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Behavioral Sleep Problems and their Potential Impact on Developing Executive Function in Children

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Bedtime resistance and night waking are common sleep problems throughout childhood, especially in the early years. These sleep problems may lead to difficulties in neurobehavioral functioning, but most research into childhood sleep problems has not emphasized the importance of the developmental context in which disruptions in neurobehavioral and daytime functioning occur. We review the development of sleep as well as executive functioning (EF) in childhood and suggest that EF may be particularly vulnerable to the effects of these common childhood sleep problems because of its prolonged course of maturation. Behavioral problems associated with common sleep problems suggest poor self-regulation in the context of sleep loss, and developing EF skills play important roles in self-regulation. A research agenda that considers a developmental approach to sleep and sleep problems in the context of childhood EF performance is outlined to promote future research in this area.

Keywords: Bedtime problems, night wakings, behavioral insomnia of childhood, child development, neurobehavioral functioning

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INTRODUCTION

Behavioral sleep problems are the most common sleep problems in childhood within the general population. Between 15% and 30% of 2- to 5-year-old children experience regular difficulties falling asleep (i.e., *bedtime problems*) or sleeping through the night (i.e., *night waking*).[1-4] Fewer school-aged children experience behavioral sleep problems compared to preschool children, but these problems still occur in 11% to 15% of school-age children (6-12 years).[5,6] Behavioral sleep problems result in reduced sleep duration and/or sleep fragmentation, leading to varying degrees of chronic sleep restriction. As we learn more about children's sleep habits and sleep problems through population-based studies,[2,7-11] there is a need to determine how these prevalent sleep disruptions might affect children during the course of development. Given that a substantial proportion of children experience behavioral sleep problems at some point, there is a need to better understand the impact of sleep restriction and fragmentation on children's neurobehavioral functioning.

The impact of sleep restriction on neurobehavioral functioning in adults has been extensively examined,[12-14] but few studies have been conducted with children. The effects of sleep restriction and sleep problems may vary with age, because neurological functioning[15,16] and sleep needs[8] change considerably during child development. We examine research from cognitive developmental psychology and neuroscience, as well as pediatric sleep research to illustrate how neurobehavioral skills with a protracted developmental course (specifically executive functioning skills) could be negatively influenced by behavioral sleep problems.

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PROBLEMATIC SLEEP IN EARLY CHILDHOOD: BEDTIME RESISTANCE AND NIGHT WAKING

Children resist going to bed for a variety of reasons: because they wish to engage in other preferred activities, because they do not feel tired, because they have nighttime fears that make them frightened of going to sleep alone, etc. *Bedtime resistance* involves active oppositional behavior on the part of the child and in turn may lead to shorter sleep duration. *Night waking* problems occur when children wake at night and do not fall back to sleep promptly and independently. Many young children experience transient waking periods through the night, but quickly return to sleep on their own, without intervention from parents.[17-19] When children wake frequently and/or for an extended period of time and require parental assistance (e.g., parental presence, soothing activities) to return to sleep, night wakings become problematic.

Correlational studies have found a relationship between parent-reported sleep problems and child psychosocial problems, including attention problems, hyperactivity, oppositional and aggressive behavior, mood problems, and anxiety.[1,11,20-28] Poor school functioning and lower cognitive performance have also been associated with sleep problems in children, suggesting that sleep disruptions can impair cognitive processes.[29-31] Experimental studies that have assigned school-age children to restricted versus extended sleep schedules have confirmed that even limited sleep deficits (e.g., 1 h/day for 3 days) cause measurable deficits in cognitive functioning measures[32] and child behavior.[33] Thus, research strongly suggests that healthy sleep plays an important role in children's daytime functioning. However, few studies point to specific domains of functioning that are compromised when sleep is disrupted. Recently, studies have included standardized measures of attention and memory, as a means of clarifying more specific neurobehavioral impacts of sleep problems in school-aged children[34] and toddlers.[35]

