The mathematics behind a good night's sleep

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Why can't I fall asleep? Will this new medication keep me up all night? Can I sleep off this cold? Despite decades of research, answers to these basic questions about one of our most essential bodily functions remain exceptionally difficult to answer. In fact, researchers still don't fully understand why we even sleep at all. In an effort to better understand the sleep-wake cycle and how it can go awry, researchers at Rensselaer Polytechnic Institute are taking a different approach than the traditional brain scans and sleep studies. They are using mathematics.

Professor of Mathematics Mark Holmes and his graduate student Lisa Rogers are using math to develop a new computer model that can be easily manipulated by other scientists and doctors to predict how different environmental, medical, or physical changes to a person's body will affect their sleep. Their model will also provide clues to the most basic dynamics of the sleep-wake cycle.

"We wanted to create a very interdisciplinary tool to understand the sleep-wake cycle," Holmes said. "We based the model on the best and most recent biological findings developed by neurobiologists on the various phases of the cycle and built our mathematical equations from that foundation. This has created a model that is both mathematically and biologically accurate and useful to a variety of scientists.

"This is also an important example of how applied mathematics can be used to solve real issues in science and medicine," Holmes continued.

To create the model, the researchers literally rolled up their sleeves and took to the laboratory before they put pencil to paper on the mathematical equations. Rogers spent last summer with neurobiologists at Harvard Medical School to learn about the biology of the brain. She investigated the role of specific neurotransmitters within the brain at various points in the sleep-wake cycle. The work taught the budding mathematician how to read EEG (electroencephalography) and EMG (electromyography) data on the brainwaves and muscle activity that occur during the sleep cycle. This biologic data would form the foundation of their mathematic calculations.

This research foundation allowed the team to develop a massive 11-equation model of the sleep-wake cycle. They are now working to input those differential equations into an easy-to-use graphic computer model for biologists and doctors to study.

"We have developed a model that can serve other researchers as a benchmark of the ideal, healthy sleep-wake cycle," Holmes said. "Scientists will be able to take this ideal model and predict how different disturbances such as caffeine or jet lag will impact that ideal cycle. This is a very non-invasive way to study the brain and sleep that will provide important clues on how to overcome these disturbances and allow patients to have better and more undisturbed sleep."

Rogers will continue her work on the program after receiving her doctoral degree in applied mathematics from Rensselaer this spring. Her work on the mathematics of the sleep-wake cycle has already garnered attention within the scientific community, earning her a postdoctoral research fellowship from the National Science Foundation (NSF). With the fellowship, Rogers will continue her work at New York University and begin to incorporate other aspects of the sleep-wake cycle in the model such as the impacts of circadian rhythms.