How Students' Sleepy Brains Fail Them

by Judy Willis

When faced with the decision to put in an extra hour of study or get an extra hour of sleep, students need to choose wisely.

Educators are barraged with information about the value of brain food, water, exercise, and vitamins on student learning. This information is often contradictory to and not substantiated by medical or cognitive research. As a neurologist and middle school teacher, I have found the evidence supporting the value of these factors limited, particularly when scrutinized through a medical lens.

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One aspect of brain health that has been well examined through neuroimaging and cognitive testing is the influence of sleep on the brain. The findings are indeed a wake-up call with regard to the impact of sleep on focus, memory, test performance, mood, and high-risk behavior.

Sleep Tight

Nearly 40 percent of students in kindergarten through fourth grade have sleep disturbances, and those poor sleep habits in children carry into adolescence. Some sleep deprivation in children has been attributed to the rising use of computers, video games, iPODS®, and text messaging, as well as to the increased volume of homework compounded by earlier school start hours (Carskadon, Acebo, and Seifer 2001).

Sleep performs a restorative function for the body and the brain, and many brain functions become considerably less efficient after a sleepless night (Maquet 2001). Sleep-deprived children display lower brain activity while working on math problems than they do when rested, and they make more mistakes and omit more answers on tests (Drummond et al. 1999).

fMRI scans monitored activity in the brains of subjects performing simple verbal learning tasks. The temporal lobes—which are important for language processing—and the prefrontal cortex—which is active during coordinated attention and memory processing—were significantly more active during verbal learning in rested subjects than in sleep-deprived subjects. When two groups were tasked with memorizing short lists of words following either a full night's sleep or about 35 hours without sleep, word recall and recognition dropped sharply in the sleep-deprived group (Drummond et al. 2000).

Harvard researchers studied the brain's need for sleep to solidify the new information learned during the day. In a study test group of 60 students, each participant was asked to memorize 20 pairs of random words. Half were told to return 12 hours later, after a good night's rest. The other half were told not to sleep and to return in 12 hours. Seventy-six percent of the rested students correctly recalled all the words on a test, while only 32 percent of the sleepless students had all words correct (Ellenbogen 2005).

Rehearsals during Sleep

Sleep influences both the encoding and consolidating of memories, as well as the construction of new connections within networks that store the new memories. The sleeping brain is less distracted by the sensory input that bombards it all day, leaving a greater portion of its energy (metabolism) available for organizing and storing memories formed during the day. During sleep, when the prefrontal cortex receives less environmental sensory input, the executive functioning areas are less metabolically active. This reduced-activity brain state may provide the opportunity for recently learned material to be rehearsed, repeated (perhaps in dreams), and consolidated into long-term memory.

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"Dream sleep" associated with rapid eye movement (REM) sleep may be the time of encoding and consolidating during which new information is reviewed and coded into relational memories. Non-REM sleep appears to be the time during which new connections in neural networks are constructed to store the new memories and existing connections are strengthened.

During late stages of REM sleep, memories may be rehearsed and strengthened. Human subjects performing difficult tasks tend to improve their scores between sessions on consecutive days, but not between sessions on the same day—implicating sleep in the learning process (Walker et al. 2002). Mice allowed to sleep after being trained "remembered" what they had learned (connecting a sound to an electric shock) better than those deprived of sleep when tested several hours after the conditioned learning took place (Graves 2003).

REM sleep and its dreams—as forms of replaying and rehearsing new information to consolidate it from short-term to long-term memory—is an area ripe for study in the neuroscience of learning. In one research project, rats were trained on a track to reach a food reward. Electrical activity in the "place cell" neurons reflected the same or very similar activity during sleep as these hippocampal and prefrontal cortex neurons displayed during the track running behavior; even specific patterns of activity based on the rats' location on the track could be identified both in waking and sleep. Researchers concluded that during sleep, the rats were reconstructing their movements through locations on the track that led them to the reward by reactivating their original memory tracts (Ji and Wilson 2007).

During REM sleep, the brain stem sends messages to the visual center of the cortex as it does during wakefulness (Dement 1960). Because the sleeping person cannot respond to these messages physically, dreams may be the response to these neural impulses. This neural processing during sleep, therefore, could come from internal sources rather than from the physical world, yet still serve to consolidate the memory through the restimulation of the memory network (Purves et al. 2004).