Children with conditions that involve behavior problems and difficulty with self-regulation, notably attention deficit hyperactivity disorder (ADHD) and autistic spectrum disorder (ASD), present with behavioral sleep problems more frequently than children within the general population, particularly daytime sleepiness (ADHD) and shorter overall sleep duration, reflecting difficulty settling to sleep, night waking, and early morning waking (ASD).[36-40] Children with ADHD have been found to experience more fatigue and sleepiness during the day compared to samples of children without ADHD,[41,42] although not all studies have found significant differences in the amount of sleep obtained by children with ADHD and typical comparison groups.[38,43] Some studies of sleep problems in children with ADHD and ASD have found sleep disruptions other than behavioral sleep problems (i.e., sleep disordered breathing and restless leg syndrome) to be more frequent in children with ASD and ADHD.[44] There is evidence that sleep fragmentation and sleep restriction in children with ADHD is related to poorer performance on measures of sustained attention,[45,46] but few treatment studies have measured changes or improvements in the behavior of children with ADHD or ASD as a result of sleep treatments. A recent review of sleep treatment studies in children with ADHD, ASD, and other chronic conditions (e.g., visual impairment, intellectual/developmental disability) highlights the methodological weaknesses of previous sleep treatment studies conducted with children in special populations, including children with ADHD and ASD.[47]

There has been some research on the effects of sleep treatment to improve daytime functioning in typical children. The purpose of sleep treatment is to consolidate sleep at night and to reduce bedtime delays.[48-51] Not only is behavioral treatment of common sleep problems effective, but improvements in daytime behavior are observed in young children whose sleep problems are successfully treated.[52] However, many sleep treatment studies report only whether children's sleep improves as a result of treatment without assessing other behavioral outcomes or daytime functioning. There are now many published studies of behavioral interventions for sleep in children under five years of age,[50,53-55] and similar interventions are successful with older children.[56]

The severity of bedtime and night waking problems in children have typically been described in terms of overall disruptions of sleep (i.e., times waking per night, sleep duration) and the duration of the problem (i.e., months, years). At this time, clinicians and researchers do not agree on the point at which transient disturbances in children's sleep become significant enough to constitute a sleep disorder,[19] although suggested definitions for research purposes have recently been proposed.[57] In practice, childhood behavioral sleep problems are most often identified and treated when a parent finds their own sleep or evening activities significantly disrupted. Therefore, clinical presentation of childhood sleep problems depends more on the effect of the child's sleep problems on parents and families than on the effect of these sleep problems on the child. A focus on neurobehavioral outcomes in the context of sleep problems will help to inform both clinical and research definitions of what constitutes a mild versus clinically significant sleep problem in terms of the possible effects that the sleep problem will have on the child.

SLEEP DEVELOPMENT

The amount of sleep that children receive decreases through the course of childhood, reflecting a gradual decrease in the need for sleep with age.[7,8] During sleep, children experience REM sleep alternating with NREM or slow wave periods of sleep. Like adults, toddlers (age 1-2 years) and children begin sleep in stage 1 of NREM sleep and proceed through stages 2-4, with each progressive stage involving slower, more synchronous electroencephalographic (EEG) activity. Interspersed with periods of NREM sleep are periods of REM sleep, which are characterized by EEG activity that resembles wakefulness. Throughout the night, children cycle through these different sleep states, but depending on their age they spend more or less time in certain states of sleep than others. Most notably, younger children spend a much higher proportion of their time asleep in REM sleep compared to older children and adults.[58,59] As children age, they also experience a decreased number of sleep cycles over the course of a night, and sleep becomes more efficient, so that periods of waking from sleep at night become less common with age.[58] Overall, differences in sleep architecture over the course of childhood are thought to reflect differences in sleep need across different points in ongoing neurological development, especially the rapid decrease in REM sleep in the first few years of life followed by its slow decline through childhood and adolescence.[60,61]

