COMMENTARY

Napping helps preschoolers learn

Sara C. Mednick[1]

A great deal of research supports the claim that sleep benefits cognitive function in adults. However, evidence-based research on how much sleep children need for healthy cognitive development is scarce. Despite this lack of clarity, certain facts appear consistent across studies. First, recommendations for sleep need have fluctuated throughout history, with children always sleeping less than the experts recommend. Second, children are sleeping less now than ever before (1). Without targeted research on the impact of sleep on cognitive development, experts are unable to make informed recommendations for school start times, bedtimes, and nap times.

Napping is the core of infant sleep and remains an essential part of many children's sleep diet until they begin kindergarten. PNAS now presents a unique study by Kurdziel et al. to illuminate what may be one of the primary functions of daytime napping in preschool-aged children: memory consolidation (2). Preschoolers were trained in the morning on a visuospatial memory task similar to the game "Memory," and then either napped or played quietly without napping. Recall was tested 30 min after the nap and the following morning, 24 h posttraining. The authors found that when children napped they showed greater conservation of knowledge both in the postnap and 24-h recall conditions, whereas there was significant long-term forgetting when they did not nap. These data are unique in clearly indicating napping as a valuable resource for memory consolidation in preschool-aged children.

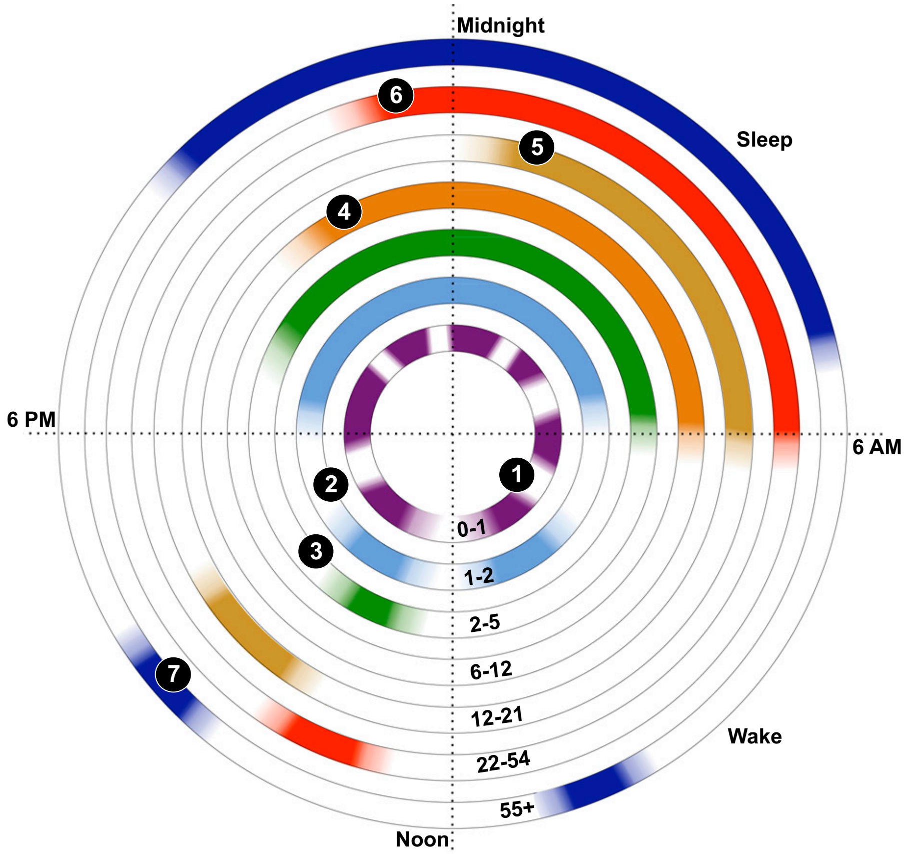

Fig. 1. A map of nocturnal sleep and naps from infancy to older adulthood. Each circle represents an age group, with colored areas showing nocturnal and daytime sleep periods. (1) Infant polyphasic sleep is shown in the innermost circle in purple. (2) After the first year of life, children (light blue) begin to sleep through the night and daytime sleep consolidates into two naps. (3) Toddlers (green) have later bedtimes and only one (or no) afternoon nap. (4) Children between 6 and 12 y of age (orange) maintain a steady sleep duration between 8 and 10 h at night, with decreased night wakings and infrequent naps (20). (5) A marked delay in sleep patterns is a normal feature of adolescent development (brown), with later bedtimes in postpubertal adolescents. Because of social pressures, including early school start times, sleep can be severely curtailed and many teenagers nap after (and during) school. (6) Adults (red) usually get 6–8 h of sleep, with 30% taking short naps during the afternoon. (7) Older adults experience sleep-phase advancement with earlier bedtimes and wake times and frequent short naps during the day.

Numerous studies demonstrate positive effects of sleep on memory consolidation in adults (3). Although seldom researched, similar results have been shown across younger age groups. Infants who nap within 4 h of training on an artificial language show generalization of language rules compared with infants who stayed awake (4). On a visuospatial task similar to the one used by Kurdziel et al. (2), performance improvement following sleep in 6- to 8-y-olds was comparable to adults (5). In older children (9- to 12-y-old), a period of sleep following training on a list of word-pairs improved recall more so than an equivalent period of wakefulness (6). In fact, in these older children memory was improved after sleep regardless of whether the sleep period immediately followed training or came after 12 h of wakefulness. Taken together with studies of younger children, these findings indicate that as children age, they can afford increasingly longer wake windows between initial learning and sleep-dependent memory consolidation. This hypothesis is consistent with a recent study showing a negative correlation between vocabulary and attention span and nap frequency in toddlers (7).

