INSIGHTS

POLICY FORUM

SOCIAL SCIENCE

Informing sleep policy through field experiments

Evidence is particularly needed from poorer communities

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Recent progress in sleep science has greatly improved our understanding of the neurobiology of sleep and its importance for physical and mental functioning. Lab experiments have shown that insufficient sleep causes declines in cognitive and physiological function, and community studies have documented widespread sleep deprivation. Adults in the US sleep just 6.1 hours per night when objectively measured (*1*), well below the 7 to 9 hours recommended by experts (*2*). Evidence is emerging that sleep duration and quality are even lower in developing countries and among the poor in rich countries (*3*–*5*). This has led to predictions that increased sleep would have profound benefits for society, including increased productivity, academic performance, health, and safety (*6*). Why do people not sleep more, given these predicted benefits?

A standard economic model would posit that, when deciding how much time to spend in bed, people weigh benefits of sleeping more against costs, while facing a fixed overall "time budget" (*7*). When viewed through this lens, it becomes evident that we know surprisingly little about the calculus of sleep in people's lives. Field experiments—experimental studies in natural environments—can

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A wholesale vegetable seller sleeps in Kolkata, India. Field experiments can improve our understanding of sleep in natural environments.

help measure the impacts of sleep on the outcomes people value, such as time use, financial well-being, health, and happiness, over long periods of time.

Using affordable and accurate wearable devices such as actigraphs to measure sleep, field experiments combine the strengths of lab and community studies. They use controlled, randomized interventions—as in pragmatic clinical trials—to measure the causal effect of improved sleep in natural environments on real-world costs and benefits. One such example is a recent study in India (see the first box) that randomized 452 adults to treatments that encouraged increases in nighttime sleep duration and/or daytime naps over 3 weeks (*5*).

The measurement of ecologically valid costs and benefits through field studies is central to policy decisions. Lab experiments typically adopt as endpoints sleep itself or aspects of cognition, such as sustained attention, which can be precisely and reliably measured across studies. But it is difficult to know how such effects translate into real-world outcomes. For instance, among data-entry workers enrolled in the same sleep study in India, performance in the commonly used psychomotor vigilance task (PVT) correlated only modestly with people's productivity, hours worked, and earnings in their data-entry job (*5*).

Field experiments also study sleep in natural environments, which often differ markedly from lab conditions. This divergence could be particularly large when studying sleep among the global poor, who often struggle with noise, heat, light, mosquitoes, shared sleep spaces, and physical and psychological distress. The costs and benefits of sleep may be quite different in such contexts.

Because field experiments can accommodate larger sample sizes than is feasible in the lab, they can study more modest but also more realistic changes in sleep. Studying such modest increases in sleep may lead to quite different conclusions than lab studies, which instead typically experimentally induce severe sleep restriction. Researchers can thus evaluate scalable and policy-relevant interventions as they would play out in practice. For example, field experiments have been used to evaluate pragmatic policies to improve sleep, such as delayed school start times (*8*) and restricted work shifts among physicians (*9*).

Because they can be conducted over long durations and in natural settings, field experiments can also capture how people adjust their lives in response to changes in sleep. Chronically sleep-deprived people may cope by structuring their workdays differently, by adopting countermeasures such as increasing caffeine intake, or even by selecting into work that is less sensitive to cognitive performance, thus mitigating the impacts of sleep deprivation.

Field studies can also capture the "opportunity costs" of sleep: the reduced time available for other activities such as work, exercise, and leisure. If people value these activities highly enough, they might reasonably decide to set aside less time for sleep despite the cost of fatigue the following morning. Yet these costs are often neglected in the literature. For instance, before the results of the study in India (*5*) were released, 119 experts from sleep science and economics made predictions about the effect of increased night-sleep duration on work performance. The experts on average predicted a 7% increase in hours worked and a 12% increase in work output, presumably because they expected reduced tiredness and higher motivation and cognitive performance. Instead, increased night sleep came at the cost of having less time available to work. Eighty-three percent of experts made predictions outside the 95% confidence interval of the results (*5*), highlighting the need to explicitly measure opportunity costs in future research.

