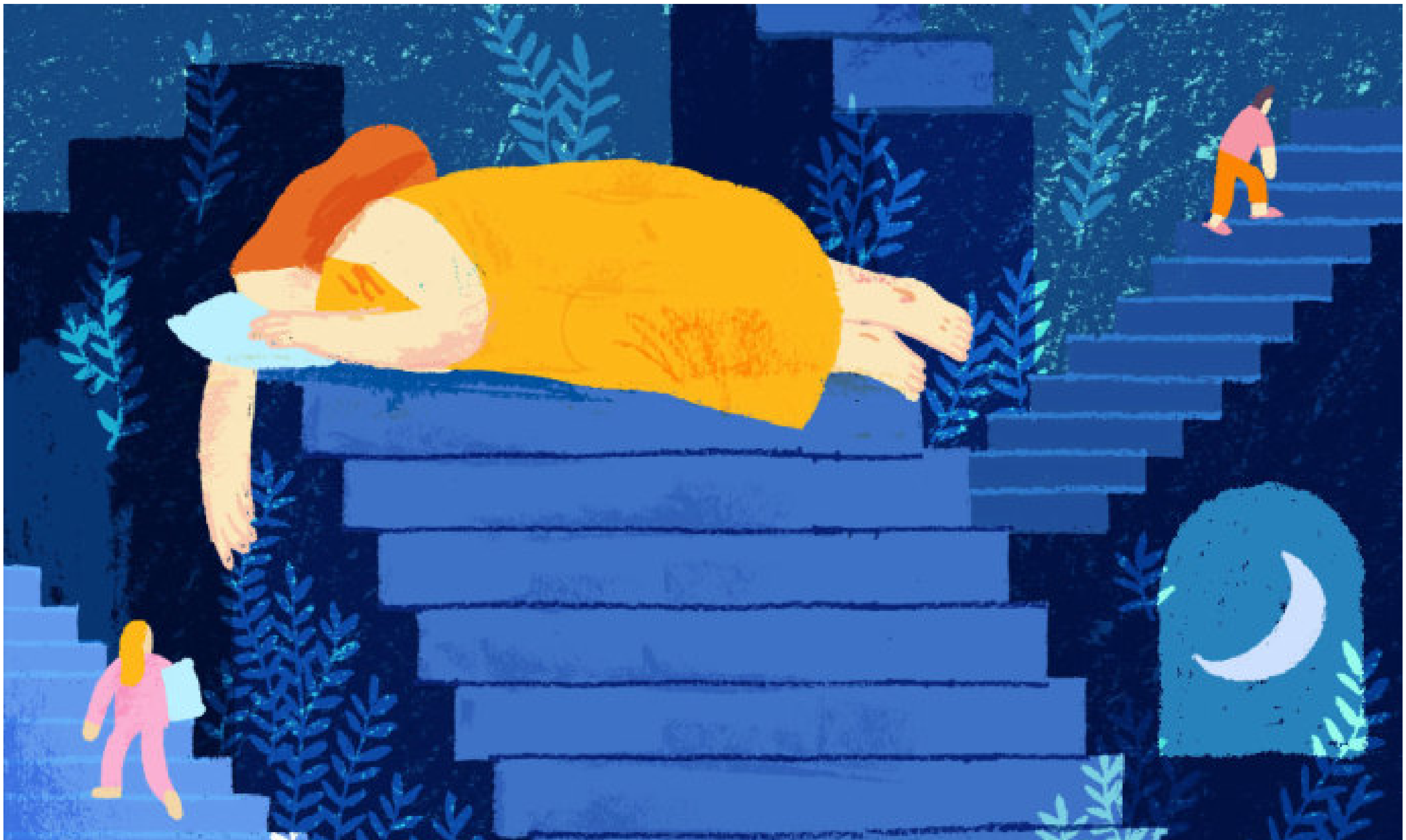
JULY 7, 2015

Why Can't We Fall Asleep?

