ASK THE COGNITIVE SCIENTIST

Are Sleepy Students Learning?

How does the mind work—and especially how does it learn? Teachers' instructional decisions are based on a mix of theories learned in teacher education, trial and error, craft knowledge, and gut instinct. Such knowledge often serves us well, but is there anything sturdier to rely on?

Cognitive science is an interdisciplinary field of researchers from psychology, neuroscience, linguistics, philosophy, computer science, and anthropology who seek to understand the mind. In this regular American Educator *column, we consider findings from this field that are strong and clear enough to merit classroom application.*

By Daniel T. Willingham

Question: Some of my students seem really sleepy—they stifle yawns and struggle to keep tired eyes open—especially in the morning. This can't be good for their learning, right? Is there anything I can do to help these students?

Answer: Sleep is indeed essential to learning, and US teenagers (and teenagers in most industrialized countries) don't get enough. Although recent work shows there is a strong biological reason that teens tend not to sleep enough, there is some good news in this research. First, the impact on learning, although quite real, does not appear to be as drastic as we might fear. Second, the sleep deficit teens tend to run is not inevitable; with some planning, they can get more shuteye.

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Researchers studying both humans and other animals have worked over the last 50 years to answer what would seem to be a straightforward question: Why do we sleep? The need for sleep appears to be as basic and universal as the need to eat. All animals sleep (with the possible exception of sharks), and all animals, if deprived of sleep, will "catch up" with extra sleep when given the chance. The universality of sleep across species indicates that it is essential to life. Yet its purpose is not known. It may be related to energy conservation or nervous system recuperation.[1] One thing sleep clearly doesn't do: it doesn't provide a time for the brain to "turn off." Most of the brain is active during most of the time you're asleep.[2] But whatever sleep does for the brain, it's clear that lack of sleep brings wide-ranging cognitive costs,[3] and sleepiness is a major contributor to workplace and automotive accidents.[4]

As many teachers and parents are well aware, US high school students don't sleep enough. Although no set of guidelines is considered authoritative, a generally accepted rule of thumb is that adolescents should ideally get nine or more hours of sleep

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each night. Eight hours is considered borderline, and less than eight, insufficient. By this measure, only about 8 percent of teens report optimal sleep, and the majority—69 percent—report insufficient sleep.[5]

Despite the fact that teenagers don't get enough sleep, research confirms that students actually sleep less as they get older. Large-scale studies of sleep habits in as many as 20 countries show that students sleep less as they progress through their teen years, especially on school days. American 9-year-olds get about 10 hours of sleep on weeknights. By the time they are 18, the figure is just 7.5 hours. But on weekends, the decline is much smaller: 9-year-olds sleep just over 10 hours, and 18-year-olds sleep about 9.5 hours each night.[6]

The reduction in sleep as the teen years progress is correlated with a change in chronotype—that is, an individual's time-of-day preference. Some people like to stay up late and feel most alert at that time, whereas others prefer mornings. These preferences do have an impact on cognitive performance: people perform better on measures of attention, memory, and executive functioning when tests are administered at their preferred time of day,[7] and these effects are observed at all different ages.[8] Throughout the teen years, the preference for evenings increases,[9] and this preference is observed in cultures throughout the world.[10] Hence, the increasing sleep loss as kids move through the teen years is due to staying up late. On weekends, staying up late causes little sleep loss because kids can sleep in. On weekdays, they go to bed somewhat earlier, but not early enough to make up for the fact that they must rise quite early to get to school.

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Cognitive Consequences of Poor Sleep

What happens to students' ability to think and reason when they are sleepy? Conducting this research is more difficult than one might think. First, researchers are reluctant to conduct experiments in which they ask children to reduce sleep significantly, and parents are, of course, reluctant to enroll their children in such studies. Thus, these studies tend to entail relatively mild sleep deprivation, and usually only for one night or occasionally for as many as three or four nights. But what really concerns us is chronic insufficient sleep, not brief sleep loss.

