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Mathematical models may help shed light on body clock disruptions

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Researchers are using mathematical models to better understand the effects of disruptions like daylight savings time, working night shifts, jet lag or even late-night phone scrolling on the body's circadian rhythms.

The University of Waterloo and the University of Oxford researchers have developed a new model to help scientists better understand the resilience of the brain's master clock: the cluster of neurons in the brain that coordinates the body's other internal rhythms. They also hope to suggest ways to help improve this resilience in individuals with weak or impaired circadian rhythms. The study, "Can the Clocks Tick Together Despite the Noise? Stochastic Simulations and Analysis," appears in the *SIAM Journal on Applied Dynamical Systems*.

Sustained disruptions to circadian rhythm have been linked to diabetes, memory loss, and many other disorders.

"Current society is experiencing a rapid increase in demand for work outside of traditional daylight hours," said Stéphanie Abo, a Ph.D. student in applied mathematics and the study's lead author. "This greatly disrupts how we are exposed to light, as well as other habits such as eating and sleeping patterns."

Humans' circadian rhythms, or internal clocks, are the roughly 24-hour cycles many body systems follow, usually alternating between wakefulness and rest. Scientists are still working to understand the cluster of neurons known as suprachiasmatic nucleus (SCN) or master clock.

Using mathematical modeling techniques and differential equations, the team of applied mathematics researchers modeled the SCN as a macroscopic, or big-picture, system comprised of a seemingly infinite number of neurons. They were especially interested in understanding the system's couplings—the connections between neurons in the SCN that allow it to achieve a shared rhythm.

Frequent and sustained disturbances to the body's circadian rhythms eliminated the shared rhythm, implying a weakening of the signals transmitted between SCN neurons.

Abo said they were surprised to find that "a small enough disruption can actually make the connections between neurons stronger."

"Mathematical models allow you to manipulate body systems with specificity that cannot be easily or ethically achieved in the body or a petri dish," Abo said. "This allows us to do research and develop good hypotheses at a lower cost."

More information: Stéphanie M.C. Abo et al, Can the Clocks Tick Together Despite the Noise? Stochastic Simulations and Analysis, *SIAM Journal on Applied Dynamical Systems* (2023). DOI: 10.1137/22M147788X

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