What a rat can tell us about touch

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In her search to understand one of the most basic human senses – touch – Mitra Hartmann turns to what is becoming one of the best studied model systems in neuroscience: the whiskers of a rat. In her research, Hartmann, associate professor of biomedical engineering and mechanical engineering in the McCormick School of Engineering and Applied Science at Northwestern University, uses the rat whisker system as a model to understand how the brain seamlessly integrates the sense of touch with movement.

Hartmann will discuss her research in a daylong seminar "Body and Machine" at the American Association for the Advancement of Science (AAAS) annual meeting in Washington, D.C. Her presentation is part of the session, "Linking Mechanics, Robotics, and Neuroscience: Novel Insights from Novel Systems," to be held Friday, Feb. 18.

Rats are nocturnal, burrowing animals that move their whiskers rhythmically to explore the environment by touch. Using only tactile information from its whiskers, a rat can determine all of an object's spatial properties, including size, shape, orientation and texture. Hartmann's research group is particularly interested in characterizing the mechanics of sensory behaviors, and how mechanics influences perception.

"The big question our laboratory is interested in is how do animals, including humans, actively move their sensors through the environment, and somehow turn that sensory data into a stable perception of the world," Hartmann says.

Hundreds of papers are published each year that use the rat whisker system as a model to understand neural processing. But there is a big missing piece that prevents a full understanding the neural signals recorded in these studies: no one knows how to represent the "touch" of a whisker in terms of mechanical variables. "We don't understand touch nearly as well as other senses," Hartmann says. "We know that visual and auditory stimuli can be quantified by the intensity and frequency of light and sound, but we don't fully understand the mechanics that generate our sense of touch."

In order to gain a better understanding of how the rat uses its whiskers to sense its world, Hartmann's group works to both better understand the rat's behavior and to create models of the system that enable the creation of artificial whisker arrays.

To determine how a rat can sense the shape of an object, Hartmann's team developed a light sheet to monitor the precise locations of the whiskers as they came in contact with the object. Using high-speed video, the team can also analyze how the rat moves its head to explore different shapes.

More recently, Hartmann's team has created a model that establishes the full structure of the rat head and whisker array. This means that the team can now simulate the rat "whisking " into different objects, and predict the full range of inputs into the whisker system as a rat encounters an object. The simulations can then be compared against real behavior, as monitored with the light sheet.

These advances will provide insight into the sense of touch, but may also enable new technologies that could make use of the whisker system. For example, Hartmann's lab created arrays of robotic whiskers that can, in several respects, mimic the capabilities of mammalian whiskers. The researchers demonstrated that these arrays can sense information about both object shape and fluid flow.

"We show that the bending moment, or torque, at the whisker base can be used to generate three-dimensional spatial representations of the environment," Hartmann says. "We used this principle to make arrays of robotic whiskers that in replicate much of the basic mechanics of rat whiskers." The technology, she said, could be used to extract the three-dimensional features of almost any solid object.

Hartmann envisions that a better understanding of the whisker system may be useful for engineering applications in which vision is limited. But most importantly, a better understanding of the rat whisker system could translate into a better understanding of ourselves.

"Although whiskers and hands are very different, the basic neural pathways that process tactile information are in many respects similar across mammals," Hartmann says. "A better understanding of neural processing in the whisker system may provide insights into how our own brains process information."

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