The alternative is not to ask students to sleep less as part of an experiment, but rather to measure typical sleep and cognition in a large group of students and test whether the poor sleepers differ from the good sleepers. This method seems to get at the sleep issue of interest but carries drawbacks of its own. Poor sleepers may differ from good sleepers in many ways other than the amount of sleep they get—for example, socioeconomic status (homes of low-income families tend to be noisier and more crowded), diet, level of anxiety in the child, and so on.

While both types of research have limitations, in this case both also lead to similar conclusions: poor sleep leads to worse performance on an array of cognitive and behavioral measures. Most of these effects are seen in both younger children[11] (under 12 years) and older children[12] (aged 12–18). (This article will focus on older children, as most of the research has been conducted on this age group.) What's surprising is that the consequences of sleep deprivation are not as widespread as you might think—some cognitive functions seem little affected—and the effect is not as large as you might guess.

In both correlational and experimental studies, poor sleepers show slightly worse performance than good sleepers on measures of executive function—that is, tasks that require maintaining or manipulating information in mind.[13] For example, a student might hear a sequence of four letters and numbers in random order, and be asked to report first the numbers, then the letters, each in ascending order (e.g., if a subject heard "8 J 3 R," she should say, "3 8 J R"). Each sequence is scored as correct (1 point) or incorrect (0 points). In one study like this, subjects who got insufficient sleep averaged 10.7 points (of 24 possible) and subjects who got sufficient sleep averaged 11.7 points.[14]

There are also reliable effects of sleep deprivation on students' mood and behavior. Both younger and older kids who have slept less are rated by parents as more irritable, hyperactive, and inattentive. They are also more likely to be anxious or depressed.[15] However, since these findings come from correlational studies, we must question whether the mood disturbances are caused by lack of sleep, or are merely associated with it. Data from children with sleep-related breathing disorders (e.g., sleep apnea, which involves pauses in breathing and shallow breathing that disturb sleep) are helpful in showing that sleep loss actually causes changes in mood. Some cases of disordered sleep can be corrected via surgery that helps children's breathing, and such children not only sleep better postsurgery, they show dramatic improvement in mood.[16]

Teachers and parents most often note that sleep-deprived children of all ages seem inattentive and have difficulty concentrating.[17] Most will seem sleepy and lacking in focus, but some become impulsive and hyperactive. Indeed, it has been suggested that sleep-deprived children are behaviorally similar to children with attention deficit hyperactivity disorder.[18] Curiously, formal studies of attention in which the speed and accuracy of responses is recorded (in contrast to ratings of attention made by parents or teachers) show little or no cost when young children are sleep deprived.[19] This finding contrasts with that of adults, who do show sleep-related deficits on attention tasks.[20] Young children also show little (if any) effect of sleep deprivation on memory.[21] This finding is particularly surprising, as sleep is known to have a consistent and fairly robust effect on memory in adults.[22] (It's important to keep in mind here the limitations of this body of research mentioned above. Some children may suffer severe, chronic sleep deprivation and may experience attention and memory problems,

but researchers are not going to design studies in which children must endure long-term sleep loss.)

In sum, sleep deprivation influences many (but not all) aspects of children's mood, cognition, and behavior. But do these effects have consequences for performance at school? Yes. Again, the data are mostly correlational, but experiments draw the same conclusions.[23] Lack of sleep is associated with poorer school performance as rated by students themselves[24] and by teachers.[25] Restricted sleep is also associated with lower grades in studies in the United States,[26] a finding replicated in Norway[27] and Korea.[28] Students who sleep less are more likely to repeat a grade (21 percent vs. 11 percent in one study of Belgian 8- to 10-year-olds[29]), and according to studies conducted in Germany[30] and Turkey,[31] they score lower on standardized tests taken at the end of schooling.

Biological Changes That Prompt Teen Sleep Loss

Why don't teens get enough sleep? The answer would seem obvious: teens are hypersocial, and so they stay up late on the phone or on Facebook. And they feel pressure from peers to stay up late, as it's a mark of being grown up. Those social factors may play a role, but biological factors are likely more important.