Despite these potential strengths, field experiments have until recently been rare in sleep science. One reason is the historical dif-

Sleepless in Chennai

A field experiment in Chennai, India (*5*), measured sleep in a low-income urban population and evaluated interventions to improve sleep. Using actigraphy, low levels of nighttime sleep duration and efficiency were documented compared to levels observed in rich countries. At baseline, participants sleep on average just 5.6 hours each night (see the first figure), with an average sleep efficiency of only 70%. Seventy-one percent of participants sleep less than 6 hours per night on average. The study features two cross-randomized interventions to increase sleep:

1. A bundle of interventions to increase nighttime sleep, including devices to improve people's home sleep environment, information, and encouragement and/or modest financial incentives to increase sleep.
2. An offer of a daily half-hour nap in the early afternoon in a quiet office.

The nighttime treatments increased nighttime sleep duration by an average of 27 minutes without affecting efficiency and had no significant impact on a host of outcomes (see the second figure). By contrast, naps resulted in significant improvements but also reduced time available to work (see the second figure). The contrasting effects of naps and nighttime sleep may be explained by naps having higher sleep quality or because naps were timed to coincide with the mid-afternoon circadian dip. Deidentified data are publicly available at www.sleepdata.org.

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ficulty of objectively measuring sleep in the field. Another is that social scientists who conduct policy experiments have neglected the importance of sleep, and experimental sleep scientists have largely prioritized the controlled and standardized outcome measurements in the lab. Advances in actigraphy have enabled sleep scientists to document sleep in the field (*3*, *10*) and have inspired recent field experiments by social scientists interested in sleep (*5*, *11*).

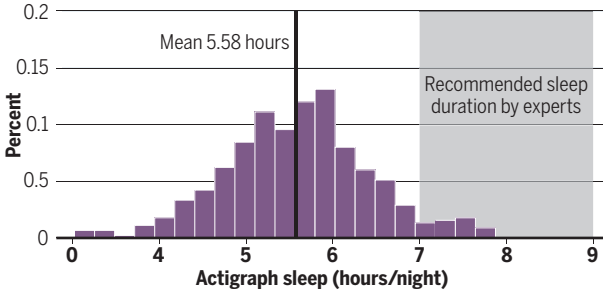
As field research progresses, it should not focus solely on sleep duration but instead should engage with the multidimensional nature of sleep. In addition to time in bed and sleep duration, sleep science has shown that sleep efficiency, fragmentation, and variability are all important dimensions of sleep (*10*). The benefits of increasing sleep duration, say through inducing more time in bed, may be small in settings with low sleep quality unless sleep can be improved along other dimensions as well. Consistent with this view, increased nighttime sleep caused no gains in any outcomes from an intervention that substantially increased sleep duration without improving its (poor) quality (see the first figure). A key objective of future research should be to test interventions that target not only sleep duration, but other dimensions as well. Sleep disorders, such as sleep apnea, are widely underdiagnosed and undertreated, and the impact of untreated sleep disorders in low-income countries requires systematic study.

One such intervention is cognitive behavioral therapy for insomnia (CBT-I). Clinical trials show that a short course of CBT-I improves multiple dimensions of sleep, including sleep efficiency, sleep onset latency, and wake after sleep onset (*12*). In addition to potential benefits from improved sleep quality, CBT-I may have low opportunity costs for recipients because it does not require more time in bed. Importantly for policy, CBT-I can also be effectively delivered as a self-help therapy over the internet (*12*). A brief, manualized version has also recently been developed for low-resource settings where mental-health professionals are scarce (*13*). Existing trials of CBT-I and other clinical sleep interventions have understandably focused on sleep itself as the primary outcome and on a limited set of important secondary outcomes such as positive affect or comorbidities. Adding measures such as time use, earnings, work performance, and financial well-being to such trials would be a valuable next step. In one example of such work, an internet-delivered CBT-I intervention increased job satisfaction and reported self-control among workers (*14*).

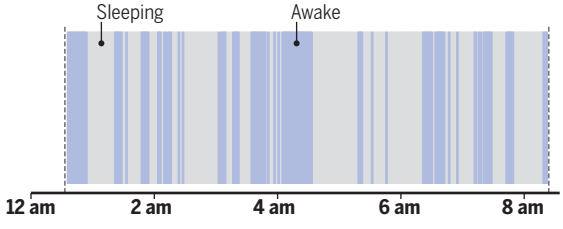
Beyond providing a more complete picture of the costs and benefits of such clinical interventions, what kinds of research would help inform policies on sleep around the globe? Economists have emphasized two broad justifications for policy-makers to take action to change individual behaviors.

