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Infant Sleep Predicts Attention Regulation and Behavior Problems at 3–4 Years of Age

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This longitudinal study assessed the role of early sleep patterns in predicting attention regulation and behavior problems. Sleep of 43 infants was assessed using actigraphy at 12 months of age and then reassessed when the children were 3–4 years old. During this follow-up, their attention regulation and behavior problems were also assessed using a computerized test and parental reports. Lower quality of sleep in infancy significantly predicted compromised attention regulation and behavior problems. These findings underscore the need to identify and treat early sleep problems.

The first years of life are characterized by rapid brain maturation (Choe et al., 2013; Huppi et al., 1998; Knickmeyer et al., 2008; Matsuzawa et al., 2001). Maturation and consolidation of sleep–wake patterns are highly important developmental milestones in infancy. The most rapid development in sleep organization takes place during the first six months of life, followed by more moderate changes later on (Coons, 1987; de Weerd & van den Bossche, 2003; Goodlin-Jones, Burnham, Gaylor, & Anders, 2001; Henderson, France, & Blampied, 2011; Henderson, France, Owens, & Blampied, 2010; Mirmiran, Maas, & Ariagno, 2003). By six months of age most infants are "sleeping through the night" (Henderson et al., 2010), which means that they have one extended period of uninterrupted sleep as reported by

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parents. However, many infants continue to have fragmented sleep, characterized by multiple and extended night-wakings, constituting a very common complaint of parents of infants and toddlers (Bayer, Hiscock, Hampton, & Wake, 2007; Johnson, 1991; Petit, Touchette, Tremblay, Boivin, & Montplaisir, 2007; Thunstrom, 1999).

The correlates or consequences of fragmented sleep in infancy are not entirely clear. One area that received much attention is temperament. Poor sleep has been associated with difficult temperament or poor behavior regulation, but findings were often inconsistent and mostly rely on subjective parental reports on infant sleep and temperament (Ednick et al., 2009; Keener, Zeanah, & Anders, 1988; Sadeh, Lavie, & Scher, 1994a; Scher, Epstein, Sadeh, Tirosh, & Lavie, 1992). Much less is known about the cognitive correlates of poor sleep in infancy as it is more difficult to assess these functions in infants and toddlers. In older children it has been established, in both correlative and experimental designs, that poor or insufficient sleep is associated with compromised cognitive or neurobehavioral functioning (Astill, Van der Heijden, Van Ijzendoorn, & Van Someren, 2012; Bernier, Carlson, Bordeleau, & Carrier, 2010; Sadeh, Gruber, & Raviv, 2002, 2003). However, studies examining naturalistic sleep quality and cognitive performance or related skills in early childhood are scarce and often consist of preterm infant samples rather than normative ones (Anders, Keener, & Kraemer, 1985; Dearing, McCartney, Marshall, & Warner, 2001; Ednick et al., 2009; Freudigman & Thoman, 1993; Gertner et al., 2002; Lukowski & Milojevich, 2013; Scher, 2005; Weisman, Magori-Cohen, Louzoun, Eidelman, & Feldman, 2011; Whitney & Thoman, 1993). Some of these studies have documented links between sleep measures and mental development indices (mostly derived from the Bayley Scale of Infant Development) during the first year of life, providing inconsistent associations between infant sleep and cognitive development. Other studies demonstrated links between infant sleep and specific cognitive skills such as recall memory for imitated behavioral sequences (Lukowski & Milojevich, 2013) or language-related memory (Gomez, Bootzin, & Nadel, 2006; Hupbach, Gomez, Bootzin, & Nadel, 2009).