Humans know that it's time to go to sleep via internal cues generated by the body. There are two types of internal cues. One is a circadian rhythm in which hormones that induce sleepiness are released at night and those that induce wakefulness are released throughout the day, beginning early in the morning. Two of the most important hormones are melatonin, which makes you sleepy (and the release of which is suppressed by light exposure), and cortisol, which makes you wakeful. The cyclical workings of these hormones are obvious to anyone who has suffered from jet lag: your body's release of hormones that affect sleepiness remains (at first) on your home schedule when you travel. The second internal cue for sleep is sleep pressure, meaning that the longer you have been without sleep, the more you feel inclined to sleep.[32]

We are also sensitive to cues external to the body that it's time to go to sleep: cues like reduced light and knowing it's the right time for sleep. These external cues are also important for adjusting the internal circadian cues; if you travel to a new time zone, your body does not stay on your home schedule forever. External cues (especially the local day-night cycle) adapt the internal cues to the new time zone.

Both sleep pressure and circadian rhythms appear to be affected by puberty,[33] likely through interactions with other hormonal changes occurring at that time. The precise mechanism is not well understood, but the contention that the change is biological is supported by the observation that sleep rhythms change in the adolescence phase of other species.[34]

Some studies of adolescents lend fairly direct support to this hypothesis. For example, in one study,[35] researchers measured cortisol levels in 357 children when they were 9 years old, and then again at ages 11, 13, and 15. At each age, cortisol was measured upon waking, between 3 p.m. and 7 p.m., and just before sleep. These collections continued for three days. Because cortisol is associated with wakefulness, levels are highest in the morning and fall during the day. That pattern was observed at all ages in this study, but the decline in cortisol levels during the day differed by age: it was steepest for the youngest children and shallowest for the oldest children. In other words, there is a daily cycle—a wave form—for cortisol, and the wave flattens as children go through adolescence. That means the internal signal about when one should be sleepy and when one should be wakeful is weaker in teens than in younger children. (The signal returns to its earlier, stronger form in the early 20s.) The weakness of the melatonin and cortisol signals means teenagers should be less sleepy in the evening (and so they stay up later) and less wakeful in the morning.[36]

If teenagers don't go to sleep at night because of weak internal cues that it's time to sleep, we might expect they would be more susceptible to external cues such as light or noise that would keep them awake. Although there are no data (positive or negative) showing teens are more likely to stay awake in the presence of light or noise than younger children or adults, there is evidence these external cues cost them sleep. For example, teens sleep less in spring than they do in winter, plausibly because it gets dark earlier in winter.[37] Other data show that teens living in brightly lit urban districts are more likely to be "night owls" than "morning people."[38]

Other studies are consistent with the hypothesis that teens are especially dependent on external cues to help them fall asleep. Many studies show a correlation between electronic media use and later bedtimes, and therefore less sleep.[39] One interpretation of this correlation is that kids who would stay up late anyway use electronic media—phones, computers, games—to pass the time until they feel sleepy. But another interpretation is that they don't feel sleepy *because* they are using these devices and, in particular, are exposed to lighted screens and content that make them wakeful. Some small-scale experimental studies show that playing an action video game or watching a movie they find exciting makes it more difficult for teens to go to sleep.[40] Many teens report that they watch television to help them go to sleep,[41] though nighttime television viewing is associated with daytime sleepiness.[42]

Interventions to Help Teens Sleep

Lack of sleep affects how students do in school, but just how large a cost does it exact? By standard measures, not a very big one. The effect size for most of these studies is about d=.10, which statisticians classify as a "small" effect. Now, it might be that studies to date have not measured school performance with very sensitive

measures, and that the real cost of sleep loss is actually bigger. And of course, there is a quality-of-life issue here. Most parents, upon seeing their child miserably sleepy and dragging through a school day, would not shrug and say, "Well, as long as it doesn't affect your grades." So how might we help teens sleep more?