Changes in normative sleep during childhood are often studied separately from the incidence and impact of behavioral sleep problems. Cross-sectional studies examining normative sleep schedules in children often use parent report of whether the child has a "sleep problem"[4,62] without assessing the nature of the problem. Night waking frequency tends to peak in young children around 1 and 2 years of age.[2,4,24] Delayed sleep onset and bedtime resistance tend to be less common than night waking in 1- and 2-year-olds, increase in prevalence in 3- and 4-year-olds, and decline in frequency as children approach school age.[2] The tendency of behavioral sleep problems to decline in prevalence as children reach school age suggests that these problems might be self-limiting in some children. However, longitudinal research and follow-up studies also indicate that sleep problems and disorders can emerge and resolve at different ages, while in some children they persist with the presence of a sleep problem in infancy being a strong predictor of sleep problems in early childhood.[18,63,64] It is noteworthy that sleep problems are far more common during early childhood compared to later childhood, at the same period when there could be a greater need for sleep to support ongoing neurological development.

THE DEVELOPMENT OF EXECUTIVE FUNCTIONING IN CHILDHOOD

Behavioral sleep problems are most prevalent at the time in development at which children's self-regulatory abilities undergo rapid age-related change. These self-regulatory abilities—"executive functions"—are a set of processes that guide perception, emotion, and action, especially in situations marked by distraction, novelty, or stress.[65] Young parents, for example, typically leave the office at the end of the day and drive straight to pick up their children from school. On some occasions though, they may have to first stop and buy food for dinner and then pick up their children. The ability to adjust habitual patterns of behavior in this way draws on the executive functions—processes that help us to formulate and maintain plans while resisting overlearned habits and powerful emotions.

Executive functions (EF) are profoundly underdeveloped in preschool-aged children, as illustrated by performance in a variety of simple laboratory tasks. For example, in a multi-location search task, 2-year-old children retrieve a small reward hidden in 1 of 3 different hiding locations.[66] On the first trial, children do very well, easily finding the hidden reward. However, in later trials, when the reward is hidden at a new location, children struggle by repeatedly (and erroneously) searching for the reward at the first location. And in the Dimensional Change Card Sort task,[67] 3-year-old children sort cards one way (e.g., by shape) and then are instructed to switch and sort the same cards in a new way (e.g., by color). Again, children do well on initial trials, accurately sorting cards by their shape, but then struggle when the sorting rule changes to color. Instead of switching to the new rules, they persist in using the old rules. Thus, children's difficulties pertain to the regulatory demands of the task. They have little trouble learning to find hidden rewards or sort cards using simple rules. Instead, they struggle when asked to flexibly override what they first learned. Other tasks used to study the development of executive control include the Delay of Gratification procedure. In this task, children are given the option of enjoying a small immediate reward or waiting for a larger preferred reward. These tasks assess self-regulation under conditions in which motivation is enhanced and emotions are aroused.[68,69] Strong emotional responses may make it more difficult to use EF skills to act in socially appropriate ways,[70] and may lead children to act in ways they know are "wrong" (e.g., a child may fail to wait his/her turn in a game when excited, even when he/she knows the rule and will wait in other situations).

EF shows continued development into early adulthood, as illustrated by better performance in rule-use tasks,[71] and a greater capacity to withstand delays with increasing age. These protracted cognitive developmental changes are thought to be associated with age-related changes in the structural and functional organization of lateral prefrontal cortex.[72] By almost any anatomical or functional metric, including cortical thickness,[73] regional volume,[74] myelination,[75] resting metabolism,[76] and rate of synaptogenesis,[77] lateral prefrontal cortex is among the slowest-developing regions of cortex. These ongoing changes in structure occur in a region of the brain that is well-known from adult neuroimaging and neuropsychology studies to be linked with EF.[78] Lateral prefrontal cortex tends, for example, to be more active in trials that require response inhibition and mental flexibility compared to trials that do not.[79] As well, damage or dysfunction in lateral prefrontal cortex leads to pronounced performance deficits in inhibitory control[80] and mental flexibility.[81] The fact that behavioral sleep problems occur with great frequency at a point in development in which the capacity for behavioral self-regulation and associated neural circuitry undergo rapid age-related change calls for closer consideration of how children's sleep and their neurobehavioral development might be related.