Rapid brain maturation during the first three years calls for assessment of more complex domains of cognitive functioning and executive control. Indeed, a number of studies have tried to assess if early infant sleep patterns predict later cognitive functioning and executive control (Bernier et al., 2010; Dearing et al., 2001; Dionne et al., 2011; Holditch-Davis, Belyea, & Edwards, 2005; Sheridan et al., 2013; Weisman et al., 2011). For instance, delayed sleep consolidation at 6 and 18 months of age predicted delays in language development at 5 years of age (Dionne et al., 2011). In another study, reported infant sleep problems (at 12 and 18 months) predicted lower IQ scores at 5 years of age (Sheridan et al., 2013). Interestingly, concurrent sleep measures at 5 years were not significantly associated with IQ scores. However, poor sleep at 5 years was associated with concomitant increased emotional problems. Finally, it has been demonstrated that higher reported ratio of nocturnal sleep (reflecting sleep consolidation and concentration at night), at both 12 and 18 months, predicted better performance on executive tasks (e.g., conflict Stroop task, working memory) at 18 and 24 months (Bernier et al., 2010). A critical aspect of executive control, which develops at the preschool age and is essential for children's self-regulation of behavior and emotions, is the ability to deal with conflict and ignore irrelevant information (Posner & Rothbart, 2000). This development has been demonstrated in a variant of the Stroop paradigm specially designed for young children, known as the Spatial-Stroop (Berger, Jones, Rothbart, & Posner, 2000; Gerardi-Caulton, 2000).

However, there is no current literature on the effects of early sleep deprivation/disturbances on such computerized objective measures of executive control.

A few studies suggested that infant sleep predicts compromised behavior regulation or behavior problems in later development (Feldman, 2009; Hairston et al., 2011; Scher, 2005; Thunstrom, 2002; Touchette, Petit, Tremblay, & Montplaisir, 2009). For instance, it has been argued that infant sleep problems predict a diagnosis of attention deficit hyperactivity disorder (ADHD) at 5.5 years of age (Thunstrom, 2002). However, other studies concluded that early childhood sleep problems are mostly transient and do not leave a significant mark on later development (Price, Wake, Ukoumunne, & Hiscock, 2012; Wake et al., 2006).

It is important to note that most of the studies cited above have relied on parental reports on infant sleep. It has been suggested that parents are able to reliably report on their infants' sleep schedule (e.g., sleep onset, duration) but when it comes to sleep quality (e.g., night-wakings) parental reports and objective sleep assessment are significantly discrepant (Sadeh, 1994, 1996, 2008; Sadeh, Flint-Ofir, Tirosh, & Tikotzky, 2007). Parents are aware of infant night wakings when infants vocalizes and require attention (Anders, Halpern, & Hua, 1992; Burnham, Goodlin-Jones, Gaylor, & Anders, 2002). Night-wakings of self-soothing infants go unnoticed by their parents. Therefore, in assessing the role of sleep consolidation or sleep fragmentation and its potential impact on the developing child, objective infant sleep measures are required.

The goal of the present study was to assess if objective measures of infant sleep quality predict later cognitive and behavioral function. To accomplish this, actigraphy was used to objectively determine sleep patterns, the Spatial-Stroop task was used to assess attentional executive control, and parental reports were used to assess behavior problems. We hypothesized that poor infant sleep and concurrent sleep would predict and be associated with compromised attention control and behavior problems at 3–4 years of age.

METHOD

Participants

Parents were recruited through prenatal courses or announcements in Internet forums for expectant parents, or in the hospital during the first 48 hours after birth. Eighty-seven infants and their parents participated in the initial study when the infants were one year old. In the follow-up study, we managed to locate and recruit 43 children (21 girls) to participate in the follow-up procedures. The original exclusion criteria (based on parental reports) included significant complications during pregnancy or delivery and infants with medical problems including breathing-related sleep problems. The final sample was comprised of families from the middle-upper socioeconomic class (see Table 1 for demographic characteristics).

We compared the characteristics of families who completed the follow-up procedures to those who were not included in the second phase of the study and found no differences on family background variables (i.e., family size, parental age, and education) child early characteristics (i.e., birth weight, gestational age, apgar, birth order, sex) and early sleep variables and found no differences between these samples.

