Sleep, Learning, and Memory

Note: This document comprises materials available at this site: http://healthysleep.med.harvard.edu/healthy/

The Characteristics of Sleep

At a Glance

- Sleep is a state that is characterized by changes in brain wave activity, breathing, heart rate, body temperature, and other physiological functions.
- Depending on the sleep stage, different physiological functions may be more active and variable (for example, during REM sleep), or less active and more stable (for example, during NREM sleep).
- The reasons why we dream and the meaning of our dreams, despite scientific investigations, still largely remain a mystery.

What Is Sleep?

During some stages of sleep the brain is just as active as when we are fully awake.

Every night, nearly every person undergoes a remarkable change: we leave waking consciousness and for hours traverse a landscape of dreams and deep sleep. When we wake, we typically remember little or nothing about the hours that have just passed. Except in rare instances, we never contemplate and appreciate that we are sleeping while we are asleep. Thus, although everyone sleeps, most people would be hard-pressed to precisely define sleep. All organisms exhibit daily patterns of rest and activity that resemble the daily sleep and wakefulness patterns seen in humans. From observing changes in behavior and responsiveness, scientists have noted the following characteristics that accompany and in many ways define sleep:

- Sleep is a period of reduced activity.
- Sleep is associated with a typical posture, such as lying down with eyes closed in humans.
- Sleep results in a decreased responsiveness to external stimuli.
- Sleep is a state that is relatively easy to reverse (this distinguishes sleep from other states of reduced consciousness, such as hibernation and coma).

From observations of behavioral changes that accompany sleep and simultaneous physiological changes, scientists now define sleep in humans based on brain wave activity patterns and other physiological changes as described below.

Physiological Changes During Sleep

Many physiological variables are controlled during wakefulness at levels that are optimal for the body's functioning. Our temperature, blood pressure, and levels of oxygen, carbon dioxide, and glucose in the blood remain quite constant during wakefulness. During sleep, however, physiological demands are reduced and temperature and blood pressure drop. In general, many of our physiological functions such as brain wave activity, breathing, and heart rate are quite variable when we are awake or during REM sleep, but are extremely regular when we are in non-REM sleep.

Brain Activity For centuries, physicians believed that sleep was a period of brain inactivity, yet research over the last 60 years has shown us that the brain remains active during sleep. There is a progressive decrease in the activation or "firing" rate of most neurons throughout the brain as sleep progresses from wakefulness to non-REM sleep. Also, the patterns of neuron firing change from a seemingly random and variable activity pattern during wakefulness, to a much more coordinated and synchronous pattern during non-REM sleep.

During REM sleep (the stage of sleep most associated with dreaming) there is an increase in the firing rate of most neurons throughout the brain, as compared to non-REM sleep. In fact, the brain in REM sleep can even be more active than when we are awake. Patterns of brain activity during REM sleep are more random and variable, similar to during wakefulness. This pattern of brain activity during REM sleep probably underlies the intense dreaming that occurs during this state.

In all mammals and many other animals, sleep can be defined in much the same way that we define sleep for humans. However, there are some notable differences among species. When humans sleep, the entire brain is involved. Dolphins and whales, on the other hand, need to maintain consciousness while they sleep so they can occasionally surface to breathe. In these marine mammals, sleep occurs in only one hemisphere of their brain at a time—allowing for some degree of consciousness and vigilance to be maintained at all times.

Body Temperature Through a process known as thermoregulation, the temperature of our body is controlled by mechanisms such as shivering, sweating, and changing blood flow to the skin, so that body temperature fluctuates minimally around a set level during wakefulness. Just before we fall asleep, our bodies begin to lose some heat to the environment, which some researchers believe actually helps to induce sleep. During sleep, our central set temperature is reduced by 1 to 2°F. As a result, we use less energy maintaining our body temperature. It has been hypothesized that one of the primary functions of sleep is to conserve energy in this way.

Body temperature is still maintained, although at a slightly reduced level during non-REM sleep, but during REM sleep our body temperature falls to its lowest point. Curling up in bed under a blanket during the usual 10- to 30-minute periods of REM sleep ensures that we do not lose too much heat to the environment during this potentially dangerous time without thermoregulation.

Respiratory Changes Our breathing patterns also change during sleep. When we are awake, breathing is usually quite irregular, since it is affected by speech, emotions, exercise, posture, and other factors. As we progress from wakefulness through the stages of non-REM sleep, our breathing rate slightly decreases and becomes very regular. During REM sleep, the pattern becomes much more variable again, with an overall increase in breathing rate.