BRINGING CHILD SLEEP INTO THE CONTEXT OF EXECUTIVE FUNCTIONING DEVELOPMENT

There has been relatively little attention to the relationship between EF performance and child sleep. Only one study of very young children (12 to 26 months old)[35] has specifically considered the ongoing development of children's self-regulation skills in the context of sleep. Other researchers have previously proposed that poor sleep may specifically affect EF because of noticeable declines in performance on EF tasks and/or self-regulation in children and adults with poor sleep.[82-84] Experimental sleep restriction studies in adults (e.g., limiting sleep to 4 h/night) have also reported evidence of difficulties in planning and organizing behavior,[12] though not all adults studies have reported decreased performance on basic EF functions, such as working memory.[14] Sleep problems that occur in ADHD and in ASD may be relevant to the connection between sleep problems and poor EF performance. In both ADHD and ASD, EF skills tend to develop more slowly compared to typically developing children, and EF deficits are evident among children and adolescents with these diagnoses.[85-88] Children with ADHD have difficulty with EF skills such as organization and behavioral inhibition, and children with ASD show reduced performance in attention and EF domains, beyond the effects of general intellectual functioning.[89,90] It is notable that these conditions, which include core deficits in EF, frequently co-occur with sleep problems. However, the available literature on sleep treatment studies for children with ASD and ADHD is not of sufficient quality to determine whether a causal relationship between improved sleep and improved EF might exist in these conditions.[47] Neurological differences that characterize ASD and/or ADHD might also reduce the extent to which relationships between sleep and EF functioning can be applied to typically developing children with sleep problems. Further research examining the relationship between behavioral sleep problems and EF functioning in children with ADHD or ASD could help to inform our understanding of the relationship between sleep and EF functioning as well as providing information relevant to the treatment of sleep problems in the management of these disorders.

If sleep problems lead to EF difficulties in typically developing children, it could help to account for the association between poor daytime functioning and sleep problems. This may occur in 4 ways:

First, behavioral sleep problems may interfere with children's ability to implement developing EF skills in daily life. Specifically, sleep problems and short sleep duration contribute to fatigue; in turn, lower levels of energy would impair the ability to implement EF skills. The execution of novel skills and behaviors requires greater intentionality, and likely more energy, compared to overlearned, well-established behaviors. As young children's EF skills are undergoing development they may be particularly influenced and impaired by fatigue. This would have consequences for behavioral and emotional regulation, leading to increased negative emotionality, difficulty transitioning between different daytime tasks, oppositional behavior, and other daytime activities requiring application of EF skills. Recent research confirms that EF skills measured in standardized laboratory conditions relate strongly to behavior problems among children aged 2 to 6 years.[91,92] The consistent reports of increased behavior problems in the context of sleep difficulties and sleep restriction[1,11,20-28,33] suggest that poor sleep quality interferes with children's ability to regulate their behavior. The disruption of EF skills, such as working memory, would also explain difficulties in school performance (e.g., lower reported grades[31] and greater failure to meet grade requirements) among children who receive less sleep.[29-31] If children are not able to maintain relevant information in mind when presented with novel information in a school setting, their overall school performance would be expected to suffer.

Second, there might be a concurrent causal association between behavioral sleep problems and EF early in development. An underdeveloped capacity for self-regulation could make it difficult for children to establish consistent sleep patterns. This could be evidenced either at bedtime, when children need to adhere to a routine and avoid distractions, or at night, when, having awoken, they need to soothe themselves back to sleep. Regardless of when such sleep issues occur, mitigating potential sleep disruption would require a capacity for cognitive and behavioral self-regulation, something which is underdeveloped in young children. From this perspective, maturation and development of EF might account for the decrease in prevalence of behavioral sleep problems from infancy through to elementary school.