Sleep patterns among the urban poor in India

Data are from (*5*), based on 452 study participants in Chennai, India (see the first box). Hours asleep, averaged at the participant-level over 7 nights in their home environments (before any treatments were administered), are shown (top). Sleep-wake patterns are shown for a single night for a representative participant (bottom). This participant stayed in bed for 7 hours and 45 minutes but slept for only 5 hours and 20 minutes (sleep efficiency = 69%). The participant awoke 31 times, and the longest sleep episode lasted 45 minutes. These statistics are close to the median observation on each dimension.



A typical night



First, people may sleep less than is socially optimal because of externalities, where some people are harmed by others' actions. For example, noise pollution due to traffic may disturb sleep in the surrounding community. Similarly, constraints imposed on individuals by others—such as employers or policy-makers—may result in too little sleep if decision-makers undervalue the benefits of sleep. For instance, school-district administrators may underappreciate the value of later school start times, which increase student sleep duration and reduce tardiness and daytime sleepiness (*8*). Or employers may undervalue well-rested employees because some of the benefits will accrue outside the office and may not translate into overall higher work output (*5*). Here, policies that directly set standards, regulate work shifts and school timings, or impose fines on the externality-producing actions may be warranted.

Second, individuals may not be trading off their private costs and benefits of sleep correctly. This might be the case because well-established psychological factors such as limited self-control keep them from following their own best interests, recommending policies that provide incentives to sleep, limit temptations, or help individuals commit to getting enough sleep. Alternatively, individuals may underestimate the value of sleep or simply not have the necessary information to overcome barriers (*11*). In such cases, information campaigns or other forms of encouragement to increase sleep could be warranted. Measurement of people's beliefs about the benefits and costs would be valuable to understand the scope for intervention.

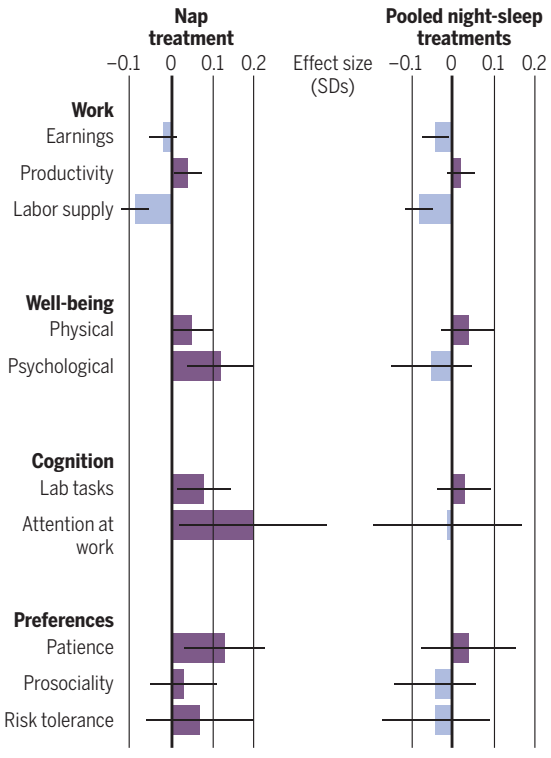
Of course, this view of sleep as a choice has its limitations. Low sleep duration and quality due to psychological distress or uncomfortable living conditions are not freely chosen. But they may still be amenable to actions such as using therapy to manage stress or investing in a better sleep environment. Similarly, sleep may be shortened by hard constraints faced by individuals, such as work shifts and school timings. These may be thought of as choices made by different actors in society—for example, by firms or policy-makers.

