

COMMENTARY

ON SLEEP AND DEVELOPMENT: RECENT ADVANCES AND FUTURE DIRECTIONS

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ABSTRACT The authors of the monograph discuss conceptual and methodological issues in the study of sleep-behavior associations, report on the advantages and disadvantages of various techniques for assessing sleep in infants and children, and suggest the importance of examining sleep-behavior relations across multiple disciplines of influence. The primary focus of this commentary is to highlight how these new perspectives contribute to our emerging understanding of sleep-behavior relations in infancy and childhood, as well as to propose further challenges and avenues for future research.

Researchers have long recognized the importance of sleep in infant and child development. Yet the preponderance of early studies on the topic were conducted for the purposes of diagnosing and treating pediatric sleep problems. More recent attention has been devoted to examining associations between sleep and functional outcomes in numerous domains, from those associated with motor development to cognitive functioning to social relationships. These recent advances in the field require an integration of conceptual and methodological issues, consideration of the advantages and disadvantages of techniques for sleep assessment, and focus on sleep-behavior relations across multiple domains of influence. To this end, the authors of this monograph propose a framework for studying the various manners in which contextual factors—from those associated with the child to those linked with culture—impact sleep and behavioral outcomes in a complex, multidirectional manner. They also highlight the importance of considering elements

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associated with time, as contextual influences change as children develop and across generations. The authors then present data from seven longitudinal studies examining sleep-behavior relations at multiple levels of influence, most commonly those associated with child-level and immediate-level factors. The goal of this commentary is to highlight how these new perspectives contribute to our emerging understanding of sleep-behavior relations in infancy and early childhood, as well as to propose remaining challenges and avenues for future research.

CONTRIBUTIONS OF THIS MONOGRAPH

One of the primary contributions of this monograph is in its description of a transactional framework for understanding the manner in which various contextual influences contribute to sleep-behavior associations in infancy and childhood. As the authors indicate, the model is largely based on work by Bronfenbrenner (Bronfenbrenner, 1979; Bronfenbrenner & Ceci, 1994). As described in Chapter I, the proposed framework includes multiple levels of influence, from those associated with the child (such as brain development, medical issues, and temperament), the family (such as family sleeping arrangements, parental cognitions and decisions about sleep-related behaviors, and parent mental health), the broader social environment (such as relationships with friends, school start times and other associated demands, both academic and extracurricular, and access to electronic devices, including cell phones, video games, and the Internet), and the cultural context (such as differences in accepted sleep arrangements by culture and poverty). Interconnections exist among the various levels of influence, such that the broader social environment might serve to impact family-related factors (as in a situation in which parents are pressured from friends or other relatives to modify their sleeping arrangements with their child; see also Sadeh & Anders, 1993; Sadeh, Tikotzky, & Scher, 2010). The influences in the proposed framework are also dynamic, as the contribution of each level to sleep-behavior relations likely changes with ontogenetic time (as children get older) and across phylogeny (due to developments across generations). As such, the model proposed by the monograph authors is useful for examining sleep-behavior relations in context by focusing on the dynamic nature of multiple levels of influence.

An additional strength of the monograph is that the authors demonstrate how to apply the proposed model to the study of infant and child development through the inclusion of seven studies conducted with independent samples of participants from three countries. The studies primarily focus on child- (infant reactivity: Chapter IV; motor development: Chapter V) and family-level factors (paternal caretaking and maternal sleep: Chapter VII; the

attachment relationship: Chapter VIII; bedtime routines: Chapter IX; bed-sharing and co-parenting: Chapter X), as well as their interaction (marital conflict and child regulation: Chapter VI). In this way, the researchers examine the complex social-contextual influences on sleep-behavior relations in developmental samples.

