'Wristwatch' biosensor to track alcohol use

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The device looks like a runner's digital watch. Black, plastic and oversized, it dominates mathematician Gary Rosen's wrist. But what Rosen has strapped on is no simple timepiece. It's one of the very few prototypes of a computer designed to record, in minute detail and real time, its wearer's sobriety. Or drunkenness.

Rosen, professor and chair of mathematics, leads the USC portion of a federally funded effort to improve the wristwatch-like device, the so-called transdermal alcohol biosensor created by Giner, Inc. of Newton, Mass.

While the device can monitor whether someone has been drinking over days and weeks — substantially longer than tests of blood, breath or urine and much more sensitively than biochemical measures — some problems remain.

"As is, the device measures the alcohol content in sweat, but what we want to know is what's going on with alcohol levels in the blood," said Rosen. "What our group is trying to understand, mathematically, is how does what you see in sweat relate to what's in the blood?"

Quantifying that relationship is key to being able to compare alcohol levels measured by the device to blood alcohol concentration (BAC), the "gold standard" for law enforcement and research science, Rosen said.

To understand the relationship, Rosen's team has been working on a math-based computer model of how the body processes alcohol. Ultimately, the model will be used as part of a data analysis software system for the biosensor.

The USC team includes Rosen's colleagues Chunming Wang, professor of mathematics, and Miguel Dumett, assistant professor of mathematics, as well as doctoral students Ting Wang and Asher Shamam and a number of undergraduates, including alumnus Joseph Sabat, class of 2004. In a separate part of the project, Rosen's colleague Jack Feinberg, professor of physics, has looked into an alternative technology that could be used to detect alcohol in a future biosensor.

The USC work is part of a larger interdisciplinary project headed by psychiatrist Robert Swift of Brown University Medical School and supported by a grant from the National Institute of Alcohol Abuse and Alcoholism. Swift, a leading authority on alcohol addiction, abuse and treatment, said the project was initiated because of an urgent need for better ways to collect more reliable field data on drinking. Such a monitoring device also has great commercial potential, especially in the criminal justice arena.

"A more accurate monitor is key for relating alcohol use to pathology, and for the kind of population study that would ask, 'How much can pregnant women [safely] drink?'" Swift said. It's also important for studies comparing different alcohol treatments.

"If Gary's work is successful, and so far everything has been going well, he may be able to go back [to the data] and say 'this person consumed three standard doses of alcohol on this evening,' " said Linda Tempelman, a co-investigator on the project and director of biochemical research and development at Giner.

Building a Model

The biosensor project fits in well with Rosen's previous interdisciplinary work on the control of complex systems. Collaborating with engineers and other scientists, Rosen has studied system control in a number of different applications, including systems for the manufacture of semiconductors and for suppressing potentially damaging noise — like that produced by the opening of a car airbag in an accident — in products from the aerospace, automotive and computer industries.

The simplest example of system control theory, analogous to what Rosen studies, is the thermostat on a heater, which switches itself on or off depending on two parameters — the temperature the thermostat has been set to and measurement of the actual air temperature.

"Imagine designing a similar feedback system with 50 or even thousands of different parameters," Rosen said. "The complexity explodes."

And that's where Rosen comes in.

For Rosen, one of the central tasks in building a rigorous model of alcohol metabolism is to define the parameters — from sex, weight and age to the rate of diffusion of alcohol through the layers of skin. Based on biological data collected by Swift and others, the team has already incorporated more than two dozen parameters into the model.

Values for the parameters that appear in the model must be estimated from experimental data. This is similar to what must be done in numerical weather modeling, which requires that the values of hundreds of parameters be estimated.

“But even 25 can be computationally challenging,” said Rosen. From a mathematical perspective, the problem involves “visualizing a surface in a 25-dimensional space.”

Dealing with Complexity

Some of the parameters are difficult to define. For example, the huge variation in how individuals metabolize alcohol adds a major wrinkle to the problem. In the lab, Swift can calibrate the biosensor to an individual by giving the person a known amount of alcohol while they are wearing the device, and then using a Breathalyzer to determine the concentration of alcohol in the blood. The clinical data “gives you the parameters for one person,” Rosen said. But in order to use the monitor in practical applications in the field, researchers need to calibrate the device not simply to a specific individual but to general group parameters.

In spite of these challenges, the team has made substantial headway in the two years since the project began. “We’ve got a forward model that mathematically describes alcohol’s movement through the body — from ingestion to the blood to the sweat,” Rosen said. The USC team, which has presented their results at a number of professional meetings, has also developed an algorithm, which they continue to improve, that can be used to calibrate the device for groups of people.

The trick now, he said, is to invert the model, go backwards — something that can be done only by calling on the powers of mathematics. That will allow the team to start with measurements of alcohol in sweat, as detected by the wrist monitor, and calculate backwards to figure out the blood alcohol level.

“The nature of mathematics is that [doing an inversion] is going to amplify any error, however small. So we have to make sure the model doesn’t do that,” Rosen said. “Conceivably, as you calculate backwards, the noise value would become large enough to hide the signal, and that would be a problem.”

This is what happens in math in real-world problems, noted Rose, a member of the Center for Applied Mathematics (CAMS) in the College. “The kind of math that theoreticians deal with is exact. But in applied math, you have to deal with real data.”

Working on interdisciplinary projects has shifted the way Rosen approaches research. “In the old days, I was only interested in doing pure math. Now, I look for problem-driven work — math, but math that will help other scientists do something useful,” he said.

Source: USC College

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