TABLE 1
Sample Characteristics

	Mean	*SD*	*Range*
Demographic			
Child's age	3.69	.37	3.10–4.30
Mother's age	33.59	4.38	24–42
Father's age	35.20	4.90	23–49
Mother's education	16.30	2.50	12–25
Father's education	16.07	3.01	11–30
Number of children	1.11	0.89	0–3
Number of rooms in the house	3.66	0.85	2–6
Child's sex	22 boys	21 Girls	

Procedure

The study was approved by the Tel Aviv University Ethics Committee (the University's committee and the Helsinki Committee of the Sourasky Medical Center). Signed informed consent was obtained from all the parents.

When the infants were one year old their sleep was assessed with actigraphy for four nights. When the children were 3–4 years old their sleep was reassessed and their parents completed the Child Behavior Checklist and Conners Abbreviated Teacher-Parent Questionnaire. During this study phase the children were invited to the university and their executive control was tested using a computerized test of attention (Berger et al., 2000).

After completion of each study phase the parents received a graphic report on their child's sleep patterns and a gift (with a value of about $10).

Instruments and Measures

Sleep Assessment

Actigraphy. Actigraphy has been established during the last decade as a useful method for studying and assessing sleep–wake patterns in infants, children and adults. Validation studies against standard polysomnography have yielded between 85% and 95% agreement for sleep–wake scoring (Meltzer, Montgomery-Downs, Insana, & Walsh, 2012; Sadeh, Acebo, Seifer, Aytur, & Carskadon, 1995; Sadeh, Lavie, Scher, Tirosh, & Epstein, 1991). The actigraph is a wrist-watch-like device that records body motion data that can be translated to reliable and valid sleep–wake measures. Its main advantage is that it provides an objective description of sleep patterns for extended periods (e.g., more than a week) with no interference with the child's natural sleep environment.

In the present study we used the miniature actigraph (Ambulatory Monitoring Inc., Ardsley, NY), with amplifier setting 18 and a 1-minute epoch interval according to the standard working mode for sleep–wake scoring. The actigraph was attached to the infant's ankle during the nocturnal sleep period.

The Actigraphic Sleep Analysis (ASA) program was used to score the data based on validated sleep–wake scoring algorithm for infants (Sadeh et al., 1995) and young children (Sadeh, Sharkey, & Carskadon, 1994b). The derived measures included: (1) Total sleep period— from sleep onset time to morning awakening time; (2) True sleep time—sleep time excluding all periods of wakefulness at night (3) Sleep percent—percent of true sleep time from total sleep period; and (4) Number of night-wakings lasting 5 minutes or longer. Actigraphic sleep measures were averaged across the monitoring period to obtain the final summary measures used for data analysis.

The spatial conflict task. The spatial conflict task (Berger et al., 2000; Gerardi, 1997; Gerardi-Caulton, 2000) is a Stroop-like task, suitable for young children, in which there are two dimensions, one relevant (in this case the identity of an animal) and one irrelevant (in this case the spatial location of the stimulus on the monitor screen). The task is presented to the child as a "help the animal find its home" game in which the child is requested to press a key corresponding to the house of the animal (see Figure 1): if the picture appears on the same side as the corresponding inside-the-house picture, it is a compatible trial; if the picture is on the opposite side, it is an incompatible trial. Interference effects created by the incompatibility between stimulus and response spatial locations were measured. Since the child has to inhibit a prepotent response to comply with task demands it is considered a nonverbal measure of executive attention. At the beginning of each trial, two houses appear on the left and right bottom corners of the screen, with a picture inside each house. A central looming lasts until the experimenter is sure that the child's attention is focused on the screen, after a picture appears in either the left upper corner or the right upper corner. The picture stays on the screen until the child's response or a maximum of 15 sec. After the response, there is an animated