The presented studies are unique because of their use of longitudinal designs, which are rarely found in developmental research on sleep-behavior relations. Most of the empirical chapters feature longitudinal assessments of both sleep and behavior (infant sleep and infant reactivity: Chapter IV; infant sleep and motor development: Chapter V; child sleep, marital conflict, and child regulation: Chapter VI; infant sleep, maternal sleep, and paternal involvement: Chapter VII; child sleep, bedtime routines, and parental laxness: Chapter IX; parent-child sleep arrangements, maternal depression, and co-parenting: Chapter X); one chapter included independent assessment of attachment at one wave of testing and child sleep at another (Chapter VIII). Such studies are important in that they are truly developmental in nature: change over time is observed in the same sample of participants. For these reasons, the topic of this monograph is significant, and the longitudinal and sleep methodology demanding. The authors of this monograph demonstrate that rigorous studies are feasible and allow for important insights as to the manner in which changing contextual influences contribute to sleep and development over time.

Another primary contribution of this monograph is in its call to action. The authors propose five core issues relevant to the study of sleep-behavior relations across development. This call to action includes increased focus on sociocultural issues and the family environment so as to better characterize the context in which sleep-behavior relations emerge. This issue is significant in that many studies have examined sleep in association with cognitive or social-emotional outcomes in infancy and childhood but few have attempted to determine how family functioning, the broader social context, and cultural values and principles may influence these associations (although see Burnham, Goodlin-Jones, Gaylor, & Anders, 2002; Bell & Belsky, 2008; Bordeleau, Bernier, & Carrier, 2012; Scher, 2008; Simard, Nielsen, Tremblay, Boivin, & Montplaisir, 2008; Spilsbury, Storfer-Isser, Rosen, Kirchner, & Redline, 2005). The authors also recommend increased focus on biobehavioral processes, with researchers examining multiple aspects of biological and physiological indicators that may be associated with sleep-behavior relations. An additional issue is associated with sleep assessment, such that many researchers adopt different methods of assessing sleep and, perhaps by extension, use varied sleep-related measures in statistical analyses. This particular issue is of critical importance in that developmental researchers often use different measures to assess sleep—and even when the same assessment tool is used, researchers may use different variables in their

statistical models (e.g., Scher & Asher, 2004; Simard, Bélanger, & Carrier, 2013). This complicates the development of a unified literature in that various means of measuring sleep may reveal distinct associations, even if the same outcome measure is employed. Finally, the authors also suggest a movement toward more sophisticated research design and statistical approaches, particularly those that can accommodate large longitudinal datasets. These recommendations for future research are certainly timely and may serve to better integrate the study of sleep-behavior relations across disciplines. In the following sections, we discuss additional remaining challenges and future directions for the study of sleep-behavior relations across development.

REMAINING CHALLENGES AND FUTURE DIRECTIONS

Causality

Despite widespread recognition of the influence of sleep on adult functioning, significant questions still remain as to whether sleep impacts daytime behavior of infants, children, and their parents. In a recent review, Ednick and his colleagues (Ednick et al., 2009) reported that although the existing literature generally indicates associations between sleep and daytime behavior in infancy and early childhood, there is not sufficient evidence to state that sleep is causally related to functional outcomes. Obtaining evidence of causality is important not only for informing questions associated with the significance of sleep for infant and child development, but also for the practical purpose of developing intervention efforts. Longitudinal studies such as those presented in this monograph are useful in indicating that variability in sleep habits precedes developments in other domains. However, we cannot be confident that sleep causes change in specific developmental outcomes until experimental studies are conducted with typically developing infants and children who have not been referred for or diagnosed with sleep problems.