Cardiovascular Activity One of the possible functions of sleep is to give the heart a chance to rest from the constant demands of waking life. As compared to wakefulness, during non-REM sleep there is an overall reduction in heart rate and blood pressure. During REM sleep, however, there is a more pronounced variation in cardiovascular activity, with overall increases in blood pressure and heart rate. Additionally, changes in blood flow that cause erections to occur in males or swelling of the clitoris in females is characteristic of REM sleep The underlying reason for these considerable neural and physiological variations in REM sleep is currently unknown, and may be a by-product of REM-related changes in nervous system activity or related to dream content.

Increased Physiological Activity During Sleep For the most part, many physiological activities are reduced during sleep. For example, kidney function slows and the production of urine is decreased. However, some physiological processes may be maintained or even increased during sleep. For example, one of the greatest changes induced by sleep is an increase in the release of growth hormone. Certain physiological activities associated with digestion, cell repair, and growth are often greatest during sleep, suggesting that cell repair and growth may be an important function of sleep.

Dreams

One of the most notable but least understood characteristics of sleep is dreaming, during which our thoughts follow bizarre and seemingly illogical sequences, sometimes random and sometimes related to experiences gathered during wakefulness. Visually intense dreaming occurs primarily during REM sleep. However, not all dreams occur during REM sleep. For example, night terrors actually occur during non-REM sleep.

Varying explanations for dreaming, as well as the meanings of dreams, have been offered by philosophers and psychologists throughout history. Even with recent scientific investigations of dreaming, our dreams still remain something of a mystery. Some experts suggest that dreams represent the replay of the day's events as a critical mechanism in the formation of memories, while others claim that the content of dreams is simply the result of random activity in the brain.

Summary

Clearly the changes in brain activity and physiological functions during sleep are quite profound. These changes are used to help define the occurrence of sleep. Ultimately, some of these changes may help us to answer the difficult question of "Why do we sleep?" Although scientists are unsure exactly why we sleep, there are many clues about the functions that sleep serves and how getting more and higher quality sleep can improve our health and wellbeing.

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External Factors that Influence Sleep

At a Glance

- There are many factors, both internal and external, that can influence the quantity and quality of the sleep we obtain.
- Sleep scientists understand how various factors affect sleep and why they have the effects they do.
- Often people who experience sleep issues overlook relatively simple factors that may be causing them to miss out on the sleep they need.

Sleep in the Real World

The internal mechanisms that regulate our almost ceaseless cycles of sleep and wakefulness make up a remarkable system. However, a variety of internal and external factors can dramatically influence the balance of this sleep-wake system.

Changes in the structure and function of the brain during development can have profound, if gradual, effects on sleep patterns. The amount of sleep we obtain generally decreases and becomes more fragmented throughout our lifespan. These and other variations associated with age are covered at length in the essay Changes in Sleep with Age.

Other factors that affect sleep include stress and many medical conditions, especially those that cause chronic pain or other discomfort. External factors, such as what we eat and drink, the medications we take, and the environment in which we sleep can also greatly affect the quantity and quality of our sleep. In general, all of these factors tend to increase the number of awakenings and limit the depth of sleep.

Light's Effect

Light is one of the most important external factors that can affect sleep. It does so both directly, by making it difficult for people to fall asleep, and indirectly, by influencing the timing of our internal clock and thereby affecting our preferred time to sleep.

Light influences our internal clock through specialized "light sensitive" cells in the retina of our eyes. These cells, which occupy the same space as the rods and cones that make vision possible, tell the brain whether it is daytime or nighttime, and our sleep patterns are set accordingly.

Due to the invention of the electric lightbulb in the late 19th century, we are now exposed to much more light at night than we had been exposed to throughout our evolution. This relatively new pattern of light exposure is almost certain to have affected our patterns of sleep. Exposure to light in the late evening tends to delay the phase of our internal clock and lead us to prefer later sleep times. Exposure to light in the middle of the night can have more unpredictable effects, but can certainly be enough to cause our internal clock to be reset, and may make it difficult to return to sleep.

Jet Lag and Shift Work

Normally, light serves to set our internal clock to the appropriate time. However, problems can occur when our exposure to light changes due to a shift in work schedule or travel across time zones. Under normal conditions, our internal clock strongly influences our ability to sleep at various times over the course of a 24-hour period, as well as which sleep stages we experience when we do sleep.

