners' Teacher Rating Scale; BRIEF = Behavior Rating Inventory of Executive Function; GEC = Global Executive Composite; BASC = Behavior Assessment System for Children

Table 5

Associations Between Parent-Reported Sleep Problems and Behavioral Symptoms (ADHD Group Only)

Measure	CSHQ Total Score		
	<i>n</i>	<i>r</i>	<i>p</i>
CPRS-R DSM-IV Inattentive	33	0.375	0.032
CPRS-R DSM-IV Hyperactive/Impulsive	33	0.352	0.045
CTRS-R DSM-IV Inattentive	25	0.397	0.049
CTRS-R DSM-IV Hyperactive/Impulsive	25	0.259	0.212
BRIEF-P Parent GEC	31	0.343	0.059
BRIEF-P Teacher GEC	23	0.321	0.135
BASC-2 Parent Anxiety	33	−0.105	0.562
BASC-2 Parent Depression	33	0.414	0.017
BASC-2 Teacher Anxiety	33	0.087	0.631
BASC-2 Teacher Depression	25	0.088	0.675

Note: CPRS = Conners' Parent Rating Scale; CTRS = Conners' Teacher Rating Scale; BRIEF = Behavior Rating Inventory of Executive Function; GEC = Global Executive Composite; BASC = Behavior Assessment System for Children. BRIEF scores were obtained by combining GEC scores from the BRIEF and the BRIEF-P, depending on the age of the child.

Table 6

Associations Between Parent-Reported Sleep problems and Neuropsychological Function (ADHD Group Only)

Measure	CSHQ Total Score		
	<i>n</i>	<i>r</i>	<i>p</i>
ACPT-P Mean Reaction Time	32	−0.16	0.39
ACPT-P Variability	31	0.12	0.54
WPPSI-III VIQ	32	−0.27	0.14
WPPSI-III PSQ	33	−0.08	0.66
Auditory Working Memory	31	0.03	0.89
CANTAB SWM	33	0.33	0.07
CANTAB SSRT	33	−0.21	0.25
NEPSY Statue	33	−0.09	0.61
Conflicting Motor	33	0.09	0.61
PANESS Total Overflow	30	−0.03	0.86
PANESS Total Timed	19	−0.14	0.57
PANESS Gaits & Stations	31	0.003	0.99

Note: ACPT-P = Auditory Continuous Performance Test for Preschoolers; WPPSI = Wechsler Preschool and Primary Scales of Intelligence; SWM = Spatial Working Memory; SSRT = Stop Signal Reaction Test; PANESS = Physical and Neurological Assessment of Subtle Signs