Although relatively small in number, experimental studies have indicated that sleep is associated with daytime functioning in typically developing infants and children. Manipulations of sleep in samples of infants and young children have primarily focused on daytime naps instead of nighttime sleep, and include outcomes associated with cognitive functioning. One paradigm commonly used for assessing the impact of daytime napping on memory in young children requires researchers to randomly assign children to participate in either a nap group or a no-nap group. Children in the nap group are scheduled so that the delay between exposure and test in a memory paradigm includes at least 30 minutes of time during which the child is expected to nap; children in the no-nap group are scheduled so that the delay occurs during a

period of time when the child is expected to remain awake (Gómez, Bootzin, & Nadel, 2006; Hupbach, Gómez, Bootzin, & Nadel, 2009). Use of this procedure has indicated that 15-month-old children who were exposed to a string of novel speech before napping demonstrated better generalization of a linguistic rule after a 4 hr delay relative to children who remained awake after learning; napping did not facilitate memory for the learned information (Gómez et al., 2006). Results from a separate study by the same research team indicated that the effect of napping on generalization was not transient; children who napped after learning demonstrated better generalization of the linguistic rule after a 24 hr delay (Hupbach et al., 2009; although see Werchan & Gómez, 2014). The immediate and long-term benefits of napping have also been demonstrated with preschoolers; those who napped after learning novel spatial relations remembered more information both shortly after napping and after 24 hr relative to children who did not nap. A subset of participants completed polysomnography recordings in the laboratory, and the findings revealed that sleep spindle density was positively associated with recall performance. As such, the authors suggest that sleep spindle density may serve as a marker of interactions between the hippocampus and neocortex, a process necessary for memory consolidation and storage (Kurdziel, Duclos, & Spencer, 2013).

Although only a few studies have been featured here, these findings indicate that experimental manipulations of sleep are possible in infants and children. Creativity and ingenuity are necessary to identify ways in which daytime naps and nighttime sleep might be modified so as to examine effects on daytime behavior. As well, additional work is undoubtedly needed to broaden our understanding of causal relations between sleep and functional outcomes in infancy and childhood.

Daytime Napping and Nighttime Sleep

Research should be conducted to disentangle the possible contributions of daytime naps and nighttime sleep to functional outcomes in infants and children who commonly nap during the day. Many of the studies conducted to date focus on daytime napping or nighttime sleep to the exclusion of the other. However, examining both aspects of 24 hr sleep is likely important due to maturation-based changes and individual differences in the distribution of sleep during infancy and early childhood (Iglowstein, Jenni, Molinari, & Largo, 2003). It is plausible that daytime naps, nighttime sleep, and 24 hr sleep duration may be differentially associated with various functional outcomes and that the pattern of association may differ with age. The few studies that have included collection of 24 hr sleep data—including two chapters in this monograph (Chapter VIII and Chapter IX)—suggest that this is the case.

The authors of Chapter VIII examined associations between attachment security and dependency at 15 months in relation to child sleep at 2 years; they included 24 hr recordings of child sleep using actigraphy. Their findings indicated that attachment was preferentially associated with nighttime sleep relative to sleep obtained over a 24 hr period. In particular, attachment security at 15 months was positively associated with nighttime sleep duration and sleep efficiency at 2 years, whereas attachment dependency was related to fewer nighttime sleep minutes. The authors interpreted these findings in the context of parent-child interactions. They indicate that one potential explanation for their results may be that children with secure attachment relationships are better able to self-regulate during the night, a skill that may be developed through parent structuring of self-regulatory abilities during the daytime hours. Alternatively, the consistent and sensitive manner in which parents of securely attached children respond to them during the night may help promote better nighttime sleep. It may be the case that attachment-sleep relations were obtained when considering nighttime sleep only due to the increased need to self-regulate during the night relative to during daytime naps, although this possibility requires additional empirical attention.

