COMMENT

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The human sleep project

To establish the true role of sleep, researchers must gather real-world data from thousands, even millions, of people, says **Till Roenneberg**.

Sleep is essential for health, performance and wellbeing. Yet in many countries, people are getting one to two hours less of it each night than their ancestors did 50–100 years ago. Even when people have the opportunity to sleep, many cannot. Sleep pathologies are approaching epidemic levels, affecting an estimated 70 million people in the United States alone (see go.nature.com/6dgqhg). And in some countries, direct and indirect costs of sleep-related problems are thought to approach 1% of gross domestic product[1]. Despite these alarming numbers, sleep research ranks only 91st in the 235 categories on this year's funding list of the US National Institutes of Health — below, for instance, studies of tobacco (see go.nature.com/ces1rf).

Researchers have made great advances in understanding which neurotransmitters and brain regions are involved in sleep[2], and how the timings of sleep and wakefulness are controlled by an internal (circadian) clock[3], among other things. Yet we still do not have answers to the most basic questions. It is not really understood, for instance, what sleep is for, how much is optimal, how sleep quality can be measured and predicted, or the role of genetic and environmental factors in determining ideal sleeping patterns.

One reason for this lack of understanding is that most of what is known about sleep comes from laboratory studies. Subjects in these studies tend to be mice or hamsters that are kept in artificial light–dark cycles, or people who have been instructed to sleep at certain times in beds that are not their own, with electrodes fastened to their heads. Assessments of sleep are also often based on subjective responses to questions about how 'well' people feel after they have slept, or whether they think they experienced a good night's sleep. To learn about sleep in the real world, and to establish how to manage sleep to improve productivity, health and ▶

quality of life, we need a multidisciplinary 'human sleep project'.

An attempt to probe sleep *in situ* has been made by my research group at the Ludwig Maximilian University of Munich in Germany. Since 2000, our group has been building a database on daily sleep behaviour called the Munich Chronotype Questionnaire (MCTQ). We have publicized our project in newspapers, on the radio and on television, requesting people to fill out an online questionnaire. Participants are asked to provide the times at which they go to bed, prepare for sleep, fall asleep, wake up and get up[4]. In exchange, they receive a document revealing how their sleeping behaviour compares with the rest of the population. Importantly, people give this information for both working and non-working days. Our database now includes entries from more than 150,000 individuals from all over the world.

Using these data, we have assessed how the amount of sleep that people get, and when they get it, changes with factors such as age, season, location and even daylight saving time[4]. Our results suggest that although people sleep for the same amount of time on work-free days as they did ten years ago, on work days, they sleep for about 38 minutes less than they used to[4]. We also discovered that throughout their school and working lives, people seem to oscillate between undersleeping on work days and oversleeping on work-free days (see 'Losing sleep'), with 80% of people needing an alarm clock to wake up on work days[4]. These findings indicate that much of the working population experiences what we call 'social jet lag': people switch between different 'time zones' every week, one dictated by their work schedules, the other by their biological clock.

BEDTIME STORY

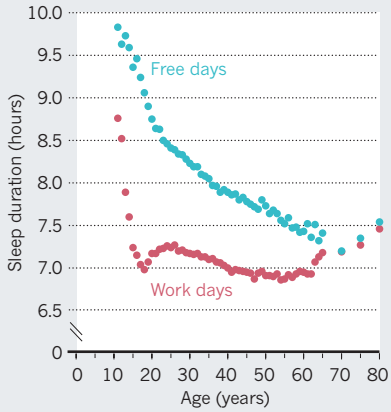
The practice of going to sleep and waking up at 'unnatural' times could be the most prevalent high-risk behaviour in modern society. With every hour of social jet lag (the difference between the social and the biological time zone), the chances of being overweight or obese increase by 33% (ref. 4). This substantiates an association between sleep duration and metabolic problems that was found five years ago[5]. My colleagues and I have also associated social jet lag with smoking, with increased consumption of alcohol or caffeine[4], and with signs of depression such as appetite loss and feelings of sadness[6].

I believe that what has emerged from the MCTQ database is only the tip of the iceberg. Thanks to the Internet and personal monitoring devices, it should be possible to obtain systematic and quantitative information about the sleeping patterns of thousands, even millions, of people.

To transform our understanding of sleep, a broad data-collection strategy is required.

LOSING SLEEP

Answers to a questionnaire indicate that many people oversleep on free days and undersleep on work days, experiencing 'social jet lag'.



SOURCE: REF. 4

This would involve inviting millions of people to fill out online questionnaires, tens of thousands to keep online sleep diaries and several thousand to submit real-time data from recording devices. A subset of these people would then be asked to supply their DNA. (Once the sleep phenotype is better understood, researchers would be in a good position to probe its genetics.)

A key goal of a human sleep project would be to identify simple, effective indicators that sidestep the need for cumbersome electrodes, or for blood or saliva samples, which are used to obtain conventional markers of circadian rhythms, such as the hormone melatonin. Many sleep-tracking devices are now available or are in development, such as wristwatch-like gadgets that measure movement and light. Other devices use information detected by mobile phones, or communicate with mobile phones, which can upload data to the Internet. These can monitor skin temperature and skin conductance (a measure of perspiration, indicative of stress levels), respiration rate, blood-oxygen levels, electrical activity in the heart, and even blood pressure. Such parameters could potentially enable researchers to establish individuals' circadian timing, and when and how well they sleep.

Computer scientists with expertise in biomedical, Internet and mobile-phone technologies will be crucial for designing and building tracking devices, and for developing standard operating procedures for the generation, uploading and storage of data. Ultimately, the analysis of data collected in such a project could give rise to fresh hypotheses that lead to new experiments in the laboratory. These in turn may help researchers to improve *in situ* recording methods.

Data should be collected from various time zones and geographical locations, and at different times of year. It is also important that participants represent diverse populations, and should include people living in different states of modernization (people living without electricity and people living in large cities), as well as, for instance, shift-workers, people who are blind, people with metabolic syndromes, and so on.

Together with colleagues from the chronobiology laboratory at the university hospital in Porto Alegre, Brazil, we have begun to measure sleep, activity, light exposure and other variables in an Afro-Brazilian community, the Quilombos. This group of people is culturally and genetically homogeneous. But the diversity of the lifestyles of individual populations, which are scattered throughout Brazil, offers an opportunity to investigate the changes to human sleep over the past 150 years of industrialization: some live on farms with no electricity; others live and work in modern cities.

A human sleep project would need around US$30 million of funding from governments and national and international granting agencies. Biotechnology companies may also want to invest in return for using the project's results to guide the mass production of simple sleep-tracking devices. Such devices will be valuable to sleep researchers, to physicians who want to diagnose and treat sleep problems, and perhaps even to pilots or business executives who want to optimize their sleep patterns while travelling, as well as to people who simply want to sleep better.

The project could also lead people to adopt more individualized schedules, which some fear would disrupt the synchronization of societies. But if work schedules were adapted to suit the biological clocks of most of the population, the benefits to society would outweigh a relatively small disruption. The MCTQ indicates that in 44% of the population assessed, the circadian timing of people differs by only 30 minutes, and that in 77% of the population, the timing falls within a three-hour range.

I am convinced that a human sleep project, and the changes in behaviour it would bring, could be one of the most cost-effective ways to improve health, performance and quality of life for millions for people. A preparatory meeting will take place this August in Munich, in conjunction with the congress of the European Biological Rhythms Society. ■

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