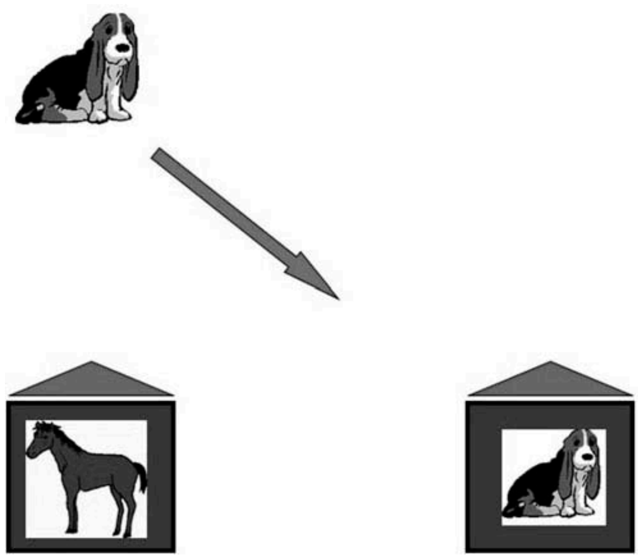

FIGURE 1 Spatial conflict task: Find the house for the animal. The arrow is not presented during the task. This is an example of the incongruent condition. Adapted to black and white from color screens.

feedback. There are two experimental conditions in this task (spatially compatible and incompatible trials) presented in a random order. At the beginning of the task, there are four practice trials in which the picture appears in a neutral position (central upper position). The task consists of 32 trials and takes about 10 min to complete. Derived measures: Percent of correct responses to congruent and incongruent stimuli and the difference between these scores.

This task has been successfully used in the literature with children of preschool and kindergarten age and provides a reliable "conflict measure," calculated as the difference between the percent of correct responses to congruent and incongruent stimuli (Gerardi, 1997; Gerardi-Caulton, 2000). Moreover, it has been demonstrated that measures derived from the task show clear developmental patterns and are strongly correlates with additional well-established measures of executive control derived from child behavior questionnaires and laboratory tasks of inhibitory control (Gerardi-Caulton, 2000).

Behavior Problems

Behavior problems were assessed using parental reports on the Child Behavior Checklist (CBCL) and Conners Abbreviated Teacher-Parent Questionnaire. We used the Hebrew version of the CBCL that has been translated and validated in Israel (Achenbach & Edelbrock, 1983; Achenbach, Edelbrock, & Howell, 1987; Zilber, Auerbach, & Lerner, 1994). The derived measures included the Total Behavior Problem score and the scores on the Externalizing and Internalizing factors. The Conners questionnaire was designed to address behavior problems and symptoms associated with difficulty in regulating attention, hyperactivity and behavior control (Goyette, Conners, & Ulrich, 1978). The Conners Abbreviated Questionnaire has been translated to Hebrew and validated in Israel (Margalit, 1983). The derived measure was the total score. Raw scale scores of the CBCL and the Conners Abbreviated Questionnaire were used in data analysis.

Data Analysis Plan

We used Pearson correlations to assess stability of sleep measures from the 1-year age-period to the follow-up period as well as to assess the direct links between sleep and attention regulation and behavior problems (while controlling for age).

To further explore the attention regulation on the spatial conflict task and its links to sleep quality we performed analysis of covariance using General Linear Models (SAS, 1990). The outcomes of the congruent and incongruent tasks were used as the repeated dependent variable (task demands) and the sleep percent or night-wakings were used as a continuous independent variables (in separate analyses).

RESULTS

The sample main characteristics are described in Table 1. Descriptive data of the main study variables are described in Table 2.