Third, sleep disturbance might adversely impact EF in individuals of all ages, but have a more pronounced effect on younger as compared to older children, given that executive functioning develops slowly. This could, in turn, undermine the stability of sleep-related behaviors to the extent that, in young children, sleep is dependent on self-regulation. In essence then, there could be a dynamic, concurrent association between sleep disruption and cognitive-behavioral dysregulation early in development. Namely, disrupted sleep compromises children's executive functioning, which in turn, leads to further sleep disruption.

Fourth, a more speculative possibility is that sleep disruption in early childhood is longitudinally associated with decrements in later EF. Given that EF and its associated neural circuitry undergoes rapid development between 2 and 5 years, and that sleep plays a critical restorative role in brain functioning, disrupted sleep early in development could have negative longitudinal consequences for the development of EF. The possibility that sleep reduction at certain ages might have lasting impacts on cognitive performance has been raised by certain pediatric sleep researchers.[30]

Ultimately, the relationship between EF and sleep problems should be empirically studied at the neurological level. Suggested neurological effects of poor sleep have ranged from decreased neuroplasticity, reducing the degree to which neurons may respond to experiential output and learning, to loss of function in neurons.[61,93-95] Neuroplasticity can be observed behaviorally as the rapid ability with which children can learn certain skills with limited exposure compared with adults, and research in the early neurological development of specific systems has generally found increased neuroplasticity to be present at earlier ages and stages of development.[96] Cognitive and neurological development from birth through adolescence is characterized by learning and mastering behavior relevant to social, cognitive, linguistic, and emotional regulation domains. If sleep disruption is a process that can interfere with neuroplasticity, it might have more lasting and impairing effects on the developing neurological systems supporting EF, which take years to mature.

An important feature of the proposed relationships between EF and behavioral sleep problems is the focus on understanding neurobehavioral effects of sleep in a developmental context. Interpreting the effects of sleep problems in children requires a model that takes into account ongoing changes in neurological development. It is also important to note individual variations in the timing of how EF skills develop normatively, and how EF maps on to neurological maturation in childhood. A developmental context stresses the importance of individual differences.[97] As such, our approach draws attention to why and how sleep problems will differentially affect children. Similar levels of severity and frequency of sleep problems may affect individual children differently. This variation in the impact of sleep disruptions could be due to differences in how well children are able to execute EF functions under optimal conditions, as a function of both their development and individual characteristics. In other words, two children who have similar levels of severity and frequency of sleep problems may evidence varying levels of impairment in their daytime functioning due to variability in the development of their EF skills.

A developmental approach also recognizes risk and resilience factors.[97] Although we do not deal with the myriad potential influences on, and moderators of, the relationship between sleep and daytime functioning, we acknowledge these factors exist and are important to consider. While the basic pathway between sleep problems and EF abilities may be similar for all children, other intervening factors, such as the presence of additional environmental stressors (e.g., family stress, parents' marital conflict), or comorbid conditions (e.g., ADHD) could alter the expression of the behavioral problems in the context of sleep disruption.

A RESEARCH AGENDA FOR STUDYING EF AND SLEEP IN CHILDREN

The associations between behavioral sleep problems and EF in early development discussed above call for closer empirical examination: we suggest a number of research directions.