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Sleep Construction

The term *neuroplasticity* describes the brain's ability to change or increase the dendrite connections and synapses between neurons, and thereby impact memories stored in neural networks. It is during the later hours of REM and non-REM sleep that the brain converts the greatest amount of amino acids into the proteins that are the building blocks of neuron-to-neuron connections such as dendrites (Benington and Frank 2003).

To convert the circulating amino acids into the proteins from which new connections are constructed, the brain needs nerve growth hormones and neurotransmitters such as neurotrophic growth factor and serotonin. The levels of both of these chemicals are especially high during later stages of sleep, the period when most new dendrite branching takes place (Murck et al. 2001).

In animal experiments, memory consolidation is associated with the synthesis of new proteins in the hippocampus and subcortical frontal lobe memory storage areas. Dendrite growth and new synapse formation correlate with the levels of nerve growth factor BDNF, brain-derived neurotrophic factor protein (Lo 1995). The increased release of nerve growth factor and serotonin during the later REM and non-REM sleep states—after six to eight hours of sleep—appears to influence plasticity through chemical and physical changes (McAllister, Katz, and Lo 1996; Alsina, Vu, and Cohen-Cory 2001). In animals, increased brain oxygen use triggers the construction of proteins from amino acids. This increase is evident on their fMRI scans 24 hours after information is stored (Drummond et al. 2000).

The *More* One Knows, the Easier It Is to Learn *More*

According to neuroplasticity theory and animal research, these brain cell networks that form connections with increasing dendrites and synapses are the hard-wiring associating newly learned information with previously stored, related knowledge in permanent memories (Benington and Frank 2003). The brain cell networks grow when increasing numbers of dendrites branch out from the nerve cells and link more and more neurons together. A correlation appears to exist between the number of dendrites and the efficiency of the brain to recognize similarities between new experiences and already stored ones (patterning) and to link new information with existing categories of knowledge (encoding into the memory circuit) (Leutgeb et al. 2005).

Construction of neural networks takes time, as dendrite sprouts grow and new synapses form (Bennington and Frank 2003). This construction of memory storage appears most active during the longest periods of uninterrupted deep (non-REM) sleep that begin after six to eight hours of sleep. During these hours, the brain may construct the physical structures that represent the networks where the recent memories can, with further rehearsal (review and network restimulation), become long-term memories (Maquet 2001).

This sleep/memory research provides support for what many students have discovered through their own study habits: reviewing notes while still alert is more effective than reviewing right before falling asleep. The quality and quantity of retained memory is superior when students review their notes thoroughly, stop, and go to sleep when they begin to feel drowsy. Retained memory diminishes when students extend their review time any number of hours once they become drowsy and thereby reduce their sleep time to less than six or eight hours (Stickgold, James, and Hobson 2000). A study of students who received low grades (C and lower) reported sleeping an average of 20 minutes less and going to bed an average of 40 minutes later on school nights than students with higher grades. The recognition of the correlation between sleep and memory has led some researchers to test and confirm their predictions that increasing sleep time from six or less to eight hours can increase memory up to 25 percent (Frand 2000).

Sleep and Syn-*naps*

Nightly sleep is not the only way to maintain healthy brains and support learning and memory. Syn-*naps*, or brain breaks, are important throughout the day to keep neurons firing efficiently. Depending on students' ages and focus abilities, the number of syn-*naps* needed will vary. Syn-*naps* should take place before fatigue, boredom, distraction, and inattention set in. As a general rule, to keep children alert and engaged, syn-*naps* should be scheduled after 10 minutes of concentrated learning for elementary school and 15–30 minutes for middle and high school students (Willis 2006).

These three- to five-minute breaks do not need to disrupt the flow of learning. Simply stretching, drinking water, or moving to a different part of the room can provide a fresh outlook. A bit of physical activity, such as jumping jacks or singing a song can be revitalizing. During these breaks, the newly learned material has the opportunity to go from short-term to working memory while children relax and refresh their supply of neurotransmitters (the brain's chemical messengers). Physical movement during syn-*naps* increases blood flow to the cranial circulation, and the deep breathing of exercise increases the blood levels of oxygen.