Individuals who travel across time zones or work the night shift typically have two symptoms. One is insomnia when they are trying to sleep outside of their internal phase, and the other is excessive sleepiness during the time when their internal clock says that they should be asleep. Half of all night shift workers regularly report nodding off and falling asleep when they are at work. This should be seen as an important concern both for individuals and society, given that airline pilots, air traffic controllers, physicians, nurses, police, and other public safety workers are all employed in professions in which peak functioning during a night shift may be critical.

The effects of shift work and jet lag on sleep are covered in much greater detail in Jet Lag and Shift Work and You and Your Biological Clock.

Pain, Anxiety, and Other Medical Conditions

A wide range of medical and psychological conditions can have an impact on the structure and distribution of sleep. These conditions include chronic pain from arthritis and other medical conditions, discomfort caused by gastroesophageal reflux disease, pre-menstrual syndrome, and many others. Like many other sleep disruptions, pain and discomfort tend to limit the depth of sleep and allow only brief episodes of sleep between awakenings.

Individuals of all ages who experience stress, anxiety, and depression tend to find it more difficult to fall asleep, and when they do, sleep tends to be light and includes more REM sleep and less deep sleep. This is likely because our bodies are programmed to respond to stressful and potentially dangerous situations by waking up. Stress, even that caused by daily concerns, can stimulate this arousal response and make restful sleep more difficult to achieve.

Medications and Other Substances

Many common chemicals affect both quantity and quality of sleep. These include caffeine, alcohol, nicotine, and antihistamines, as well as prescription medications including beta blockers, alpha blockers, and antidepressants.

The pressure to sleep builds with every hour that you are awake. During daylight hours, your internal clock generally counteracts this sleep drive by producing an alerting signal that keeps you awake. The longer you are awake, the stronger the sleep drive becomes. Eventually the alerting signal decreases and the drive to sleep wins out. When it does, you fall asleep.

A chemical called adenosine, which builds up in the brain during wakefulness, may be at least partly responsible for sleep drive. As adenosine levels increase, scientists think that the chemical begins to inhibit the brain cells that promote alertness. This gives rise to the sleepiness we experience when we have been awake for many hours. Interestingly, caffeine, the world's most widely used stimulant, works by temporarily blocking the adenosine receptors in these specific parts of the brain. Because these nerve cells cannot sense adenosine in the presence of caffeine, they maintain their activity and we stay alert.

If sleep does occur following the intake of caffeine, the stimulant's effects may persist for some time and can influence the patterns of sleep. For instance, caffeine generally decreases the quantity of slow-wave sleep and REM sleep and tends to increase the number of awakenings. The duration of its effect depends on the amount of caffeine ingested, the amount of time before sleep that the person ingests the caffeine, the individual's tolerance level, the degree of ongoing sleep debt, and the phase of the individual's internal clock.

Alcohol is commonly used as a sleep aid. However, although alcohol can help a person fall asleep more quickly, the quality of that individual's sleep under the influence of alcohol will be compromised. Ingesting more than one or two drinks shortly before bedtime has been shown to cause increased awakenings—and in some cases insomnia—due to the arousal effect the alcohol has as it is metabolized later in the night. Alcohol also tends to worsen the symptoms of sleep apnea, which will further disrupt sleep in people with this breathing disorder.

Dozens of prescription drugs that are used to help control common disease symptoms may have varying effects on sleep. Beta blockers, which are used to treat high blood pressure, congestive heart failure, glaucoma, and migraines, often cause decreases in the amount of REM and slow-wave sleep, and are also associated with increased daytime sleepiness. Alpha blockers, which are also used to treat high blood pressure and prostate conditions, are linked to decreased REM and increased daytime sleepiness. Finally, antidepressants, which can decrease the duration of periods of REM sleep, have unknown long-term effects on sleep as a whole. Some antidepressants, from the class of drugs known as SSRIs, have been found to promote insomnia in some individuals.

The Sleep Environment

The bedroom environment can have a significant influence on sleep quality and quantity. Several variables combine to make up the sleep environment, including light, noise, and temperature. By being attuned to factors in your sleep environment that put you at ease, and eliminating those that may cause stress or distraction, you can set yourself up for the best possible sleep.

We've already noted that too much light at night can shift our internal clock and makes restful sleep difficult to achieve. To minimize this effect, nightlights in hallways and bathrooms can be used. As for noise, although background sounds may relax some people, the volume level must be low. Otherwise, increased frequency of awakenings may prevent transitions to the deeper stages of sleep. Research shows that the ideal temperature range for sleeping varies widely among individuals, so much so that there is no prescribed best room temperature to produce optimal sleep patterns. People simply sleep best at the temperature that feels most comfortable. That said, extreme temperatures in sleeping environments tend to disrupt sleep. REM sleep is commonly more sensitive to temperature-related disruption. For example, in very cold temperatures, we may be deprived entirely of REM sleep. Lastly, it is worth mentioning that the preferences of a spouse or bedmate may have a significant effect on sleep, especially when a partner's sleep and wake times vary, or if he or she snores or suffers from sleep-disordered breathing.