The rather obvious "tell them to go to sleep" might actually work. Although parents are less likely to set bedtimes as their children move through high school, students with parent-set bedtimes do get more sleep on school nights than students without them. On weekends, sleep patterns of the two groups do not differ.[43]

What else might be done? The core of the problem for teens seems to be that weak internal cues to sleep make it likely they will stay up later at night. They will sleep later in the morning to compensate, but they can't do so on weekdays when they must get up for school. Indeed, by some estimates, school start time is the most important predictor of sleep/wake patterns in students.[44] So why not start school later?

If kids know school starts later and they can therefore sleep later, won't they just stay up later? Surprisingly enough, the answer seems to be "no." Researchers have examined sleep patterns in schools with different start times, and students do get more sleep if their school starts later.[45] The same applies to college students,[46] but these data must be interpreted with considerable caution, as college students have much more control over their class schedules.

One study tracked the performance of students in seven Minneapolis high schools as they changed their start times from 7:15 a.m. to 8:40 a.m. Researchers reported that the later start time was associated with better student attendance, fewer reports of sleeping in class, and reduced depression among students. There was no impact on grades, but the researchers cautioned that they were not terribly confident in this analysis because of difficulties in equating grades across different courses and different schools.[47]

A second study comes from the school system in Wake County, North Carolina. Between 1999 and 2006, 14 middle schools in the system changed their start times—nine to later times, but five schools switched to earlier times. The researcher examined data from standardized state tests and calculated that earlier start times were associated with lower test scores, equivalent to about a 2 percentile point decline.[48]

Perhaps the best study on the subject comes from the United States Air Force Academy. Like many high schools, the Academy divides the day into seven periods. Students sign up for classes, but if there are multiple sections, they are randomly assigned to one; hence, a student cannot arrange to avoid (or ensure) an early morning class. Analysis of grades shows that those students who happen to have later start times earn higher grades.[49]

What Are the Implications?

Inadequate sleep represents a challenge to educators that is in one sense overt—teachers see students drowsy in class every day—and in another sense subtle, because it seems like a common nuisance rather than a real threat to education. And indeed, the problem should not be overstated, at least insofar as it affects education. The impact of typical levels of inadequate sleep on student learning is quite real, but it is not devastating. All the same, its impact lasts for years, and there is every reason to think that it is cumulative.

The impact of inadequate sleep on learning is not devastating. All the same, there is every reason to think it is cumulative.

Starting school later seems like a natural solution, but the logistics of the change are far from simple. The Fairfax County School Board in Virginia has considered whether to change the county high schools' 7:20 a.m. start time on no fewer than eight occasions in the past 24 years.[50] Recently, it decided to hire a consultant to develop a plan for later high school start times.[51] Some of the obstacles (in Fairfax and elsewhere) include: increased costs associated with transportation; objections from parents to a later start because they don't want to leave their child at home unattended when they leave for work; objections from parents and students to a later end to the school day because it interferes with athletics as well as afterschool clubs and jobs; and objections from parents to changes in elementary school start times (necessary due to bus route changes prompted by the change in the high school start time).

Another change that administrators could contemplate without the logistical problems of a later start time would be to adjust the schedule of classes. Put simply, it's a good bet that most middle and high school students are sleepiest during the first period and grow more alert as the day wears on. So what ought to be scheduled for first period? Are there classes where the sleepiness cost could best be borne? In high school, perhaps electives could come at the start of the day. If these are the classes students are most interested in, that may give them an incentive to go to sleep earlier so they get to school on time; they also may feel more alert if they find these electives more exciting than their required classes.

Finally, teachers can explain to students (and if possible, their parents) that they can influence the amount of sleep they get.

Although students must fight their own biological system to acclimate to the school schedule, they are not wholly victims of it. Just as travelers can adapt to new time zones, so too can students train their bodies to sleep at a reasonable hour. According to current research, the best strategy is to maintain a consistent bedtime and to refrain from gaming, movies, or other activities they find exciting in the few hours before bedtime. The payoff in grades may accumulate slowly or even be mostly unnoticeable, but the payoff in reduced sleepiness and overall mood will likely be almost immediate. ☐

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