1) *Include developmentally appropriate measures of EF that are sensitive to a range of EF abilities when investigating the effects of sleep problems in children.* There are several methods to measure EF-based skills in children between the ages of 2 and 7 years.[98] Beyond this period, standardized tasks also exist for the measurement of EF skills in older children.[99] Two aspects of EF should be measured. First, there are EF measures that assess more cognitive aspects of EF including switching attention, working memory, inhibiting automatic behavior in accordance with a rule, and performing tasks that include conflicting information. Second, other measures involve emotional and motivational processes along with cognition, notably delay of gratification tasks and "gambling" tasks.[69,100] Both cognitive and emotional/motivational EF skills could be compromised, perhaps differentially, due to sleep problems; emotional/motivational EF tasks may be more relevant to difficulties with behavior and emotion regulation. Another important element in measurement relates to the fact that many

EF measures used in developmental psychology are scored as pass/fail.[67] These tasks are useful for determining the average age when children typically develop certain cognitive abilities, but they are less useful for measuring differences in EF ability within groups of children of a particular age. EF measures that are scored on a continuous basis, or a battery of tasks, would be more appropriate to detect a range of ability among children of the same age such that variation in EF can be related to sleep disruptions.

2) *Include measures of EF in longitudinal studies to investigate potential critical periods for the effects of sleep problems.* Some researchers have suggested that sleep problems during certain ages/stages may compromise the development of particular cognitive skills.[30] Longitudinal studies that assess the onset and offset of sleep problems concurrently with the development and performance in EF-related tasks could help clarify this issue. Similarly, including EF measures in treatment studies for children at different ages could test (a) if EF deficits resolve concurrently with sleep problems or sleep problems have lasting effects on EF after sleep problems resolve, and (b) if changes in EF might mediate the relationship between the secondary improvements in emotional and behavioral functioning that can occur in response to sleep interventions. This research would have important implications for both the treatment and prevention of early sleep problems. Longitudinal studies would also be important to determine the types of risk that chronic sleep problems involve with respect to the development of EF performance. For example, do early sleep problems that are resolved by the time a child is 3 or 4 years of age predict different types of EF dysfunction than sleep problems at age 5-6 years? What is the relationship between the amount of sleep disruption (i.e., short sleep duration) and amount or type of EF dysfunction? Is there a recovery period after a sleep problem is resolved, after which time a child will no longer experience difficulties in EF functioning? Such questions are highly relevant to understanding the role of sleep problems throughout childhood, and could be addressed through longitudinal studies.

3) *Investigate EF performance in the context of problem-free sleep and experimentally induced sleep loss in children.* There are few data on naturally existing relationships between sleep patterns and EF performance among typically developing children. One way to determine whether a causal link between sleep disruption and EF disruption exists would be assessment of EF in response to experimentally induced sleep deprivation and disruption. One recently published study using an experimental paradigm was conducted with toddlers (age 30 to 36 months old) by restricting nap duration[101]; a few other studies have been conducted with school-aged children.[32,33] In contrast, numerous studies have examined the impact of sleep restriction and sleep deprivation in adults, both in the domain of sleep apnea and experimental sleep restriction.[12,84,102,103] Random assignment of children to conditions of sleep restriction or fragmentation, resembling short-term bedtime resistance or night waking, could provide information on potential differential effects for these two types of common sleep problems on EF. If differential effects are identified, subsequent studies using polysomnography might elucidate specific parameters of sleep that are impaired or altered as a result of short sleep duration versus sleep fragmentation, which then could be linked with changes in EF.

4) *Measure variables that may moderate or mediate the relationship between EF and sleep problems in children.* Both EF ability and normative sleep duration show fairly wide interindividual variability. We do not yet have reliable measures to determine if a child is obtaining optimal amounts of sleep; population studies show variability in the amount of sleep between children and within the same child at different points, consistent with variations in sleep need.[4,7,8] Accounting for individual differences is necessary to investigate whether certain subgroups of children may be more vulnerable to neurocognitive disruptions in the context of sleep problems. For example, child temperament could moderate the relationship between sleep loss and neurocognitive disruptions, as suggested by research showing that sleep problems are more strongly related to externalizing behavior in children who display temperamental resistance to control.[21] As there has been so little research on EF-related skills in the context of child sleep, it is difficult speculate on which individual child variables might be most relevant in the relationship between sleep and EF.