TABLE 2
Descriptive Data of Main Study Variables

	N	*Mean*	*STD*	*Minimum*	*Maximum*
Parental reports					
Conners—Total score	43	16.09	5.19	10	30
CBCL—Total	42	21.98	13.27	0	60
CBCL—Externalizing	42	8.62	6.13	0	26
CBCL—Internalizing	42	4.10	3.11	0	15
Spatial conflict task					
Accuracy—Congruent	43	88.63	17.44	20	100
Accuracy—Incongruent	43	66.92	30.40	0	100
Accuracy—Difference	43	19.71	23.66	–18.04	88.24
Actigraphy sleep measures					
Sleep Duration (Minutes; 1-year)	43	592.43	58.66	438	748
Night-Wakings (N; 1-year)	43	1.27	.81	0	3.25
Sleep Percent (%; 1-year)	43	95.99	2.63	86.98	99.92
Sleep Duration (Minutes; follow-up)	39	542.67	52.23	390	646
Night-Wakings (N; follow-up)	39	1.86	.99	0	3.67
Sleep percent (%; follow-up)	39	93.55	3.62	86.00	99.78

Stability of Sleep Measures

Pearson correlations between 1-year and the follow-up sleep measures are presented in Table 3. These correlations reveal some significant stability over the 2–3-year follow-up interval. Particularly notable is the stability in sleep onset time and sleep percent.

Sleep, Executive Attention, and Behavior Problems

Pearson correlations (with age partialed out to control for its potential effects) between key sleep variables and attention and behavior variables are presented in Table 4.

TABLE 3
Correlations Between Sleep Measures at 1 Year of Age and During the Follow-Up

	Follow-Up (3–4 Years of Age)			
Age: 1 Year	*Sleep Onset Time*	*Total Sleep Time*	*Sleep Percent*	*Number of Night Wakings*
Sleep Onset Time	.47**	–.47**	–.06	.06
Total Sleep Time	–.22	.24	–.07	.06
Sleep Percent	.07	.07	.44**	–.31
Night Wakings-Number	–.02	.02	–.39*	.27

Note. The correlations on the diagonal reflects the stability these sleep measures.
*$p < .05$. **$p < .01$.

TABLE 4
Pearson Correlations Between Sleep Measures and Reported Behavior Measures

		Sleep Onset Time	*Sleep Duration*	*Sleep Percent*	*Night Wakings*
Conners—Total	1 year	.10	–.09	–.40*	.42**
	follow-up	.07	–.02	–.09	–.03[a]
CBCL—Total	1 year	.13	–.15	–.42**	.39*
	follow-up	.23	–.30	–.05	–.08[a]
CBCL—Ext	1 year	.06	–.14	–.45***	.40**
	follow-up	.15	–.21	–.07	–.05[a]
CBCL—Internalizing	1 year	.22	–.24	–.28	.22
	follow-up	.26	–.30	.03	–.08
Spatial conflict—Congruent	1 year	–.23	.14	.03	–.04
	follow-up	–.20	.14	.18	–.23
Spatial conflict—Incongruent	1 year	–.10	.09	.33*	–.34*
	follow-up	.01	.01	.31	–.37*
Spatial conflict—Difference score	1 year	–.03	–.02	–.39*	.41**
	follow-up	–.16	.10	–.29	.32

[a]Significant differences between the equivalent correlations for 1-year and the follow-up assessment. Based on Fisher's *z*-score transformation of Pearson's correlations.
*$p < .05$. **$p < .01$. ***$p < .005$.

