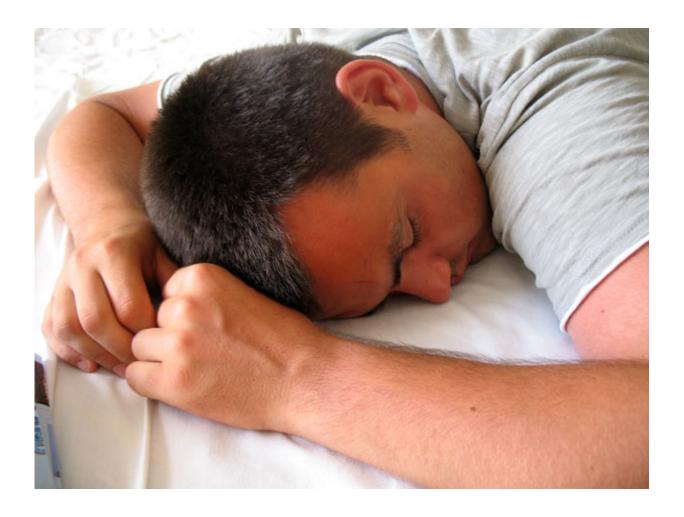# Smartphones uncover how the world sleeps

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Credit: Vera Kratochvil/public domain

A pioneering study of worldwide sleep patterns combines math modeling, mobile apps and big data to parse the roles society and biology each play in setting sleep schedules.

The study, led by University of Michigan mathematicians, used a free smartphone app that reduces jetlag to gather robust sleep data from thousands of people in 100 nations. The researchers examined how age, gender, amount of light and home country affect the amount of shut-eye people around the globe get, when they go to bed, and when they wake up.

Among their findings is that cultural pressures can override natural circadian rhythms, with the effects showing up most markedly at bedtime. While morning responsibilities like work, kids and school play a role in wake-time, the researchers say they're not the only factor. Population-level trends agree with what they would expect from current knowledge of the circadian clock.

"Across the board, it appears that society governs bedtime and one's internal clock governs wake time, and a later bedtime is linked to a loss of sleep," said Daniel Forger, who holds faculty positions in mathematics at the U-M College of Literature, Science, and the Arts, and in the U-M Medical School's Department of Computational Medicine and Bioinformatics. "At the same time, we found a strong wake-time effect from users' biological clocks—not just their alarm clocks. These findings help to quantify the tug-of-war between solar and social timekeeping."

When Forger talks about internal or biological clocks, he's referring to circadian rhythms—fluctuations in bodily functions and behaviors that are tied to the planet's 24-hour day. These rhythms are set by a grain-of-rice-sized cluster of 20,000 neurons behind the eyes. They're regulated by the amount of light, particularly sunlight, our eyes take in.

Circadian rhythms have long been thought to be the primary driver of sleep schedules, even since the advent of artificial light and 9-to-5 work schedules. The new research helps to quantify the role that society plays.

Here's how Forger and colleague Olivia Walch arrived at their findings. Several years ago, they released an app called Entrain that helps travelers adjust to new time zones. It recommends custom schedules of light and darkness. To use the app, you have to plug in your typical hours of sleep and light exposure, and are given the option of submitting your information anonymously to U-M.

The quality of the app's recommendations depended on the accuracy of the users' information, and the researchers say this motivated users to be particularly careful in reporting their lighting history and sleep habits.

With information from thousands of people in hand, they then analyzed it for patterns. Any correlations that bubbled up, they put to the test in what amounts to a circadian rhythm simulator. The simulator—a mathematical model—is based on the field's deep knowledge of how light affects the brain's suprachiasmatic nucleus (that's the cluster of neurons behind the eyes that regulates our internal clocks). With the model, the researchers could dial the sun up and down at will to see if the correlations still held in extreme conditions.

"In the real world, bedtime doesn't behave how it does in our model universe," Walch said. "What the model is missing is how society affects that."

The spread of national averages of sleep duration ranged from a minimum of around 7 hours, 24 minutes of sleep for residents of Singapore and Japan to a maximum of 8 hours, 12 minutes for those in the Netherlands. That's not a huge window, but the researchers say every half hour of sleep makes a big difference in terms of cognitive function and long-term health.

The findings, the researchers say, point to an important lever for the sleep-deprived—a set that the Centers for Disease Control and

Prevention is concerned about. A recent CDC study found that across the U.S., one in three adults aren't getting the recommended minimum of seven hours. Sleep deprivation, the CDC says, increases the risk of obesity, diabetes, high blood pressure, heart disease, stroke and stress.

The U-M researchers also found that:

- Middle-aged men get the least sleep, often getting less than the recommended 7 to 8 hours.
- Women schedule more sleep than men, about 30 minutes more on average. They go to bed a bit earlier and wake up later. This is most pronounced in ages between 30 and 60.
- People who spend some time in the sunlight each day tend to go to bed earlier and get more sleep than those who spend most of their time in indoor light.
- Habits converge as we age. Sleep schedules were more similar among the older-than-55 set than those younger than 30, which could be related to a narrowing window in which older individuals can fall and stay asleep.

Sleep is more important than a lot of people realize, the researchers say. Even if you get six hours a night, you're still building up a sleep debt, says Walch, doctoral student in the mathematics department and a co-author on the paper.

"It doesn't take that many days of not getting enough sleep before you're functionally drunk," she said. "Researchers have figured out that being overly tired can have that effect. And what's terrifying at the same time is that people think they're performing tasks way better than they are. Your performance drops off but your perception of your performance doesn't."

Aside from the findings themselves, the researchers say the work

demonstrates that mobile technology can be a reliable way to gather massive data sets at very low cost.

"This is a cool triumph of citizen science," Forger said.

More information: "A global quantification of 'normal' sleep schedules using smartphone data," *Science Advances*, advances.sciencemag.org/content/2/5/e1501705

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