The findings from Chapter VIII reveal that nighttime and 24 hr sleep duration are differentially associated with attachment. The research presented in Chapter IX indicates nighttime and 24 hr sleep duration are differentially associated with parenting practices and that these relations also differ across development. The authors conducted a longitudinal study in which they examined child sleep habits, parent adherence to a bedtime routine, and inconsistency in discipline (parental laxness) when children were 30, 36, and 42 months old. They examined relations among the included variables at each time point and found different effects at each age. When children were 30 months old, associations were not found among child sleep habits, adherence to a bedtime routine, and parental laxness. When children were 36 months, parental laxness was negatively related with nighttime and 24 hr sleep duration; adherence to a bedtime routine was positively associated with nighttime sleep duration as well. An interaction was also apparent at 36 months, such that bedtime routines were most effective at promoting nighttime sleep in parents who were more consistent in their daily interactions with their children (those low on parental laxness); no effect of adherence to a bedtime routine was found when considering mothers who were more inconsistent in their daytime behavior (high on parental laxness). At 42 months, adherence to a bedtime routine was associated with increased nighttime sleep duration; adherence to a bedtime routine and parental laxness was not associated with 24 hr sleep duration. Taken together, these findings demonstrate that nighttime and 24 hr sleep duration may differentially predict outcomes, but that the observed relations may also vary across development. Given that significant advances in self-regulation

skills are made during this time frame (from 30 to 42 months; Berger, 2011), these differential associations with child sleep may be part of an overall reorganization of the developmental system.

Whereas the findings in this monograph focus on associations between sleep and social-emotional outcomes, multiple aspects of 24 hr sleep have also been studied in relation to cognitive functioning. Bernier, Carlson, Bordeleau, and Carrier (2010) asked parents to report on the sleep habits of their children at 12 and 18 months; they then examined the data in relation to measures of executive functioning obtained at 18 and 26 months. Although data associated with the duration of daytime naps and nighttime sleep were not presented, the findings indicated that 24 hr sleep duration was unrelated to measures of executive functioning. Instead, it was the distribution of sleep that mattered: obtaining more sleep at night relative to during the day was associated with better cognitive performance. In particular, greater percentage of total sleep occurring at night at 12 months was positively associated with better performance on measures of executive functioning (including aspects of inhibition, set shifting, and working memory) and impulse control (delay of gratification) at 26 months. Concurrent relations were found when examining the percent of sleep obtained at night in relation to working memory at 18 months; cross-lagged relations indicated that the percent of sleep obtained at night at 18 months was also associated with impulse control at 26 months. Notably, these findings remained significant after relevant covariate control. The authors interpreted their findings as indicating that increased consolidation of sleep in the nighttime hours is associated with enhanced frontal lobe functioning, although the mechanism by which this occurs remains to be determined.

These studies indicate that additional work remains to be done above and beyond describing the contribution of daytime naps and nighttime sleep to functional outcomes. As illustrated by the aforementioned studies, certain outcomes may be associated with singular aspects of sleep (as in Chapter VIII) whereas others may be associated with multiple aspects that may vary across development (as in Chapter IX); in other cases, combinations of daytime and nighttime sleep duration (as in Bernier et al., 2010) may be most informative in predicting outcomes over time. Future studies should record 24 hr sleep duration as well as other relevant measures of nighttime sleep and present the findings (even when non-significant) to help establish a foundation for understanding complex sleep-behavior associations.

Polysomnography

The majority of developmental work conducted to date examines relations between sleep and functional outcomes through the use of videosomnography, actigraphy, and parent-report measures (questionnaires

or sleep diaries). One significant limitation arising from the use of these techniques is that information about the neural underpinnings of sleep is not obtained. This shortcoming in the developmental literature is noteworthy, as adult studies consistently indicate that variability in sleep stages and sleep architecture is associated with functional outcomes in adults, most commonly those that are cognitive in nature (Durrant, Taylor, Cairney, & Lewis, 2011; Morin et al., 2008; Nguyen, Tucker, Stickgold, & Wamsley, 2013; Tamminen, Ralsh, & Lewis, 2013). Future research should use polysomnography to examine whether sleep stages and sleep architecture are associated with functioning in infancy and childhood.