The results revealed significant predictive and concomitant correlations between sleep and measures of attention regulation and behavior problems. The correlations reflect significant ties between sleep quality measures (sleep percent and number of night-wakings) at 1 year of age and the attention and behavior regulation measures at the follow-up period. As could be seen from the correlation patterns, sleep schedule measures (sleep onset time and sleep duration) were not associated with any of the attention and behavior measures. The predictive correlations between sleep at 1 year of age and the follow-up attention and behavior measures were significant (e.g., higher sleep percent was associated with lower scores on the Conners, $r = –40$, $p < .05$; CBCL Total, $r = –42$, $p < .01$; CBCL externalizing, $r = –.45$, $p < .005$; and better performance on the spatial attention task: incongruent, $r = .33$, $p < .05$ and conflict score, $r = –.39$, $p < .05$; similar results were obtained for the night-waking measures), whereas none of the concomitant correlations were significant. It is important to note, that testing for significant differences in correlations (between those related to 1 year and those related the follow-up) yielded only one statistically significant difference. This pattern of results is also illustrated in the scatter plot and regression lines in Figure 2. The small sample size precluded multiple regression analyses including all sleep variables at both ages as predictors. Stepwise regression analyses revealed that for each dependent variable (attention and behavior measures) only one predictor (the one with the highest correlation [Table 4] reached statistical significance). It is important to note that the variables sleep percent and night-wakings were highly correlated ($r = .67$ at 1-year and $r = .89$ in the follow-up) and therefore the variability explained by these measures was significantly overlapping.

To examine the effect of sleep quality on spatial conflict effect we used General Linear Models (GLM) to analyze the interaction between task demands (congruent versus incongruent stimuli) and sleep quality variables. The outcomes of the congruent and incongruent tasks were used as the

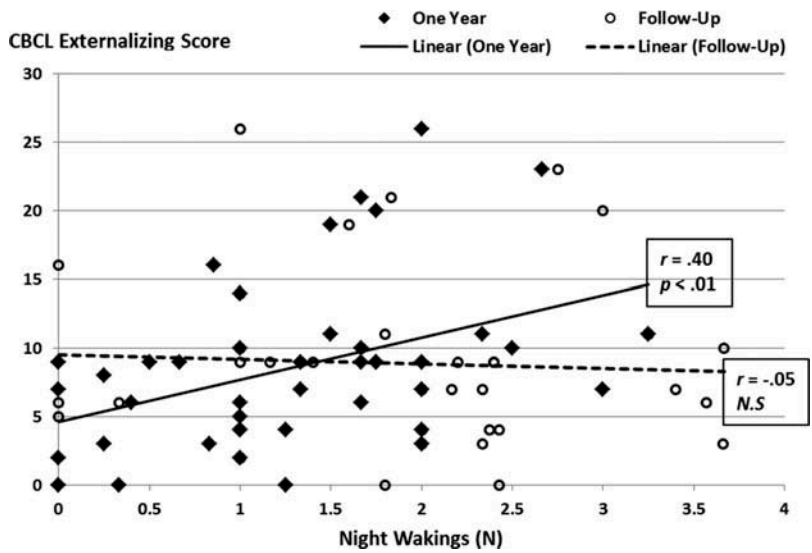

FIGURE 2 Scatter plots and regression lines of night-wakings at 1 year and in the follow-up as predictors of the Child Behavior Checklist (CBCL) Externalizing Score.

repeated within dependent variable and the sleep percent or night-wakings were used as a continuous independent variables. Main effect was found for the task demand variable with higher accuracy on the congruent trials in comparison to the incongruent trials ($F = 35.82$; $p < .0001$). Significant interaction effects were found between task demands and both sleep percent ($F = 5.17$; $p < .05$) and night-wakings ($F = 9.09$; $p < .005$), analyzed separately. These interactions indicate that an increase in night-wakings is associated with decrease in accuracy in the incongruent stimuli but this association does not exist for the congruent stimuli. The results for the equivalent follow-up sleep variables showed the same trends but failed to reach statistical significance. Figure 3 illustrates the interaction results of the GLM analysis for the night-waking at 1 year of age.

DISCUSSION

The main goal of the study was to examine the predictive and concomitant association between sleep and attention regulation and behavior problems in early childhood. To the best of our knowledge, this is the first study that used objective measures of sleep and attention regulation in a longitudinal design during early childhood.

Our results demonstrate low to moderate stability on some sleep measures from 1 year of age to 3–4 years. This stability was demonstrated in sleep onset time and in sleep percent, which reflects sleep consolidation. Non-significant stability was noted on total sleep time and the number of night-wakings. The results suggest that sleep patterns are still quite malleable during early childhood. Similar low to moderate stability in sleep patterns during this age period have been reported earlier (Tikotzky & Shaashua, 2012).