Teens

Adolescents need up to two hours more sleep than when they were in elementary school for their brains to consolidate and cement new knowledge and experience into memory and avoid behaviors associated with sleep deprivation that interfere with cognitive and attention skills. This recommendation is in part attributed to the finding that, during sleep, teenagers start to secrete melatonin, a sleep promoting neurochemical, up to two hours later in their sleep cycle than when they were younger (Wurtman and Lieberman 1985). Yet, only 15 percent of adolescents reported sleeping 8 or more hours on school nights and the older teens reported an average of 7.7 hours of sleep a night, with 11 percent sleeping less than 6.5 hours a night (Javaheri et al. 2008).

A number of problems stem from sleep deprivation in adolescents. Auto accidents among teens are a prime example. Drowsy drivers are attributed with causing 100,000 auto accidents a year in the United States; drivers age 25 or under caused more than half of these crashes by falling asleep at the wheel (Wu and Yan-Go 2006).

Academic achievement also takes a hit by sleep deprivation. During the earliest classes in middle and high school, teachers notice a comparatively lower level of alertness in their students. Twenty percent of all high school students fall asleep in school, and more than 50 percent of students report being most alert after 3:00 p.m. High school students who sleep less than six hours a night generally have poorer grades even when they study the same reported number of hours as higher-achieving students (Wolfson and Carskadon 1998).

Sleep deprivation additionally reduces the body's supply of cortisone and growth hormone and disrupts hormones that regulate appetite. Teens who sleep less than 7 hours a night are more likely to be obese (Vgontzas et al. 1999) and have more than twice the risk of high blood pressure even when the data are adjusted for sex, weight, and socioeconomic status (Javaheri et al. 2008). With less than 7 hours of sleep, teens also have higher levels of stress, anxiety, and depression, and tend to take more unnecessary risks including drug and alcohol abuse, sexual promiscuity, and unsafe driving (Williamson and Feyer 2000).

Reports indicate that some high school students drink as many as five cans of "energy drinks" a day to combat sleep deprivation. The consumption of these drinks by teens compounds the problems associated with sleep deprivation. When teens mix these drinks with alcohol, the likelihood of them becoming victims or perpetrators of aggressive sexual behavior increases (Miller 2008).

Creating Sleep-Friendly Schools

School systems can help positively influence sleep patterns in several ways when educators, school health providers, and other school personnel are knowledgeable about sleep needs and patterns as well as the signs of sleep loss. Further benefits come from informing parents about the importance of optimizing sleep quality for their children with regular sleep and wake times and bedrooms that are kept quiet, dark, and conducive to sleep. Students need to be knowledgeable about the physiology and benefits of sleep and the consequences of sleep deprivation in their academic success and physical health and safety.

In 2004, Duke University stopped scheduling any 8 a.m. classes because students weren't getting enough sleep. "They're coming in to see us, and they're ragged," said Assistant Dean Ryan Lombardi. Duke also has offered students individual health assessments to help them learn what to eat and how many hours to sleep (Grace 2004).

Minneapolis Public Schools was the first major school district to change its starting times to meet adolescent sleep needs. During the 10-year period after this change, positive impacts were noted: improvements in attendance rates, less falling asleep in school, fewer incidents of misbehavior, and increased alertness in class (Wahlstrom

et al. 2001). In addition, students reported that it was easier to stay awake when doing homework, and their moods improved as well as their grades (Kubow, Wahlstrom, and Bemis 1999; Wahlstrom 2000). Even parents reported better relationships with their children (Kubow et al. 1999).

Other school districts have adopted patterns similar to the Minneapolis schools, changing the start time for high school from 7:15 a.m. to 8:40 a.m., and middle school from 7:40 a.m. to 9:40 a.m. Among the sleep-sensitive schools with later start times are schools in Lynchburg, Virginia; West Des Moines, Iowa; and Orange County, Florida.

As sleep research has demonstrated, students from elementary school through college need an age-associated number of hours of sleep to learn effectively. Armed with this information, students can make more informed decisions. When students understand the physiology of sleep, they may realize that it's better to review their notes thoroughly and go to sleep for nine hours than to cram for an extra hour. Knowledge can help students make better decisions when they are faced with choices of an extra hour of sleep, an extra hour of study, or an hour spent playing video games and sending text messages.

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