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The Drive to Sleep and Our Internal Clock

At a Glance

- Finding sleep impossible even when you have the chance can be extremely frustrating, but this scenario is common among people who have jet lag or do shift work.
- Under normal conditions, two systems inside the body interact to allow us to sleep and remain alert when we want to.
- Understanding what happens when these two systems fall out of synch is an important step to achieving quality sleep even if you travel or work the night shift.

Sleep Drive

Nodding off at an inopportune moment can be embarrassing or even dangerous. And anyone who has experienced even a short bout of insomnia can attest to the frustration caused by the inability to sleep at a desired hour. These instances might happen more often if it weren't for two systems whose interaction governs wakefulness and sleep.

We have all experienced that undeniable drive to sleep. Staying up much later than usual, or rising after only a few hours of sleep and then attempting to stay alert and functional throughout the day, serve as an unpleasant reminder of the power of the sleep drive. And even when we feel alert and are unaware of our sleep drive, it is always present and growing while we're awake. In fact, the only true way to reduce rather than mask sleep drive is to sleep.

Scientists refer to sleep drive as a homeostatic system. Like body temperature or blood sugar, sleep is regulated internally. For instance, when body temperature falls, blood vessels constrict and we shiver; when blood sugar levels rise, the pancreas secretes insulin; and when we remain awake for an extended period of time, structures in the brain promote sleep. Furthermore, the duration and depth of our sleep vary according to the quantity and quality of sleep obtained previously.

With every waking hour there is a strengthening of the homeostatic sleep drive. This strengthening isn't directly measurable as a quantity, but experts think that it is the result of the level of brain activity during wakefulness. One hypothesis suggests that the build-up in the brain of adenosine, a by-product of energy consumption by cells, promotes sleep drive. The fact that both adenosine and sleep drive increase during wakefulness and dissipate during sleep suggests a possible link between the two.

Awake and Asleep

Homeostatic sleep drive is not the only force involved in regulating the transition from wakefulness to sleep. If it were, catnapping throughout the day and night would likely be the norm rather than the exception. After just a few hours awake, we might nod off for an hour and then rise again, only to succumb to sleep just a few hours later. Instead, most of us remain awake—and alert—for 16 hours or more each day without respite. And despite the fact that our sleep drive increases with every hour of wakefulness, we are typically no sleepier at 8:00 p.m. than we are at 3:00 p.m.

Our relatively steady state of alertness over the course of a 16-hour day is due to what scientists call the circadian alerting system, a function of our internal biological clock. The clock, which is responsible for regulating a vast number of daily cycles, is found in a relatively small collection of neurons deep within the brain. Under normal conditions, the clock is highly synchronized to our sleep/wake cycle. When it is, the clock's alerting signal increases with every hour of wakefulness, opposing the sleep drive that is building at the same time. Only when the internal clock's alerting signal drops off does sleep load overcome this opposing force and allow for the onset of sleep.

Sleep Drive and Body Clock Through the Night

In the first half of the nightly sleeping period your sleep drive is still significant, and your alerting signal is declining rapidly. In normal circumstances, this means it is easy to maintain sleep. However, after approximately four hours of uninterrupted sleep the situation changes. Now that your sleep drive has decreased, the simple absence of an alerting signal is no longer sufficient to maintain sleep. At this point, the internal clock, which was promoting alertness during the day, begins to play an active role in sleep promotion by sending signals to parts of the brain that serve this function. In this way, the homeostatic sleep drive and the circadian system, when synchronized, interact to provide consolidated periods of both alertness and sleep.

Alertness, of course, varies for most people over the course of a day. For example, the grogginess that people often experience in the mid-afternoon, and commonly attribute to a heavy lunch or a dull meeting, is usually the result of a brief lull in the strength of the alerting signal. While sleep drive continues to climb, there is an hour or two each afternoon during which the alerting signal fails to keep pace, and alertness suffers as a result. Many cultures have incorporated this lull into their lives by making mid-afternoon naps, or siestas, part of the daily routine.

Another variation in alertness can be found near the end of the waking period, when the alerting signal is at its highest. Sleep experts refer to the period from 8:00 p.m. to 9:00 p.m. (for people who follow a fairly typical sleep/wake schedule) as the "forbidden hour for sleep" because most people find it next to impossible to fall asleep between these times.