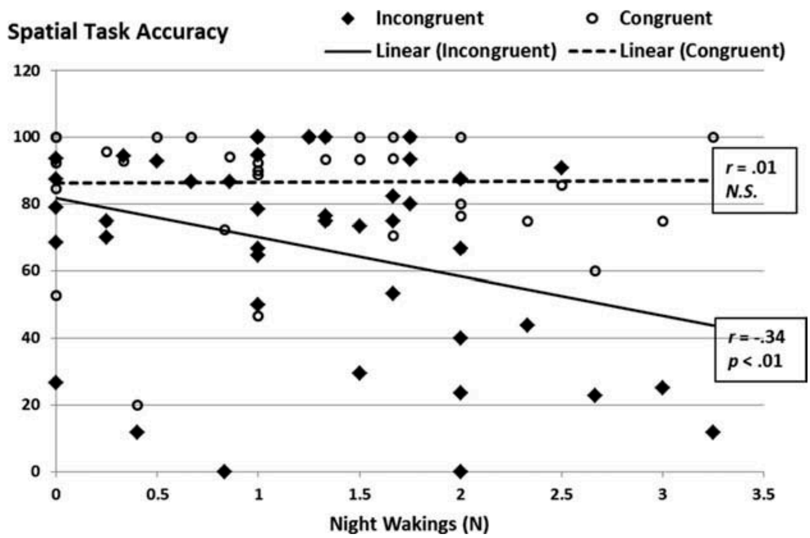

FIGURE 3 Accuracy level on the Spatial Tast according to stimuli type (congruent versus incongruent) and number of night-wakings at 1 year.

In light of this plasticity in early sleep patterns our results suggest that early sleep quality measures are more predictive of later cognitive and behavioral regulation than the concomitant sleep variables. These findings should be considered with caution because on most variables these differences between the correlations of the behavior and attention measures to the earlier versus later sleep measures failed to reach statistical significance. Nevertheless, contrary to our expectations, there were no significant concomitant correlations between sleep and attention and behavior measures in the follow-up assessment. It is important to note that reports on the links between sleep and attention/behavioral measures are often inconsistent in children (Astill et al., 2012) as well as in adults (Lim & Dinges, 2010; Riedel & Lichstein, 2000) and that it is also reasonable to assume that reports on failure to find such links are less likely to be published.

On the executive attention task, in comparison to children with good sleep at 1 year of age, children with poor sleep exhibited a larger drop in performance from congruent to incongruent stimuli, raising the possibility that sleep quality in infancy, contributes to the emerging development of executive control. On the reported measures of behavior problems (CBCL and Conners), early poor sleep predicted significantly increased level of reported behavior problems with an emphasis on externalizing problems which are related to the ability to inhibit and regulate emotions and behavior. None of the concomitant sleep measures was significantly correlated with the behavior scales. These results are consistent with earlier findings demonstrating significant associations between sleep and cognitive development during infancy (Dionne et al., 2011; Gomez et al., 2006; Hupbach et al., 2009) and with findings demonstrating a prediction of IQ scores and language development at age five years from infant sleep measures (Sheridan et al., 2013). However, our study extends previous findings by showing for the first time that early sleep patterns, measured objectively, predict preschoolers' executive attentional control. One possible explanation is that poor sleep quality at 1 year of age is a sensitive index for brain maturation or for the development of cognitive or attention regulation capacities. Considered together with other studies demonstrating links between sleep and cognitive and behavior regulation in the first years of life (Bernier et al., 2010; Dearing et al., 2001; Dionne et al., 2011; Holditch-Davis et al., 2005; Sheridan et al., 2013; Touchette et al., 2009; Weisman et al., 2011), it could be argued that sleep disruptions at an early age interfere with vulnerable brain maturational processes that later result in compromised regulatory capacities.