In both children and adults, the quality of sleep (i.e., minutes of sleep stages and quantity of sleep features) is correlated with the magnitude of memory improvement. In adults, nonrapid eye movement (non-REM) sleep yields less forgetting than a comparable period of REM sleep or waking activity (8). One electrophysiological feature of non-REM sleep, the sleep spindle, has recently gained attention for its role in hippocampal-cortical communication (9) in rodents and declarative memory consolidation during sleep in humans (10). Furthermore, experimentally increasing sleep spindles in a daytime nap improved verbal memory performance compared with

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[1]E-mail: smednick@ucr.edu.

control conditions (11). In young adults, retention of word-pairs across a sleep interval was correlated with the minutes in non-REM sleep (6), and improvement in visuospatial memory in the present study was correlated with the number of stage 2 sleep spindles in toddlers' naps (2). These results are consistent with the notion that sleep spindles orchestrate the consolidation of new declarative memories similarly across different ages.

Importantly, napping is not universal across preschoolers. Between the ages of 2- and 6-y-old, most children give up napping because of biological and social pressures (12). Until now, no studies have examined differences in sleep-dependent memory consolidation between habitual and nonhabitual napping children. Intriguingly, Kurdziel et al. (2) found that the deficits in the no-nap condition were solely because of the habitual nappers. That is, nonnappers who remained awake maintained memory performance equivalent to that of habitual and nonnappers who napped. In contrast, massive forgetting was seen when habitual nappers were prevented from napping. The authors posited that one possible reason for this difference is brain maturation; that is, more neurologically mature children are able to withstand longer wake windows without forgetting newly learned information, compared with less mature children who require sleep within a shorter window following learning. Consistent with this hypothesis, studies show that children maintain a constant total sleep time across their transitions from napping to not napping, indicating a stability in sleep requirements along with tolerance of longer wake periods (7). This relationship between brain maturity, wake windows, and sleep-dependent learning may be an important factor contributing to the transition from polyphasic napping habits in infants, to the consolidation of sleep into a biphasic pattern in preschool children, and to the eventual monophasic pattern in older children (Fig. 1).

These results may also be unique evidence that napping serves a different purpose in children and adults. Thirty-percent of healthy adults endorse appetitive napping, or napping for pleasure. Several studies have reported that habitual appetitive nappers remain in lighter sleep (stages 1 and 2), have more fluctuations between light sleep stages, and feel more refreshed upon waking from a nap compared with nonnappers (13). Furthermore, increased slow-wave sleep in nonnappers likely contributes to postnap grogginess (i.e., sleep inertia) reported in this group. Habitual nappers also gain more performance benefits from napping than nonnappers. Milner et al. reported that habitual nappers performed better in a motor learning task, and performance gains were correlated with stage 2 sleep spindles, compared with nonnappers (14). Thus, adults may choose to nap because of the extra boost in alertness and performance enhancements, whereas napping in children may be related to developmental limitations in cognitive abilities. Along these lines, it would be informative to know, do nap habits from childhood transfer to adulthood? Are there biological/genetic differences between habitual and nonnappers? Or is appetitive napping a learned, trainable skill? Further research into the biological basis of napping will shed light on this topic.

Along with cognitive development, sleep, and perhaps napping, in the early years have surprisingly long-term consequences for adolescent and adult health and well-being. Short sleep duration in children has been associated with higher body mass index (BMI) 5 y after baseline (15). In addition, children with short sleep durations had significantly higher BMIs at 32 y of age, compared with the adult BMIs of children with moderate and long sleep durations (16). Furthermore, young teenagers with poor preschool sleep habits were more than twice as likely to use drugs, tobacco, or alcohol 10 y later (17). Inadequate sleep has also been raised as a possible contributor to childhood attention deficit/hyperactivity disorder (ADHD). In one review, children with ADHD were sleepier during the day, snored more, had higher apnea-hypopnea index, and more restless sleep (18). In fact, a comparison between treatment of ADHD with a commonly prescribed ADHD drug and adenotonsillectomy found decreased ADHD scores in both treatment groups, compared with no treatment. However, along with improved sleep, the surgical group had better impulse control, response time, and total ADHD score, as well as lower hyperactivity and inattention subscales than the drug group (19). Unfortunately, none of these studies considered the effect of napping on present and future health outcomes; however, the current findings of the benefits of preschool napping on memory urge such a comparison.

Practically speaking, how does this new information on napping figure into expert recommendations for sleep schedules in schools? Currently, such data do not appear to be considered, as many schools are making the decision to eliminate naps from preschool in favor of increased active learning periods. These no-nap policies began at the same time as—and perhaps in response to—public initiatives to reward schools that have higher standardized test scores and an increased emphasis on preschool readiness. Without scientific research addressing the importance of napping for cognitive development, many school administrators across America have been forced to make the choice between giving children a period for sleep, versus for study. In light of these changes in preschool curriculum, Kurdziel et al.'s (2) findings of the essential nature of the nap for children, especially habitual-nappers, are timely and have the potential to affect educational standards. Given the individual differences in nap need, an updated framework might move away from the one-size-fits-all approach to sleep schedules, and consider each child's sleep need individually. Given that depriving a child of a nap can have dire consequences for his or her long-term memory and future test performance, addressing these issues appears to be scientifically justified.

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