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Turning Sensation into Perception

Perceiving a simple touch may depend as much on memory, attention, and expectation as on the stimulus itself, according to new research from Howard Hughes Medical Institute (HHMI) international research scholar Ranulfo Romo and his colleague Victor de Lafuente. The scientists found that monkeys' perceptions of touch match brain activity in the frontal lobe, an area that assimilates many types of neural information.

Romo and de Lafuente, both of the Institute of Cellular Physiology at the National Autonomous University of Mexico, report their results in the December 2005 issue of the journal *Nature Neuroscience*, published early online on November 6, 2005.

One of neuroscience's most difficult questions concerns how the brain converts simple sensory inputs to complete perceptual experiences. Many neuroscientists assume that perceptions arise in the sensory cortices, which are the first areas of the brain to process information coming in from sense organs, Romo said. Some recent research, however, has hinted that activity in other parts of the brain may also contribute to sensory perception.

"I think that we do not feel with our sensory cortices."

- **Ranulfo Romo**

When it comes to the sense of touch, a stimulus at the skin triggers an impulse that travels first to an area at the top of the brain called the primary somatosensory cortex (S1). The information then moves to other parts of the brain, where it can contribute to memory, decision-making, and motor outputs.

To explore what regions of the brain contribute to sensory perception, Romo and de Lafuente analyzed neural activity associated with the sense of touch in macaque monkeys. The researchers touched the monkeys' fingertips with a painless stimulus that sometimes vibrated and sometimes did not. The intensity of the vibration varied, so sometimes it was easy for the monkeys to tell that the vibration was on, while other times the vibrations were so weak

that the monkeys couldn't always detect them. The monkeys were trained to indicate to the researchers whether the stimulus was vibrating or still, and they were rewarded with treats when they were correct.

The scientists found that activity in S1 neurons, where touch information first arrives, correlated directly with the strength of the stimulus; when the strength of the vibrations was more intense, the S1 neurons' fired more rapidly. However, these neurons' activity did not correlate with the monkeys' behavioral responses. Their firing rates were directly associated with the stimulus intensity, whether the monkeys consciously felt and responded to the stimulus or not.

Romo and de Lafuente also recorded neuronal activity in the medial premotor cortex (MPC), a region of the brain's frontal lobe that is known to be involved in making decisions about sensory information. Activity here did mirror the monkeys' subjective responses to the vibrating probe. MPC neurons responded in an all-or-none manner; they fired when the monkey thought the vibrations were there—even if they weren't—and they didn't fire when the monkey thought the vibrations were absent—even if they were actually occurring.

These results indicate that the monkeys' perceptions arise not from brain activity in the sensory cortex itself, but from activity in the frontal lobe MPC, Romo said.

The MPC “is very interesting,” Romo said. “Apparently, it's able to pull information from memory and from the sensory areas, and also link this activity to the motor apparatus” so that the monkeys can physically indicate what they think is happening.

To clinch the MPC's association with the monkeys' perceptions, the researchers used an electrode to apply weak electrical stimulation to MPC neurons. They found that stimulating these neurons made the monkeys more likely to respond that they perceived a vibration, whether the vibrating stimulus was occurring or not.

Romo and de Lafuente also found that MPC neurons began to fire before the stimulus even touched the monkeys' fingertips. Romo believes this is because the monkey is expecting the stimulus and the neurons fire in anticipation.

“I think that we do not feel with our sensory cortices,” Romo said. Perceptions instead arise in higher-order brain areas from a combination of sensation, attention, and expectation. “The sensory representation is [just] to confirm something that you have already thought.”