The current results are also in line with the adult literature demonstrating the effects of sleep deprivation on executive functioning (Chuah, Venkatraman, Dinges, & Chee, 2006; Harrison & Horne, 1998; Harrison, Horne, & Rothwell, 2000; Horne, 1993; Thomas et al., 2000; Yoo, Gujar, Hu, Jolesz, & Walker, 2007). For instance, it has been demonstrated that that even a small amount of sleep deprivation significantly reduces prefrontal metabolic activity, and that such reduced activity within the prefrontal cortex is associated with corresponding decrements in performance on tasks requiring complex cognitive processing (Thomas et al., 2000). Furthermore, it has been demonstrated that sleep deprivation increase amygdala reactivity and decrease the regulation of prefrontal systems (Yoo et al., 2007). Additional evidence in adults for the link between sleep deprivation and executive functioning has been reported by Nilsson et al. (2005), who found that one night of sleep deprivation was associated with less effective executive functioning, without affecting the working memory subsystem, or psychomotor vigilance. Our findings are also in agreement with experimental findings in older children, demonstrating a causal link between sleep restriction and deficits in higher order cognitive functioning (Randazzo, Muehlbach, Schweitzer, & Walsh, 1998; Sadeh et al., 2003) and between poor sleep and behavior problems or poor inhibitory control (Sadeh et al., 2002). Moreover, considering the role of sleep in neural plasticity during early and later development (Alkadhi, Zagaar, Alhaider, Salim, & Aleisa, 2013; Gorgoni et al., 2013; Seugnet, Suzuki, Donlea, Gottschalk, & Shaw, 2011; Tononi & Cirelli, 2006; Wang, Grone, Colas, Appelbaum, & Mourrain, 2011), our findings suggest that the impact of sleep deficits at critical stages of early brain maturation could potentially lead to long-term consequences. However, much more evidence is needed to substantiate this possibility which has significant clinical and developmental implications.

In spite of the advantages of the longitudinal nature of our study, it is still impossible to infer causal relations between sleep disruptions and deficits in executive functioning. It could be that a third factor is responsible for the predictive associations found in our study. For example, it could be that slower brain maturation during infancy accounts for both early sleep disruptions and a delay in cognitive functioning. Because early cognitive functioning has not been assessed and controlled for in this study, this possibility cannot be ruled out. An additional explanation for our findings has to do with the impact parents have on the development of children's sleep and cognitive/socioemotional functioning. Parenting factors such as maternal psychopathology, parental stress, parental cognitions, and sleep-related behaviors have all been linked to the development of infants' sleep (Sadeh, Tikotzky, & Scher, 2010). Recent findings have also pointed out to the role parents have in the development of executive functions (Bernier, Carlson, Deschenes, & Matte-Gagne, 2012; Matte-Gagne & Bernier, 2011). Thus parents seem to act as external regulators of both infant sleep and child executive function, which could underlie the links between infant sleep and child executive functioning found in the present study.

Our study included children from relatively middle- and upper-class families (as manifested in the education levels of the parents). This may limit the generalizability of these findings. Furthermore, the lack of neurobehavioral or cognitive measures in infancy precluded assessing the prediction from early neurobehavioral measures to later sleep patterns. Another important limitation is that our study did not include measure of early attention and behavioral functioning and therefore we could not assess the role of early attention/behavior regulation and in predicting sleep development and the possibility that some behavioral issues compromise sleep development.

Nevertheless, the idea that poor sleep in early childhood could have long-term consequences highlights the importance of early identification and prevention of infant sleep problems. Behavioral interventions for infant sleep problems are brief and effective (Mindell, Kuhn, Lewin, Meltzer, & Sadeh, 2006; Sadeh, 2005). Realizing their important role in child development, such interventions could be made freely accessible to parents over the Internet (Mindell et al., 2011a, 2011b).

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