A Delicate Balance

It is clear that synchronization of the sleep wake schedule and the internal clock is essential to an individual's ability to maintain sleep and wakefulness when desired. This has been shown conclusively in sleep research and is widely supported by anecdotal evidence from people who fly across time zones or work night shifts. Both of these activities desynchronize sleep and wake patterns from the internal clock's circadian rhythms and result in an alerting signal that is too low when an individual wishes to be awake and too high to allow for a consolidated period of sleep.

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Sleep, Learning, and Memory

At a Glance

- Research suggests that sleep plays an important role in memory, both before and after learning a new task.
- Lack of adequate sleep affects mood, motivation, judgment, and our perception of events.
- Although there are some open questions about the specific role of sleep in forming and storing memories, the general consensus is that consolidated sleep throughout a whole night is optimal for learning and memory.

The Learning Process and Sleep

Healthy sleep is essential for optimal learning and memory function.

Sleep, learning, and memory are complex phenomena that are not entirely understood. However, animal and human studies suggest that the quantity and quality of sleep have a profound impact on learning and memory. Research suggests that sleep helps learning and memory in two distinct ways. First, a sleep-deprived person cannot focus attention optimally and therefore cannot learn efficiently. Second, sleep itself has a role in the consolidation of memory, which is essential for learning new information.

Although the exact mechanisms are not known, learning and memory are often described in terms of three functions. **Acquisition** refers to the introduction of new information into the brain. **Consolidation** represents the processes by which a memory becomes stable. **Recall** refers to the ability to access the information (whether consciously or unconsciously) after it has been stored.

Each of these steps is necessary for proper memory function. Acquisition and recall occur only during wakefulness, but research suggests that memory consolidation takes place during sleep through the strengthening of the neural connections that form our memories. Although there is no consensus about how sleep makes this process possible, many researchers think that specific characteristics of brainwaves during different stages of sleep are associated with the formation of particular types of memory.

Sleep, Learning, and Memory (1:52)

Sleep researchers study the role of sleep in learning and memory formation in two ways. The first approach looks at the different stages of sleep (and changes in their duration) in response to learning a variety of new tasks. The second approach examines how sleep deprivation affects learning. Sleep deprivation can be total (no sleep allowed), partial (either early or late sleep is deprived), or selective (specific stages of sleep are deprived).

Sleep Stages and Types of Memory

Different types of memories are formed in new learning situations. Scientists are exploring whether there is a relationship between the consolidation of different types of memories and the various stages of sleep.

The earliest sleep and memory research focused on **declarative memory**, which is the knowledge of fact-based information, or "what" we know (for example, the capital of France, or what you had for dinner last night). In one research study, individuals engaged in an intensive language course were observed to have an increase in *rapid-eye-movement* sleep, or REM sleep. This is a stage of sleep in which dreaming occurs most frequently. Scientists hypothesized that REM sleep played an essential role in the acquisition of learned material. Further studies have suggested that REM sleep seems to be involved in declarative memory processes if the information is complex and emotionally charged, but probably not if the information is simple and emotionally neutral.

Researchers now hypothesize that slow-wave sleep (SWS), which is deep, restorative sleep, also plays a significant role in declarative memory by processing and consolidating newly acquired information. Studies of the connection between sleep and declarative memory have had mixed results, and this is an area of continued research.

Research has also focused on sleep and its role in **procedural memory**—the remembering "how" to do something (for example, riding a bicycle or playing the piano). REM sleep seems to plays a critical role in the consolidation of procedural memory. Other aspects of sleep also play a role: motor learning seems to depend on the amount of lighter stages of sleep, while certain types of visual learning seem to depend on the amount and timing of both deep, slow-wave sleep (SWS) and REM sleep.

The Impact of Sleep Deprivation on Learning and Performance

Another area that researchers study is the impact that a lack of adequate sleep has on learning and memory. When we are sleep deprived, our focus, attention, and vigilance drift, making it more difficult to receive information. Without adequate sleep and rest, over-worked neurons can no longer function to coordinate information properly, and we lose our ability to access previously learned information.

In addition, our interpretation of events may be affected. We lose our ability to make sound decisions because we can no longer accurately assess the situation, plan accordingly, and choose the correct behavior. Judgment becomes impaired.

Being chronically tired to the point of fatigue or exhaustion means that we are less likely to perform well. Neurons do not fire optimally, muscles are not rested, and the body's organ systems are not synchronized. Lapses in focus from sleep deprivation can even result in accidents or injury.