BY MARIA KONNIKOVA

THE NEW YORKER



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Here's what's supposed to happen when you fall asleep. Your body temperature falls, even as your feet and hands warm up—the temperature changes likely help the circadian clocks throughout your body to synchronize. Melatonin courses through your system—that tells your brain it's time to quiet down. Your blood pressure falls and your heart rate slows. Your breathing evens out. You drift off to sleep.

That, at least, is the ideal. But going to sleep isn't always a simple process, and it seems to have grown more problematic in recent years, as I learned through a series of conversations this May, when some of the world's leading sleep experts met with me to share their ongoing research into the nature of sleeping. (The meetings were facilitated by a Harvard Medical School Media Fellowship.) According to Charles Czeisler, the chief of the Division of Sleep and Circadian Disorders at Brigham and Women's Hospital, over the past five decades our average sleep duration on work nights has decreased by an hour and a half, down from eight and a half to just under seven. Thirty-one per cent of us sleep fewer than six hours a night, and sixty-nine per cent report insufficient sleep. When Lisa Matricciani, a sleep researcher at the University of South Australia, looked at available sleep data for children from 1905 to 2008, she found that they'd lost nearly a minute of sleep a year. It's not just a trend for the adult world. We are, as a population, sleeping less now than we ever have.

The problem, on the whole, isn't that we're waking up earlier. Much of the change has to do with when we choose to go to bed—and with how we decide to do so. Elizabeth Klerman is the head of the Analytic and Modeling Unit, also in the Sleep and Circadian Disorders division at Brigham and Women's Hospital. Her research tracks how multiple individual differences in our environment affect our circadian rhythms and our ability to fall asleep easily and soundly. "When you go to bed affects how long you can sleep, no matter how tired you are," she told me.

A wide array of factors can determine just how quickly you'll be able to drift off to sleep when you choose to do so. To determine their relative importance—and separate the things that truly make a difference from the ones that aren't all that essential—Klerman first assesses her subjects' habits and histories: What is their sleep-wake history—that is, what are their usual routines, and what are the problems they've encountered in the past? What about pharmaceuticals: Which do they use, and are any targeted as sleeping aids? Once this information has been gathered, she brings them to the lab, monitors their sleep in a controlled environment, and determines how each of the various factors affects the ability to fall asleep.

Part of how easily we go to sleep is genetic: many sleep disturbances, ranging from insomnia to circadian disruption, have a large genetic component. (Elizabeth Kolbert wrote about insomnia for this magazine, in 2013.) If you're "out of phase" from typical bedtimes due to circadian disruption, for example, your melatonin levels are off: the hormone that should be telling you to fall asleep isn't produced in enough quantity, or the requisite receptors are missing. While we are still a long way off from fully understanding the precise ways in which genes affect sleep in humans, the neurobiologist Dragana Rogulja, who studies the transition from wakefulness to sleep in *Drosophila melanogaster*, the fruit fly, has begun to answer that question for other animals. Many sleep genes, she points out, are conserved across species. And the sleep patterns in the flies, she told me, are remarkably similar to those in humans. One specific mutation in the flies' genes can lead to a "sleep initiation deficit." Isolating that gene and tracking its mechanism of action through the flies' bodies and brains may bring us a step closer to understanding how similar deficits operate in human sleepers.

Even so, however, our genes haven't really changed in the past century. Genetic predisposition can't explain why so many of us have started to have more trouble falling asleep. The vast majority of the story has to do with our environment. Good "sleep hygiene," many researchers have found, is essential when it comes to falling asleep; it can even overcome some unfortunate genetic predispositions. Conversely, bad sleep hygiene can equal, in its effects, some of the most problematic genetic disorders.