In each case, it is crucial to rigorously evaluate proposed policy solutions and iterate on their design. Such research has often exploited quasi-experiments, in which changes in policy are "as if" random. An example is a study that compared students in two schools, one of which delayed school start times on one day of the week by 60 minutes to accommodate a weekly staff meeting (*8*). Policy evaluation—even of quite complex and ambitious policies—is increasingly amenable to randomized field experiments in partnership with policy-makers and organizations. An excellent example is a recent field experiment that evaluated the elimination of extended-duration shifts for resident physicians. Motivated by correlational evidence that sleep-deprived physicians make more mistakes, this study found that eliminating extended shifts of 24 hours or more (and instead limiting shifts to no more than 16 hours) increased physicians' sleep but increased serious medical errors, possibly because of increased patient handoffs between physicians (*9*). This underscores the value of evaluating policy changes using field experi-

GRAPHIC: N. DESAI/*SCIENCE* BASED ON BESSONE *ET AL.* (*5*)

The effects of nighttime and nap treatments

Point estimates and 90% confidence intervals are shown, from the study from the first box (*5*), for the pooled night-sleep interventions (right) and the nap intervention (left). All outcomes are standardized around the control group mean, and a positive value implies a "better" outcome. The following outcomes are index variables, which combine multiple measures: (i) physical well-being: performance in a stationary biking task, blood pressure, and self-reported illnesses, pain, and health; (ii) psychological well-being: self-reported depression, happiness, life possibility, life satisfaction, and stress; (iii) lab tasks: measures of attention, memory, and inhibitory control; (iv) attention at work: attention to piece rates in the data-entry task; (v) patience: savings and present bias; (vi) prosociality: choices in dictator, trust, and ultimatum games; (vii) risk tolerance: negative of choices in risk aversion and loss aversion lotteries.



GRAPHIC: N. DESAI/*SCIENCE* BASED ON BESSONE *ET AL.* (*5*)

High-priority sleep research areas to inform policy-making

- Address the dearth of sleep research—both prevalence studies and field experiments—in developing countries and in low-income settings in high-income countries.
- Include a broader range of outcomes in pragmatic clinical trials, complementing usual measures of physical and mental health with economic, time use, and social outcomes such as earnings, work performance, social relationships, financial decision-making, and other outcomes directly valued by individuals and policy-makers.
- Conduct field experiments to study interventions to improve multiple facets of sleep (duration, satisfaction, regularity, efficiency, and timing) such as CBT-I in general populations.
- Study costs and benefits of naps in everyday lives, including measures of opportunity costs, such as foregone work time, and costs associated with accommodating napping.
- Study behavioral barriers to sleep at the individual level, for instance measuring the importance of incorrect beliefs about the benefits of sleep and the role of behavioral biases such as limited self-control.
- Study concrete social policies in both high- and low-income countries with the potential to improve sleep, such as improved mental health care, changes in school and work timing, noise abatement, housing vouchers, and environmental regulations. Improved sleep could be an overlooked and previously unmeasured benefit of such policies.
- Evaluate the impact of undiagnosed sleep disorders (e.g., sleep apnea) on sleep quality, health, and productivity in low-income settings.

ments, which can identify unintended consequences and guide policy corrections.

The existence of very different barriers to healthy sleep across different contexts and even across individuals implies the need for a diverse set of sleep policy tools. For example, because low-income individuals are at higher risk of housing insecurity and poor mental health (*15*), policies to improve access to housing and mental health care may be particularly valuable for them. Tools to alleviate behavioral factors such as overuse of electronics before bed may instead matter relatively more in high-income settings. Naps could be particularly beneficial in developing countries in tropical settings, where nighttime sleep may be of low quality and the opportunity cost of foregone work in the afternoon (when temperatures peak) may be low. Indeed, offering short naps to workers in India yielded more benefits than extending nighttime sleep (see the second figure). Field research across all these different contexts is needed to guide policy, as costs and benefits of policies are likely to differ substantially across contexts.

We have identified several high-priority sleep research areas to inform policy-making (see the second box). Bodies such as the National Center for Sleep Disorders Research could help to identify initiatives across the US National Institutes of Health and other federal agencies to tackle these questions, and nongovernment funders such as the Wellcome Trust and the Gates Foundation could also provide valuable support. Most pressingly, sleep research has been concentrated in rich countries and in higher-income populations within those countries, even though the majority of the world's population lives in lower-income settings. Informing policy requires documenting how much and how well people sleep across the world and measuring the costs and benefits of improved sleep, including sleep duration but also other dimensions such as efficiency, fragmentation, and variability. More frequent interdisciplinary collaborations between sleep and social scientists to tackle these issues are a natural next step in this research agenda. ■

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