For more information about how sleep deprivation affects performance, see Sleep, Performance, and Public Safety.

Low-quality sleep and sleep deprivation also negatively impact mood, which has consequences for learning. Alterations in mood affect our ability to acquire new information and subsequently to remember that information. Although chronic sleep deprivation affects different individuals in a variety of ways (and the effects are not entirely known), it is clear that a good night's rest has a strong impact on learning and memory.

Open Questions

Although current research suggests that sleep is essential for proper memory function, there are unanswered questions, as in any area of active scientific inquiry. For example, certain medications will significantly, if not entirely, suppress REM sleep. However, patients taking these medications do not report any memory impairment. Similarly, injuries or disease causing lesions to the brainstem (and subsequently eliminating a person's REM sleep) have not resulted in any obvious loss of the ability to form new memories. Exploration and debate continue.

Not all researchers are convinced that sleep plays as prominent a role in memory consolidation as others believe. In experiments in which animals completed a course through a complicated maze, the animals' amount of REM sleep increased after performing the task. Some researchers believe that the increase in REM sleep reflects an increased demand on the brain processes that are involved in learning a new task. Other researchers, however, have suggested that any changes in the amount of REM sleep are due to the stress of the task itself, rather than a functional relationship to learning.

Researchers are likewise split with regard to the impact of sleep deprivation on learning and memory. For example, rats often perform much worse on learning tasks after being selectively deprived of REM sleep. This suggests that REM sleep is necessary for the animals' ability to consolidate the memory of how to perform the task. Some scientists have argued that the observed differences in learning are not actually due to the lack of REM sleep, but may be due to the animals not being as well rested because they were deprived a portion of their sleep.

Summary

In the view of many researchers, evidence suggests that various sleep stages are involved in the consolidation of different types of memories and that being sleep deprived reduces one's ability to learn. Although open questions (and debate) remain, the overall evidence suggests that adequate sleep each day is very important for learning and memory.

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http://healthysleep.med.harvard.edu/healthy/matters/benefits-of-sleep/learning-memory

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Consequences of Insufficient Sleep

Most people don't get enough sleep. We are a society that burns the candle at both ends, a nation where people stay up all night to study, work, or have fun. However, going without adequate sleep carries with it both short- and long-term consequences.

In the short term, a lack of adequate sleep can affect judgment, mood, ability to learn and retain information, and may increase the risk of serious accidents and injury. In the long term, chronic sleep deprivation may lead to a host of health problems including obesity, diabetes, cardiovascular disease, and even early mortality

Sleep, Performance, and Public Safety

At a Glance

- The demands and expectations of our modern society have placed increasing demands on our time, and more than ever people are making up for those demands by cutting back on sleep.
- At the same time, it is becoming increasingly clear that the cost of insufficient sleep is much higher than most people recognize.
- Scientific research is revealing, for example, how sleep loss, and even poor-quality sleep, can lead to an increase in errors at the workplace, decreased productivity, and accidents that cost both lives and resources. Awareness can help you improve your sleep habits and in turn your safety.

Costly, Preventable Accidents

Insufficient sleep may not have led the news in reporting on serious accidents in recent decades. However, that doesn't mean fatigue and inattention due to sleep loss didn't play a role in these disasters. For example, investigators have ruled that sleep deprivation was a significant factor in the 1979 nuclear accident at Three Mile Island, as well as the 1986 nuclear meltdown at Chernobyl.

Investigations of the grounding of the Exxon Valdez oil tanker, as well as the explosion of the space shuttle Challenger, have concluded that sleep deprivation also played a critical role in these accidents. In both cases, those in charge of the operations and required to make critical decisions were operating under extreme sleep deprivation. While the Challenger disaster put the multi-billion dollar shuttle program in peril, the Exxon Valdez oil spill resulted in incalculable ecological, environmental, and economic damage.

In addition to the ties between such high-profile disasters and sleep deprivation, there is a growing recognition of the link between lack of sleep and medical errors in our hospitals. According to the Institutes of Medicine, over one million injuries and between 50,000 and 100,000 deaths each year result from preventable medical errors, and many of these may be the result of insufficient sleep, Doctors, especially newly graduated interns, are often expected to work continuous shifts of 24 to 36 hours with little or no opportunity for sleep.

Although it is difficult to estimate the extent that sleep deprivation plays in medical errors, studies have shown a significant impact. For example, a 2004 study led by Dr. Charles Czeisler of the Division of Sleep Medicine at Harvard Medical School found that hospitals could reduce the number of medical errors by as much as 36 percent by limiting an individual doctor's work shifts to 16 hours and reducing the total work schedule to no more than 80 hours per week.