Some of the elements of sleep hygiene are basically the same as good health practices. Nicotine, caffeine, and alcohol all negatively impact sleep, the more so the closer they're consumed to bedtime. We fall asleep faster when we exercise and have regular mealtimes. Eat too late or too much and sleep becomes more elusive. (The effect is reciprocal: sleep disturbance is associated with weight gain.) Go to bed hungry, and sleep likewise escapes your grasp. Any schedule variability, in fact, may detract from sleep ability: in some preliminary results, Rosalind Picard, the director of the Affective Computing Research Group at M.I.T.'s Media Lab and the co-director of the Advancing Wellbeing Initiative, found that sleep variability was one of the most important factors in determining how well someone slept: it was better to go to bed at a consistent time than to try to pull an all-nighter tonight and "catch up" tomorrow. Regular sleep schedules also predict better G.P.A. and mood.

But it may be that the most important aspect of sleep hygiene has to do with light—which, of course, has gotten more pervasive during the past century, especially at night. Humans have evolved to be exquisitely sensitive to the most minute changes in the light around us. In fact, there are specific photoreceptors in the eye that only respond to changes in light and dark, and which are used almost exclusively to regulate our circadian rhythms. These melanopsin receptors connect directly to the part of the brain that regulates our internal body clocks. They work even in many people who are blind: though they can't see anything else, their bodies still know how to adjust their circadian clocks to stay on schedule. Light helps the body predict the future: it's a sign of how our environment will change in the coming hours and days, and our bodies prepare themselves accordingly. As the Harvard circadian neuroscientist Steven Lockley told me, "Our clocks have evolved to anticipate tomorrow."

Now, however, that natural prediction system is being constantly wrong-footed. The problem isn't just artificial light in general. Increasingly, we are surrounded by light on the short-wave, or "blue light," spectrum—light which our circadian systems interpret as daylight. Blue light emanates from our computers, our televisions, our phones, and our e-readers; ninety per cent of Americans use electronic devices that emit it. When we spend time with a blue-light-emitting device, we are, in essence, postponing the signal to our brain that tells it that it's time to go to sleep. ("What have we done with our dusk?" Charles Czeisler asks.) When "dusk" gets pushed progressively later because of these false light cues, we get a surge of energy rather than the intended melatonin release.

Czeisler has found that artificial light can shift our internal clocks by four or even six time zones, depending on when we're exposed to it. In one study, out earlier this year in the journal *PNAS*, Czeisler and his colleagues asked people to read either a printed book or a light-emitting e-book about four hours before bed, for five evenings in a row. The effects were profound. Those who'd read an e-book released less melatonin and were less sleepy than those who'd read a regular book; their melatonin release was delayed by more than an hour and a half, and their circadian clocks were time-shifted. It took them longer to fall asleep. The next morning, they were less alert. These resetting effects can result not just from prolonged reading but from a single exposure. In his sleep lab, Lockley has seen it happen after exposing subjects to short-wavelength light for less than twelve minutes.

Many people who can't get to sleep turn to sleeping aids. Unfortunately, existing pharmaceuticals may not be enough to significantly counteract the effects of environmental overstimulation. The sleep we get from existing medications is different from regular sleep, and may not be as effective as we think. Matt Bianchi, the chief of the Sleep Medicine Division and head of the Sleep Informatics Laboratory at the Massachusetts General Hospital, says that people using sleep aids only sleep, on average, thirty to forty minutes more than people who don't use them. And no drugs on the market mimic exactly the natural progression of sleep. Instead, many of them suppress REM and slow-wave sleep and thus, Bianchi has written, may "impair the restorative value of sleep." Some sleeping aids also come with the risk of parasomnia—behaviors such as eating or leaving the house while asleep, with no subsequent memory of the event in question. And none of these drugs are typically recommended for more than a week at a time. (Ian Parker wrote about Ambien and its possible successors in 2013.)

