

# Monkeys found to wonder what might have been

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(PhysOrg.com) -- Monkeys playing a game similar to "Let's Make A Deal" have revealed that their brains register missed opportunities and learn from their mistakes.

"This is the first evidence that [monkeys](#), like people, have 'would-have, could-have, should-have' thoughts," said Ben Hayden, a researcher at the Duke University Medical Center and lead author of the study published in the journal *Science*.

The researchers watched individual neurons in a region of the brain called the [anterior cingulate cortex](#) (ACC) that monitors the consequences of actions and mediates resulting changes in behavior. The monkeys were making choices that resulted in different amounts of juice as a reward.

Their task was like the TV show "Let's Make a Deal" with the experimenters offering monkeys choices from an array of hidden rewards. During each trial, the monkeys chose from one of eight identical white squares arranged in a circle. A color beneath the white square was revealed and the monkey received the corresponding reward.

Over many weeks, the monkeys were trained to associate a high-value reward with the color green and the low-value rewards with other colors. After receiving a reward, the monkey was also shown the prizes he missed.

What the researchers saw was that neurons in the ACC responded in proportion to the reward -- a greater reward caused a higher response. They also found that these same neurons responded when monkeys saw what they missed. Most of these ACC neurons responded the same way to a real or imagined reward.

To measure how these responses might help the monkey to learn, the researchers kept the high reward in the same position 60 percent of the time, or moved it one position clockwise, so that a monkey could possibly notice and adapt to that pattern. The monkeys chose targets next to potential high-value targets more often than those next to low-value targets, (37.7 percent to 16.7 percent), which suggested that they understood the relationship between the high value target on the current trial and its likely location on the next trial. The monkeys learned the pattern and chose the high value more often than by a chance.

"It is significant to learn that the neurons have a dual role, because the monkey can only adapt his behavior when he gets information on both of those events, real and missed," said Michael Platt, Duke professor of neurobiology and evolutionary anthropology and senior author of the study.

People are much more likely to gamble if they see they could have won big by gambling in the past. Thus the researchers hypothesized that the monkeys would also select the target if it had offered a large reward on the previous trial and the monkey had missed it, and indeed, they observed this pattern. The effect may have reflected an increased willingness to switch to a new target, because the likelihood of switching increased with larger missed rewards, they noted.

"This was not merely a function of the high-value targets holding a positive association for the monkey," Platt said.

The monkeys' ACC neurons signaled missed [reward](#) information, and used a coding scheme in the [brain](#) that was similar to the coding used to signal real outcomes, Platt said. The researchers suspect that these [neurons](#) actually helped the monkeys to make better choices in the future.

Source: Duke University Medical Center ([news](#) : [web](#))

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