When making decisions, monkeys use different brain areas to weigh value and availability

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There are many calculations at play in our minds when we make a decision, whether we are aware of them or not. Seventeenth-century

mathematician Blaise Pascal first introduced the idea of expected value, which is reached by multiplying the value of something (how much it's wanted or needed) with the probability that we might be able to obtain it. Now some very 21st century research is showing for the first time in monkeys which parts of the brain are involved in the two-pronged decision-making process that determines this expected value. The study appears August 30 in *Neuron*.

"For a long time we thought that representations of value and probability were being evaluated in the same, single part of the brain," says Peter Rudebeck, an assistant professor of neuroscience and psychiatry at the Icahn School of Medicine at Mount Sinai and the lead author of the new study. "What's exciting here is that we're showing that it's being done in two different parts of the brain, which are separate both functionally and anatomically."

The researchers focused on two areas of the brain, the orbital frontal cortex (OFC) and the ventrolateral prefrontal cortex (VLPFC). Studies of people who have had their OFCs damaged due to injury or disease have indicated that injuries to that region of the brain resulted in impaired decision-making abilities. "But when we tried to duplicate this effect experimentally in monkeys by creating lesions in their OFCs, we didn't see the same result," Rudebeck explains.

Further examination revealed that the difference came from how much of the brain was damaged. "When surgeons remove a tumor from the OFC, they remove not only the gray matter, the cortex of the brain, but will also inadvertently affect the white matter, which carries the connections between different parts of the brain," he says. "We knew the VLPFC sits right next to the OFC, so we decided to look at that as well."

Two sets of experiments were devised: the first looked at how the monkeys weighed probability when making decisions, and the second

looked at how they weighed value.

In the first set, monkeys played a sort of slot machine game, where they were shown images on a touch screen and had to determine which image was most likely to get them a reward—a banana-flavored pellet. The researchers periodically changed the probability, but the control monkeys were able to adjust their choices accordingly. Animals with OFC and VLPFC lesions were then given the same task: those with OFC lesions performed the same as the control animals, whereas the monkeys with VLPFC lesions lost the ability to track probability.

In the second set of experiments, the monkeys had a choice of two rewards when they played a game—peanuts or M&Ms. These rewards were hidden under objects that the monkeys had previously learned predicted either of the two rewards. Because monkeys generally like peanuts and M&Ms equally, they turn over objects overlying peanuts and M&Ms at the same rate. But to shift the value toward one treat over the other, in favor of the peanuts, the monkeys were given M&Ms immediately before the experiment. Having already had their fill of M&Ms, the control monkeys favored the objects overlying peanuts, as expected. Those with VLPFC lesions had the same inclination. The monkeys with OFC lesions, however, showed a preference for the objects overlying M&Ms.

"We've known for a long time that these two parts of the brain are highly interconnected," Rudebeck says. "They both send connections to another area of the frontal lobe, the ventromedial prefrontal cortex (VMPFC). Imaging studies with fMRI suggested that the VMPFC may be where choices ultimately get made."

The investigators tested this in a separate set of experiments, where they induced lesions in that area. "The animals were able to make a decision based on probability or value alone, but when they had to combine the

two, they were less able to do that," Rudebeck concludes. "This lines up with what we've seen in humans, because we know that people who have brain damage in that area also have trouble with making decisions."

More information: Specialized representations of value in orbital and ventrolateral prefrontal cortex: desirability versus availability of outcomes," *Neuron* (2017). DOI: 10.1016/j.neuron.2017.07.042

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