But there are non-pharmaceutical ways to facilitate sleep as well. Lockley and Czeisler have been developing a system of lights, to be used by NASA, to help us become sleepy at the right moment. They use the same wavelengths that prevent us from sleeping to make us more awake early in the day. Then they slowly transition to longer, "warmer" wavelengths to prepare our bodies for sleep. (They'll be installed on the International Space Station in October, 2016; for consumers, there are blue-light filters that can be placed on most any electronic device.) Other approaches are more behavioral. Susan Redline, a sleep researcher at Harvard Medical School, recommends cognitive-behavioral therapy. Other "mind-body therapies," she said, like tai chi, yoga, and meditation, may also be helpful. She is currently developing a yoga intervention for low-income Boston residents who report sleep problems. The work builds on previous studies suggesting that people sleep better after doing yoga. A Brazilian intervention, led by Pedro Hallal, a researcher at the Federal University of Pelotas, provided free public gyms in low-income areas; this also had promising effects on sleep.

The search for solutions matters: as a society, we're becoming worse at going to sleep, and we're doing little to counteract that decline. But why should we care? Why is sleeping less so problematic? What useful purpose does sleep even serve? As researchers learn more about what happens while we sleep, they're understanding, more and more, how vital it really is.

JULY 8, 2015

The Work We Do While We Sleep

BY MARIA KONNIKOVA

It's strange, when you think about it, that we spend close to a third of our lives asleep. Why do we do it? While we're sleeping, we're vulnerable—and, at least on the outside, supremely unproductive. In a 1719 sermon, "Vigilius, or, The Awakener," Cotton Mather called an excess of sleep "sinful" and lamented that we often sleep when we should be working. Benjamin Franklinechoed the sentiment in "Poor Richard's Almanack," when he quipped that "there'll be sleeping enough in the grave." For a long time, sleep's apparent uselessness amused even the scientists who studied it. The Harvard sleep researcher Robert Stickgold has recalled his former collaborator J. Allan Hobson joking that the only known function of sleep was to cure sleepiness. In a 2006 review of the explanations researchers had proposed for sleep, Marcos Frank, a neuroscientist then working at the University of Pennsylvania (he is now at WSU Spokane) concluded that the evidence for sleep's putative effects on cognition was "weak or equivocal."

But in the past decade, and even the past year, the mystery has seemed to be abating. In a series of conversations with sleep scientists this May, I was offered a glimpse of converging lines of inquiry that are shedding light on why such a significant part of our lives is spent lying inert, with our eyes closed, not doing anything that seems particularly meaningful or relevant to, well, anything. (The meetings were facilitated by a Harvard Medical School Media Fellowship.)

One line of evidence stems from what happens when sleep is disturbed. By looking at what can go

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wrong while we're asleep, we can get a sense of what sleep is for. Take genetic impairments. In REM-sleep behavior disorder, the usual paralysis that keeps our bodies in check as we enter REM sleep disappears, and people physically act out their dreams. The disorder is a fairly reliable predictor of neurodegenerative disease: one study, based at the Center for Sleep Research at the Hôpital du Sacré-Coeur, in Montreal, found that over half of the patients who acted out their dreams had developed some form of neurodegenerative disease twelve years later. There's sleep apnea, when your breathing pauses as you sleep, often for a few seconds but sometimes for a few minutes, before your body briefly jolts awake to restart the process. (Often, the jolt never makes it into conscious memory.) In trials, the disorder has been associated with diabetes and cardiovascular disease and has been shown to lead to cognitive impairment. About ten per cent of the population experience impairment during their waking hours as a result of chronic insomnia, a condition that has been linked to low quality of life, depression, increases in cardiovascular disease and hypertension, cognitive and motor impairment, and anumber of other medical conditions.

For sleep scientists, all of these unpleasant disorders offer tantalizing lines of inquiry. The link between many of them and neurodegenerative disease, or other forms of cognitive impairment, suggests that sleep could be required for cognitive upkeep and function. Their link with heart disease suggests that sleep might serve to relieve vascular stress. The fact that insomnia is associated with depression suggests that sleep might help us deal with emotionally stressful or otherwise disruptive events.

