A study in adaptability: Why do we change our beliefs?

October 9 2012

(Medical Xpress)—The human brain likes to make predictions about how the world works. Imagine, for example, that you move to a new town. At first, you don't know where to go for dinner. But after weeks of trying different restaurants, you pick a favorite, a little Thai place that makes the best green curry. Several months later, however, you notice the curry isn't as spicy and the vegetables seem undercooked. At first you give your favorite place the benefit of the doubt. But after a few more so-so dinners, you suddenly realize that something must have changed—perhaps the owner hired a new chef—and your notion that this is the best place around is no longer valid. So you begin searching for a new favorite restaurant.

Neuroscientists have long been interested in this adaptability, particularly in the moment when an individual discards an old belief and begins to formulate a new one. "You go from being confident in your model of the world to being uncertain and then abandoning the model altogether," says Alla Karpova, a group leader at the Howard Hughes Medical Institute's Janelia Farm Research Campus. She and her colleagues wondered what goes on in the brain when this happens. In rats, they found that the rejection of an old belief correlates with abrupt changes in activity in the medial prefrontal cortex, a brain region involved in cognitive functions such as reward anticipation and decision-making. The team's research is published in the October 5, 2012, issue of *Science*.

To examine this moment of transition in rats, the researchers designed a

experiment that allowed them to differentiate between changes in brain activity due to a change in sensory input from those due to a change in the animal's internal state—its belief. The key, Karpova says, was to use a task with stochastic reward, so that if the animal completes the task once without receiving a reward, that is not enough to conclude that the reward probability has changed. Instead, the results of multiple trials must be combined to reach that conclusion.

To set up the experiment, they placed a wall with three holes just big enough for a rat nose at one end of a cage. When the rats poked their noses in the middle hole, one of two tones sounded and handles appeared above the left and right holes. The rats quickly figured out that when they heard the first tone, they should pull the left handle to receive a tasty morsel of food. When they heard the second tone, they should pull the right handle. "When animals enter a novel environment, they just try different things out and can learn pretty complicated sequences of actions to get rewards," Karpova says. Pulling the wrong handle, they discovered, meant no treat and a time out.

But not every handle pull resulted in a treat. What's more, the handles weren't equal. Pulling the right lever rarely resulted in a treat. Pulling the left one often did. When the rats realized this, they stopped pulling the right handle altogether. If the tone associated with the right handle sounded, they simply nuzzled the middle hole to reset the experiment. The rat became "convinced that the left side was much better and confidently rejected right-side trials," Karpova says.

After a certain number of trials, however, the researchers mixed things up. They turned the tables so that the right handle often resulted in a reward while the left rarely did. At first the rats kept pressing the lever that used be more likely to give a reward. But after a while, they started to explore both sides, having realized that something was amiss. "What suddenly happens is they go into this mode where they explore both

options," Karpova says. Over time the rats began to favor the now–better option.

Karpova and her colleagues wanted to examine what happens inside the rat's brain at the moment of uncertainty. So they used electrodes to record the activity of neurons in the medial prefrontal cortex. "If this area is involved in encoding a model, then at the moment when you decide to discard your old model, things should abruptly change," she says.

Since the underlying change in confidence was the only thing that changed abruptly at such a moment in their experiment, a simultaneous abrupt change in activity in the brain could -be attributed to the rat's decision to abandon its old belief. And that's exactly what the researchers observed. When the rats seemed certain which handle they should pull, activity in the medial prefrontal cortex was relatively stable. But during the crucial moment of the onset of uncertainty, when the rat reverted to pulling both handles, "the activity abruptly and markedly changed and then remained more variable for the duration of the period when the animal sampled both options," Karpova says. "It's as if those neurons were the ones searching for the animal's new model."

The results suggest that the researchers have found the circuitry monitoring and possibly building a cognitive world—at least in rats—but they don't provide definitive proof. The ideal next experiment, Karpova says, would involve perturbing the circuitry to create a similar change in brain activity. If the researchers could show that the change makes the rats more uncertain and willing to explore, that would provide stronger evidence. Karpova also hopes to identify the trigger that sparks these changes in activity. She and her colleagues suspect it might be the neurotransmitter norepinephrine. If they're right, they can use it to manipulate the activity in the medial prefrontal cortex in just the right way to determine causality.

The research provides neuroscientists with a better understanding of the brain's capabilities, and Karpova speculates it may also help explain some neurological disorders. For example, people who have obsessive-compulsive disorder (OCD) show altered activity in the same region the researchers examined in the rats. "It's not entirely unreasonable to think that part of the issue, at least in some forms [of OCD], is an inability to get rid of your beliefs," Karpova says. "If you believe your hands are dirty, you'll keep washing them and no evidence will be sufficient to let you discard that belief."

More information:
www.hhmi.org/research/groupleaders/karpova.html

Provided by Howard Hughes Medical Institute