Long shifts and other factors that result in sleep loss have safety consequences for our highways as well. A National Sleep Foundation survey has revealed that 60 percent of adult drivers—about 168 million people—say they have driven a vehicle while feeling drowsy in the past year, and that more than one-third (103 million people) have actually fallen asleep at the wheel. Unfortunately, many of these situations end in tragedy. The National Highway Traffic Safety Administration estimates that 100,000 police-reported crashes are the direct result of driver fatigue each year, and they consider this a conservative estimate. More recent data suggests that the true number is likely much higher. The Institute of Medicine estimates—based on recent high quality naturalistic and epidemiologic studies—that drowsy driving is responsible for fully 20 percent of all motor vehicle crashes. That would mean that drowsy driving causes approximately 1 million crashes, 500,000 injuries, and 8,000 deaths each year in the U.S.

How Sleep Deprivation Affects Mental Performance

The earliest scientific evidence of a link between sleep and performance dates back to the early 1930's, when Nathaniel Kleitman, one of most significant figures in the field of sleep medicine, discovered a daily pattern in the speed and accuracy of cognitive performance. He showed that even in well-rested individuals there was a decrease in the level of individual performance that occurred in the early morning and again late at night. Thus, even when we are getting the amount of sleep we need, we can still expect normal fluctuations in our ability to function.

In addition to these normal fluctuations, not getting enough sleep—whether for just one night or over the course of weeks to months—has a significant effect on our ability to function. Sleep deprivation negatively impacts our mood, our ability to focus, and our ability to access higher-level cognitive functions. The combination of these factors is what we generally refer to as mental performance. In the laboratory, researchers use scientific studies to determine just how significantly varying levels of sleep disturbance impact various types of mental performance.

The prefrontal cortex is responsible for many higher-level cognitive functions and is particularly vulnerable to a lack of sleep.

The most immediate effect of sleep deprivation is sleepiness. In our daily lives, we may experience this as a general fatigue, lack of motivation, or even the experience of nodding off. In the research or clinical setting, scientists measure sleepiness using a variety of methods. After a period of sleep deprivation, there are noticeable changes in brain activity, as measured by an electroencephalogram (EEG). These changes correspond to a lower level of alertness and a general propensity to sleep. Any period of continual wakefulness beyond the typical 16 hours or so will generally lead to these measurable changes.

In addition to the feeling of sleepiness and changes in brain activity that accompany a night without sleep, other measures of performance are noticeably altered. Concentration, working memory, mathematical capacity, and logical reasoning are all aspects of cognitive function compromised by sleep deprivation. However, not all of these functions rely on the same regions of the brain, nor are they impacted by sleep deprivation to the same degree. For example, the region of the brain known as the prefrontal cortex (PFC) is responsible for many higher-level cognitive functions and is particularly vulnerable to a lack of sleep. As a result, people who are sleep deprived will begin to show deficits in many tasks that require logical reasoning or complex thought.

Determining just how much performance is affected by sleep loss is difficult, in part because of factors such as individual differences in sensitivity to sleep deprivation, as well as individual differences in motivation to stay alert despite sleep loss. Even so, the evidence is clear that a lack of sleep leads to poor performance. As the prevalence of inadequate sleep grows and the demands of the workplace change, it becomes increasingly critical that we recognize and take action to mitigate the impact that insufficient sleep has on our safety and well-being.

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Twelve Simple Tips to Improve Your Sleep

Falling asleep may seem like an impossible dream when you're awake at 3 a.m., but good sleep is more under your control than you might think. Following healthy sleep habits can make the difference between restlessness and restful slumber. Researchers have identified a variety of practices and habits—known as "sleep hygiene"—that can help anyone maximize the hours they spend sleeping, even those whose sleep is affected by insomnia, jet lag, or shift work.

Sleep hygiene may sound unimaginative, but it just may be the best way to get the sleep you need in this 24/7 age. Here are some simple tips for making the sleep of your dreams a nightly reality:

#1 Avoid Caffeine, Alcohol, Nicotine, and Other Chemicals that Interfere with Sleep

As any coffee lover knows, caffeine is a stimulant that can keep you awake. So avoid caffeine (found in coffee, tea, chocolate, cola, and some pain relievers) for four to six hours before bedtime. Similarly, smokers should refrain from using tobacco products too close to bedtime.