Increasingly, researchers have found ways to test these theories more directly. In 2000, Stickgold published a study in Science that became one of the most convincing validations of the role that sleep and dreams play in memory consolidation. For seven hours, over the course of three days, a group of people played the computer game Tetris. Some had never played the game before; others were familiar with it; and a third group didn't know either way, because they were amnesiacs with extensive damage to their medial temporal lobes and hippocampi. Their particular form of amnesia meant that they were unable to form new episodic memories.

Each night, as they were falling asleep, Stickgold's subjects were repeatedly awoken and asked to recall, to the best of their knowledge, what they were dreaming about. It turned out that they dreamed of Tetris. What was surprising was that even the amnesiacs had these dreams. They had no idea what they were seeing and, the next morning they remembered neither the game nor the experimenter, but they would recall dreams of falling shapes that conformed to the Tetris patterns they'd observed earlier in the day. Sometimes, they'd even report that the shapes rotated to fit into rows.

Since then, evidence for the memory-related functions of sleep, and of dreams in particular, has only mounted. In 2013, Stickgold published a summary of his research since the Tetris study, also reviewing parallel advances by other researchers in the field. In that paper, he argued that sleep isn't crucial just for memory consolidation; it is also a remarkably selective mechanism. We don't remember everything that happens to us on a given day: sometimes, we remember something simply because it's emotional, while, at other times, we work our way through mundane details to figure out why something matters. Sleeping and dreaming, Stickgold argues, help us sift through material to isolate and store the important take-away, whether it is what he calls the "gist" (the overarching point of a lot of information) or a specific detail. “When we dream, we get the pieces. When we wake, we can know the whole,” Stickgold says.

In one experiment, the University of Tübingen neurobiologist Jan Born and Ullrich Wagner, a neuroscientist at the University of Münster, taught a group of people a relatively complex math task. Though the subjects didn’t know it, there was a simpler way of solving the problem—an abstract rule that would enable a quick solution. Few of the subjects spontaneously figured out the solution the first time. Each participant was retested on the task eight hours later; some were allowed to sleep and others had to remain awake. Just under a quarter of the group that took a sleepless break came up with the faster solution. But the insight rate more than doubled among the subjects who had spent the eight hours sleeping: sixty per cent of them could now see the shortcut. As we sleep, our brains replay, process, learn, and extract meaning. In a sense, they think.

Our physical health, too, seems to be intimately tied with sleep. In one study, designed to test the impact that cardiac function has on sleep, and vice versa, a group of physiologists subjected healthy men with no history of cardiac problems to sleep deprivation. At various points, they measured their vascular fitness, checking their heart rates, their blood pressure, and their levels of certain proteins associated with heart problems. Within two days, almost every marker was elevated. Conversely, in a study looking at sleep apnea, which is strongly linked to cardiovascular disease, treatment of the apnea was found to improve vascular function in short order: once patients could sleep soundly, the stress on their hearts was relieved.

But the importance of sleep to our brain function may be even more fundamental. In addition to its memory and problem-solving functions, sleep may help our brains stay sharp, young, and healthy. Two years ago, the University of Rochester neuroscientist Maiken Nedergaard published the results of many years of research into the function of sleep. After using new techniques to peer into the waking and sleeping brains of mice, she discovered that sleep was the brain’s maintenance system. When we’re awake, our activities lead to a build-up of debris in the brain: we form toxins, such as beta-amyloid, a protein associated with Alzheimer’s, and other proteins that are usually harmless get misfolded. When we fall asleep, specific channels in our brains expand to allow cerebrospinal fluid to flow in and clear that debris. These mechanisms have been termed the “glymphatic system,” a nod to the lymphatic system, which clears waste from our bodies Conversely, when our brains don’t have enough time to rest, toxins build up, and neurodegenerative disease sets in.Indeed, one of the earliest signs of impending dementia is sleep disturbance, and some of the genes that control sleep duration are also implicated in schizophrenia. Sleep disruption may share a common biological mechanism with neurodegenerative diseases.

