Rat whiskers shed light on how neurons communicate touch

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When reaching into a pocket or purse, it is easy to use the sense of touch to distinguish keys from loose change. Our brains seamlessly integrate the tactile, sensory cues from our fingers with hand movements to perceive the different objects.

This process of "sensorimotor integration" is often severely disrupted in disorders such as stroke and neuropathy. Understanding these disorders ultimately depends on understanding the neural coding that underlies touch, a challenging problem to study in humans.

Because human and rodent brains process touch in similar ways, the rodent whisker system has been used to study the sense of touch since 1909. Rodents use their whiskers - essentially long, thick hairs - as touch sensors to explore their environment. While hundreds of papers are published each year that use the whisker system to study sensorimotor processing, crucial aspects of the information transfer from whiskers to the brain have remained unresolved.

"Specialized cells convert touch information from the whiskers into electrical signals that the brain can interpret," said Mitra Hartmann, associate professor of biomedical and mechanical engineering in Northwestern University's McCormick School of Engineering. "But exactly what information is represented electrically has been unclear."

Now Hartmann and her team are bringing the world closer to an answer. In a recent study, they discovered that whisker sensory neurons encode information about the forces and torques at the whisker's base. This finding could resolve fundamental questions about how touch is represented and processed by neurons in both the rat and the human brain.

The research, published last month in the journal *eLife*, brought together an interdisciplinary team that spanned five Northwestern departments. The study had two co-first authors: Nicholas E. Bush, a PhD student in the Interdepartmental Neuroscience Program (NUIN), and Christopher L. Schroeder, a recent PhD graduate in biomedical engineering. Co-senior author Sara A. Solla, professor of physiology in the Feinberg School of Medicine and of physics and astronomy in the Weinberg College of Arts and Sciences, guided the mathematical analysis of neural responses.

"If you want to study how the brain processes sensory information, rat whiskers are a very accessible system neurologically," Bush said. "We were able to look at the system in a much more detailed and rigorous manner than has been done in the past with the help of cutting edge tools and models."

The study's goal was to resolve whether touch-sensitive neurons in the whisker system encode kinematic or mechanical information, a distinction that has historically posed a major challenge. When a whisker brushes against an object, it moves in a particular direction, by a particular amount, and at a particular speed. Together, these features are known as kinematic properties. Mechanical properties, on the other hand, are related to the contact forces and torques at the whisker base.

"It has been challenging to characterize neural responses because kinematics and mechanics are so tightly coupled," Hartmann said. "This coupling is especially strong when whisker motion is small and stimulation is delivered near the whisker base—exactly the type of stimulation that has typically been used to date."

Hartmann's team developed a novel whisker stimulation paradigm to decouple kinematic and mechanical variables. Solla then guided mathematical modeling that exploited the decoupling to assess the neural encoding of tactile information. The team found that the electrical activity of whisker touch neurons was more accurately predicted by mechanics, rather than kinematics.

"This has been a long-standing discussion in the field," Solla said. "We hope this becomes the unified, accepted view of how touch is processed. Sensing mechanisms share many common features, so what we learn about one sense illuminates our understanding of how all senses work."

More information: Nicholas E Bush et al, Decoupling kinematics and mechanics reveals coding properties of trigeminal ganglion neurons in the rat vibrissal system, *eLife* (2016). DOI: 10.7554/eLife.13969