5) *Design and conduct studies on the relationship between childhood sleep problems and EF function in multidisciplinary teams.* Child development can be measured from many perspectives—behavioral, social, cognitive, neurological, physiological, and emotional—and each of these areas has its own history of research progress and expertise. Sleep is also a complex process that has been studied using very diverse approaches, from animal models to clinical case studies. This discussion of EF and its relationship to common behavioral sleep problems brings together evidence from the neurological, pediatric sleep, and child cognitive-developmental literatures. Basic associations between difficult behavior and child sleep problems have now been well established: it is time to advance our knowledge by drawing on the evidence of other fields to find and test connections that will inform *how* and *why* sleep problems impact child functioning.

LIMITATIONS

We have focused on the impact of common childhood sleep problems on the development and use of executive functioning skills. The protracted development of EF-based skills throughout childhood makes these skills interesting to examine in the context of sleep problems, but there are likely other pathways through which sleep restriction or fragmentation could influence neurological development and behavior throughout childhood. Reduced sleep duration has been associated with problems learning new information and committing it to memory in adults[94]: this would probably be true for children as well. Further research examining physiological and neurological variables in relation to sleep should include careful measurement of children's sleep, daytime behavior, and neurological/physiological measures of interest in order to propose a theory for the influence of these pathways on behavior. Ideally, assessment of sleep should involve actigraphy (motion logging) and/or videosomnography (time-lapse video taken at night) to verify parent reports of sleep. Neurological measures could include fMRI and other neuroimaging techniques that investigate changes in children's brains that occur in the context of sleep problems.

We have also focused on sleep at the level of the individual child. Sleep, like most childhood behaviors, occurs in the context of the family and develops through interaction with environmental variables, such as family organization, routines, and parenting practices. Many studies of children's sleep have identified family and environmental predictors of children's sleep patterns, such as cultural differences,[104,105] family disorganization,[106] parent-child relationships,[107] and socioeconomic status[108] that influence sleep in early childhood. It is possible that co-occurrence of behavioral sleep problems and poor EF in early development reflect the influence of other (or third) factors, such as the presence of family discord, psychopathology in the child, or other health-related issues. Given that behavioral sleep problems can be stressful for parents, child sleep problems can create additional difficulties for a family. Potential transactional effects are therefore likely to emerge, whereby a stressful family environment, or practices that parents maintain around their children's sleep, make sleep problems more likely.[109,110]

CONCLUSION

EF skills and their underlying mechanisms are important outcomes for researchers to measure in the context of sleep. These skills are relevant to children's everyday functioning and self-regulation, and follow an extended developmental course, potentially making these skills vulnerable to inadequate sleep. In particular, the role that optimal sleep plays in maintaining behavioral control through EF is a theoretically compelling relationship. Further evidence of the specific relationship between EF and sleep in early childhood is necessary, and could have implications for our understanding of how sleep affects children's ability to function adaptively in the course of daily life.

Advances in technology, and the accelerated pace of life in modern society are having an impact on sleep in humans of all ages, and children in industrialized countries are now sleeping less than in previous generations.[111] The ubiquity of television and other screen technologies likely plays a role in the overall decrease in sleep times for children.[112] Also, the necessity of sleep may be downplayed in favor of other activities. Over half of the 3-year-olds in Japan go to bed after 10 p.m. on a regular basis (versus approximately 22% of children in 1980).[11] This trend towards later bedtimes and shorter sleep duration in children makes it more important than ever to examine the role that sleep plays in the maintenance of health, particularly healthy development. The amount of time that children spend asleep when cognitive skills and self-regulation are developing suggests that sleep serves a number of vital functions that support neurological development. The more we know about the specific functions of sleep in children, the more we can encourage the timely treatment of sleep problems and the safe-guarding of sleep during childhood.

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