All of this research suggests that important work happens while we sleep. And yet we also know that few of us sleep enough. Some of us may no longer even know what being fully awake feels like. How is your mind today affected by a lack of sleep the night before? Increasingly, researchers are turning their attention to waking life, and asking how much it’s been changed by chronic lack of sleep.

JULY 9, 2015

The Walking Dead

BY MARIA KONNIKOVA

CREDITILLUSTRATION BY MIN HEO

Did you get enough sleep last night? Are you feeling fully awake, like your brightest, smartest, and most capable self? This, unfortunately, is a pipe dream for the majority of Americans. "Most of us are operating at suboptimal levels basically always," the Harvard neurologist and sleep medicine physician Josna Adusumilli told me. Fifty to seventy million Americans, Adusumilli says, have chronic sleep disorders.

In a series of conversations with sleep scientists this May, facilitated by a Harvard Medical School Media Fellowship, I learned that the consequences of lack of sleep are severe. While we all suffer from sleep inertia (a general grogginess and lack of mental clarity), the stickiness of that inertia depends largely on the quantity and quality of the sleep that precedes it. If you're fully rested, sleep inertia dissipates relatively quickly. But, when you're not, it can last far into the day, with unpleasant and even risky results.

Many of us have been experiencing the repercussions of inadequate sleep since childhood. Judith Owens, the director of the Center for Pediatric Sleep Disorders at Boston Children's Hospital, has been studying the effects of school start times on the well-being of school-age kids—and her conclusions are not encouraging. Most adults are fine with about eight hours of sleep, but toddlers need around thirteen hours, including a daytime nap. Teens need around nine and a half hours; what's more, they tend to be night owls, whose ideal circadian rhythm has them going to bed and waking up late. As schools have pushed their start times earlier and earlier—a trend that first started in the sixties, Owens says—the health effects on students have been severe. "It's not just sleep loss. It's circadian disruption," Owens says. "They have to wake up when their brain tells them to be deeply asleep. Waking a teen at six in the morning is like waking an adult at three at night."

The result is a kind of constant jet lag—and one that is exacerbated by sleeping in on the weekends. Executive function and emotional responses get worse, hurting everything from judgment to emotional reactivity. The ability to make good decisions can suffer, and kids can become more prone to act out and get depressed. In fact, the rise in A.D.H.D. diagnoses may, in part, be the result of inadequate sleep: in children, symptoms of sleep deprivation include hyperactivity and impaired interpretation of social cues. Owens has seen many such misdiagnoses in her clinical practice. The effects are physical, as well. Children who undersleep are more likely to gain weight and become obese. Even for infants as young as six months, amounts of sleep can predict weight gain three years later.

Schools with healthier start times, on the other hand, see an increase in attendance, test scores, G.P.A.s, and health. In one study in which an intervention pushed start times later, it wasn't just academic outcomes that improved; car crashes went down by as much as seventy per cent, and self-reported depression rates fell. Even a delay of as little as half an hour, Owenshas found, improves outcomes. "It should be about the health and well-being of the students," she told me, "and not the convenience of adults."

As we age, unfortunately, our quality of sleep only gets worse. If you sleep six hours a night for twelve days, Adusumilli says—and that's about how much many Americans sleep all year round—your cognitive and physical performance becomes virtually indistinguishable from that of someone who has been awake for twenty-four hours straight. (The same effect is produced by six days of four-hour nights.) And the performance of someone who has been awake for twenty-four hours straight is similar to that ofsomeone with a blood alcohol level of 0.1 per cent. In other words, "normal" amounts of sleep deprivation have us acting like we're drunk. (Charles Czeisler recalls presenting these facts to a *Times* journalist; when the journalist handed in the story, the editor said it couldn't possibly be true. Most people in the newsroom were sleep-deprived, and they still managed to produce the *Times*every day. Surely an intoxicated newsroom would be incapable of such a feat.)