Chapter III features discussion of various methods for recording sleep across development, highlighting the benefits and limitations of each. The authors report that polysomnography confers unique benefits to the study of sleep relative to the other available recording techniques given its ability to provide information on the neural signature of sleep that can then be examined in relation to other functional outcomes. Despite this significant advantage, the limitations of polysomnography have largely precluded its use in developmental research. Polysomnography is costly, requiring the use of expensive electrophysiological equipment and trained technicians to score and interpret the findings. Experimental issues with external validity are also common, as sleep data are usually recorded for only one or two nights in unfamiliar laboratory space while participants wear various electrodes and sensors. Other issues associated with polysomnography include participant burden due to the time demands and inconveniences of sleeping in a laboratory or hospital. For example, parents would be unlikely to agree to having both daytime naps and nighttime sleep recorded in their infant and young children. Longitudinal studies such as those reported on this monograph would also be difficult to conduct using polysomnography, particularly if more than one day or night of data were needed at each wave of testing. Given these challenges, researchers should determine whether polysomnography would be useful in their research and design their studies accordingly.

Polysomnography will likely be most beneficial when applied to questions of cognitive functioning in infancy and early childhood, given the extensive literature on sleep-cognition relations in adults. Work conducted with preschoolers used polysomnography to indicate that napping actively serves to consolidate memories (i.e., that sleep actually strengthens the memory trace, perhaps through the replay of learned information, instead of passively protecting memories from interfering information; see Ellenbogen, Payne, & Stickgold, 2006). Kurdziel and colleagues (Kurdziel et al., 2013) conducted a behavioral study to determine whether children who napped after learning novel spatial relations in a memory game demonstrated improved recall performance after the nap and the next morning relative to children who did

not sleep after learning. Their findings indicated that the children who napped recalled more information after the nap, as well as the next morning, relative to children who remained awake after learning. The authors then tested a separate group of children who napped in the laboratory while recording polysomnography after learning. The results indicated that sleep spindle density during NREM sleep was negatively related to performance at immediate recall, which the authors interpreted based on previously-demonstrated negative correlations between sleep spindle density and IQ (Geiger et al., 2011). Sleep spindle density was also positively associated with change in recall performance over the delay. Based on these data, the authors concluded that napping actively contributes to memory consolidation in preschoolers. Importantly, the same conclusions would not have been made if polysomnography was not recorded during napping, as the amount of time spent sleeping was unassociated with changes in memory over the delay. As such, the use of polysomnography in this study revealed unique findings that would not have been made apparent if another recording technique had been used.

Examining Sleep and Functional Outcomes in Nonnormative Samples

Research efforts should also be devoted to examining associations between sleep and functional outcomes in infants and children with parents who are experiencing mental health issues, as well as in infants and children with developmental disorders. Chapter X in this monograph cites the importance of parent-infant sleep arrangements associated with co-parenting relationships and maternal depression. In particular, mothers who shared a bed with their infants when the infant was 1 month old reported increased negative co-parenting relative to mothers of independent sleepers. When infants were 6 months of age, mothers who shared a bed with their infants reported reduced positive co-parenting and increased depression scores relative to mothers of independent sleepers. Although this study did not include examination of associations between maternal depression and infant functioning, the impact of maternal depression on infant outcomes is well-documented in both the cognitive and social-emotional domains (e.g., Murray, 1992). As such, one might expect that the influence of bed-sharing extends beyond reduced positive co-parenting and increased maternal depression at 6 months, possibly also affecting aspects of the mother-infant relationship as well. Additional work remains to be conducted to determine if this prediction is realized. However, the study in Chapter X highlights the importance of examining parent sleep and functioning in association with infant sleep and functioning so as to better understand how these factors contribute to infant and child development within the immediate family context.