Although alcohol may help bring on sleep, after a few hours it acts as a stimulant, increasing the number of awakenings and generally decreasing the quality of sleep later in the night. It is therefore best to limit alcohol consumption to one to two drinks per day, or less, and to avoid drinking within three hours of bedtime.

#2 Turn Your Bedroom into a Sleep-Inducing Environment

A quiet, dark, and cool environment can help promote sound slumber. Why do you think bats congregate in caves for their daytime sleep? To achieve such an environment, lower the volume of outside noise with earplugs or a "white noise" appliance. Use heavy curtains, blackout shades, or an eye mask to block light, a powerful cue that tells the brain that it's time to wake up. Keep the temperature comfortably cool—between 60 and 75°F—and the room well ventilated. And make sure your bedroom is equipped with a comfortable mattress and pillows. (Remember that most mattresses wear out after ten years.)

Also, if a pet regularly wakes you during the night, you may want to consider keeping it out of your bedroom.

It may help to limit your bedroom activities to sleep and sex only. Keeping computers, TVs, and work materials out of the room will strengthen the mental association between your bedroom and sleep.

#3 Establish a Soothing Pre-Sleep Routine

Ease the transition from wake time to sleep time with a period of relaxing activities an hour or so before bed. Take a bath (the rise, then fall in body temperature promotes drowsiness), read a book, watch television, or practice relaxation exercises. Avoid stressful, stimulating activities—doing work, discussing emotional issues. Physically and psychologically stressful activities can cause the body to secrete the stress hormone cortisol, which is associated with increasing alertness. If you tend to take your problems to bed, try writing them down—and then putting them aside.

#4 Go to Sleep When You're Truly Tired

Struggling to fall sleep just leads to frustration. If you're not asleep after 20 minutes, get out of bed, go to another room, and do something relaxing, like reading or listening to music until you are tired enough to sleep.

#5 Don't Be a Nighttime Clock-Watcher

Staring at a clock in your bedroom, either when you are trying to fall asleep or when you wake in the middle of the night, can actually increase stress, making it harder to fall asleep. Turn your clock's face away from you.

And if you wake up in the middle of the night and can't get back to sleep in about 20 minutes, get up and engage in a quiet, restful activity such as reading or listening to music. And keep the lights dim; bright light can stimulate your internal clock. When your eyelids are drooping and you are ready to sleep, return to bed.

#6 Use Light to Your Advantage

Natural light keeps your internal clock on a healthy sleep-wake cycle. So let in the light first thing in the morning and get out of the office for a sun break during the day.

#7 Keep Your Internal Clock Set with a Consistent Sleep Schedule

Going to bed and waking up at the same time each day sets the body's "internal clock" to expect sleep at a certain time night after night. Try to stick as closely as possible to your routine on weekends to avoid a Monday morning sleep hangover. Waking up at the same time each day is the very best way to set your clock, and even if you did not sleep well the night before, the extra sleep drive will help you consolidate sleep the following night. Learn more about the importance of synchronizing the clock in The Drive to Sleep and Our Internal Clock.

#8 Nap Early—Or Not at All

Many people make naps a regular part of their day. However, for those who find falling asleep or staying asleep through the night problematic, afternoon napping may be one of the culprits. This is because late-day naps decrease sleep drive. If you must nap, it's better to keep it short and before 5 p.m.

#9 Lighten Up on Evening Meals

Eating a pepperoni pizza at 10 p.m. may be a recipe for insomnia. Finish dinner several hours before bedtime and avoid foods that cause indigestion. If you get hungry at night, snack on foods that (in your experience) won't disturb your sleep, perhaps dairy foods and carbohydrates.

#10 Balance Fluid Intake

Drink enough fluid at night to keep from waking up thirsty—but not so much and so close to bedtime that you will be awakened by the need for a trip to the bathroom.

#11 Exercise Early

Exercise can help you fall asleep faster and sleep more soundly—as long as it's done at the right time. Exercise stimulates the body to secrete the stress hormone cortisol, which helps activate the alerting mechanism in the brain. This is fine, unless you're trying to fall asleep. Try to finish exercising at least three hours before bed or work out earlier in the day.

#12 Follow Through

Some of these tips will be easier to include in your daily and nightly routine than others. However, if you stick with them, your chances of achieving restful sleep will improve. That said, not all sleep problems are so easily treated and could signify the presence of a sleep disorder such as apnea, restless legs syndrome, narcolepsy, or another clinical sleep problem. If your sleep difficulties don't improve through good sleep hygiene, you may want to consult your physician or a sleep specialist. Learn more at When to Seek Treatment.

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