In the short term, these types of deficits have a significant effect on our performance across the board. Perception deteriorates, along with motor skills: in one study of college basketball players, well-rested players performed better than those who followed their usual schedules. Emotional control suffers—the connection between the prefrontal cortex (where we make executive decisions) and the amygdala (which is associated with fear and other emotions) degrades—and we become more impulsive and prone to depression. And our ability to think and to make sound decisions plummets. We become worse at learning, memory, and simple tasks of arithmetic and analytic reasoning. The rate of accidents and errors rises. In one study, which compared first-year interns at Brigham and Women's Hospital who worked on a regular schedule to those working on shorter, sixteen-hour shifts that included a nap, the sleep-deprived residents made more than double the number of attentional errors at night—a result that has been replicated multiple times.

Equally troubling are the health impacts in the long term. We become more prone to metabolic and endocrine problems, including weight gain, with aresulting increased risk of diabetes and cardiovascular disease. We decrease our immune function and could increase the risk of multiple types of cancer. We speed up our cognitive decline and increase the risk of dementia.

Even if you start sleeping more today, you may be too late to avoid some of the impacts of sleep deprivation. Because kids' brains are growing and changing so rapidly, they are more vulnerable to the effects of sleep deprivation than adults; those effects may well follow them throughout life, no matter their habits later on. As for adults, we can recover from relatively short bouts of sleep loss: in one study, the University of Pennsylvania sleep researcher David Dinges found that one night of good sleep was enough to help you rebound from five nights of too little sleep. But recovery from truly chronic sleep deprivation relies on the quality of sleep you are getting. It can take weeks, and sometimes longer, to recover—and we often don't have the luxury of sleeping ten hours a night for even as much as a week.

Ironically, many of us don't want to "catch up" on sleep even when we can. We honestly don't realize that we're sleep deprived; many of us think we're just fine with five or six hours a night. We earnestly believe that we're fully awake and at our best. The fact is, however, that we are very bad at knowing how much sleep is enough.

In one of her studies, Elizabeth Klerman, a sleep scientist at Brigham and Women's Hospital, allowed people to follow their own sleep schedules for two weeks; they chose how many hours they wanted to be awake, and how many hours they wanted to be asleep. Then, they went into the sleep lab. Klerman was interested in two things: sleep latency, or how long it took them to fall asleep, and sleep duration, or how long they slept. On the second night and during the second day, she told me, they slept an average of twelve and a half hours out of a possible sixteen hours of sleep opportunity, demonstrating a severe sleep deficit. On the first day in the lab, during testing of sleep latency, some fell asleep before the technician had even left the room. Many of the subjects, in other words, were pathologically sleepy. Yet they'd thought they were fully awake and at their best. We all have our "chosen level of uncomfortableness," Klerman says, but that doesn't mean we're actually doing well.

Charles Czeisler has found that we are only aware of the impact of sleep loss on our performance for the first one to two days. After that, we no longer realize that we're not functioning at our best. "Then, it's just the new you," he says. Klerman recalls one participant in another study, which restricted the amount of sleep that subjects were allowed. The subject came back once he was able to sleep normally because he wanted a second chance to fill out the forms that asked him to rate his mental acuity and how well he was functioning. He'd filled them out wrong the first time, he said: after catching up on sleep, he'd realized how impaired he'd been, and wanted a chance to downgrade his ratings. "He'd forgotten what alert felt like," Klerman says. At the time, he thought he was fully awake and capable. "Why would you expect the brain to be able to police itself?" she asks.

Taken together, the current research on sleep offers us a valuable lesson. We all want to be productive and effective at what we do. But when we try to boost productivity by expanding our waking hours, we aren't doing anyone any favors. We lose more by skimping on rest than we can ever gain back by adding a few hours to our days. We are less productive, less insightful, less happy, more likely to get sick. And we have no idea just how much we've compromised our abilities and health in the process: ask most anyone and they will tell you they do just fine with five, six hours. We systematically undervalue sleep, and yet it is fundamental to our present and future performance. And unlike most anything else, sleep is one of the few things we have to do ourselves. No one can do it for you.