Additional research is needed to examine associations between sleep and functional outcomes in infants and children with developmental disorders. Previous investigations have established that numerous developmental disorders co-occur with sleep problems, such as autism (Hodge, Carollo, Lewin, Hoffman, & Sweeney, 2014; Richdale, 1999, 2001; Richdale & Schreck, 2009; Stores & Wiggs, 1998), Down syndrome (Breslin, Edgin, Bootzin, Goodwin, & Nadel, 2011; Carter, McCaughey, Annaz, & Hill, 2009; Churchill, Kieckhefer, Landis, & Ward, 2012; Stores, Stores, Fellows, & Buckley, 1998; Stores & Stores, 2013), and attention deficit disorders (Kaplan, McNichol, Conte, & Moghadam, 1987; Trommer, Hoepfner, Rosenberg, Armstrong, & Rothstein, 1988; Sedky, Bennett, & Carvalho, 2014), among others. A call for increased research on this front is warranted given that findings obtained from samples of typically developing infants and children may not generalize to those with developmental disorders. For example, whereas typically developing children tend to experience declines in sleep problems over time (Gregory & O'Connor, 2002), some groups of children with developmental disabilities have been shown to experience increases in sleep problems with age (e.g., autism spectrum disorders; Sivertsen, Posserud, Gillberg, Lunder-vold, & Hysing, 2012). An additional complication is that different factors are likely associated with the onset and maintenance of sleep problems in children with developmental disabilities relative to those who are typically developing. For instance, the physical characteristics associated with Down syndrome are implicated in the increased incidence of sleep-disordered breathing (Silverman, 1988) and nighttime sleep fragmentation (that is, brief nighttime sleep disruptions from which the individual might not fully awaken) in this population (Levanon, Tarasiuk, & Tal, 1999). For these reasons, independent lines of inquiry are needed to understand how various developmental disorders are associated with sleep problems and behavioral functioning, with results from typically developing infants and children serving as valuable comparison groups.

Strides are being made in examining associations between sleep and functional outcomes in individuals affected by developmental disorders. At the same time, this literature is affected by the same shortcomings mentioned in this monograph in relation to work conducted with typically developing infants and children. As such, the proposed developmental ecological systems model of sleep development discussed in Chapter I of this monograph as well as the five core issues for developmental sleep research detailed in Chapter II, also directly apply to research conducted on infants and children with developmental disorders. For example, significant attention should be devoted to the core issue concerning sleep habits and family processes, given research demonstrating parents of children with developmental disorders experience increased stress relative to families with typically developing infants and children. Additionally, stresses experienced by parents vary in

relation to child diagnosis, with parents of children with autism reporting more stress relative to parents of children with Down syndrome (Dabrowska & Pisula, 2010; Sanders & Morgan, 1997). Some research suggests that child sleep problems in particular are associated with heightened levels of parental stress. As an example, Chinese children with pervasive developmental delay who also experienced sleep problems had parents who reported more stress relative to parents of children with pervasive developmental delays who did not have sleep problems (Doo & Wing, 2006). Work should also be conducted to examine how other contextual elements moderate associations between sleep and functional outcomes in infants and children with developmental disorders, as elements of the social context such as social support obtained by parents and interventions experienced by children may serve to further clarify associations between sleep and child functioning.

CONCLUSIONS

The authors of this monograph provide (a) a conceptual framework for understanding the multiple influences on sleep-behavior relations in developmental samples; (b) demonstration that the proposed framework can be applied to the study of sleep-behavior relations in infants and children; (c) use of longitudinal studies to examine changes in sleep-behavior relations and contextual influences over time; and (d) a call to action, urging scholars from multiple disciplines to attend to five core issues in sleep development research. We propose additional directions for future research. Attention should be devoted to (a) examining whether sleep is causally associated with behavior in infants and children; (b) better understanding the complex interplay between daytime naps and nighttime sleep in infants and children; (c) using polysomnography, when appropriate, to examine associations between sleep stages and architecture on behavioral outcomes; and (d) focusing on non-normative samples of participants for whom sleep-behavior relations may differ relative to those described for typically developing infants and children. Indeed, great strides have been made to date in examining associations between sleep and behavior in infants and children. Much work remains to be done, with the ultimate goal of better characterizing how the complex social environment contributes to sleep and functional outcomes in children and their families.

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