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Press Release

Patience pays off

Researchers decode the neuronal basis of decision-making processes and can thus predict actions

Göttingen, March 6, 2024. In a new study, neuroscientists show how decision-making processes are controlled in the primate brain during foraging. The team, including a researcher from the German Primate Center (DPZ) – Leibniz Institute for Primate Research in Göttingen, trained two rhesus monkeys to search for food in an experimental room. The animals were able to move freely and receive food pellets from two food boxes by pressing a button. In the course of the experiment, the monkeys learned that the amount of pellets dispensed from the boxes increased the longer they waited until the next button was pressed. If they were not rewarded with pellets after pressing the button, the monkeys waited longer the next time or switched to the other box. During the experiment, the researchers measured the neuronal activity in the front part of the brains of the two monkeys and decomposed it with the help of a mathematical model. By decoding monkeys' reward expectations from the neural activity, they were able to predict how long the rhesus monkeys were willing to wait for a higher reward and when they decided to choose another option. The results advance our understanding of self-paced actions, eventually contributing to a better understanding of neurological diseases such as Parkinson's (Nature Neuroscience).

Imagine a fisherman on a boat casting fish traps into a murky lake. To be successful, he has to check the traps regularly. But when is the best time to do this? If he checks the traps too often, it is unnecessary work and he scares the fish away. If he checks too late, he has a better chance, but may be wasting time. It is also tiring to paddle from one trap to another to check them one after the other, so the fisherman has to keep deciding whether and when it is worthwhile.

For decades, neuroscientists have been trying to understand how we manage to make the best possible decisions. Due to technical limitations, researchers have so far had to rely on experiments in which monkeys perform tasks on computer screens while the activity of their brain cells is measured. The animals are trained to sit still in a chair and are therefore restricted in their natural freedom of movement. Since it is now possible to wirelessly record the activity of several individual nerve cells, decision-making in scenarios with natural movement sequences can be investigated.

For the study, a team of researchers from Germany and the USA trained two rhesus monkeys to explore an experimental room with two button-controlled food boxes. Each time the monkeys pressed a button on one of the boxes, they had the chance to receive food pellets. The two boxes were set in such a way that the time intervals between the individual food dispenses became longer and longer during an experimental run. The longer the monkeys waited until they pressed the button again, the more pellets they received.

"When we started the experiment, we expected that our monkeys would simply choose the box based on how successful they had been with that box before," explains first author Neda Shahidi, now a junior research group leader at the Collaborative Research Center 1528 at the University of Göttingen and the German Primate Center in Göttingen. “After a while, however, they had learned to pay attention to the time since the last keystroke and also to their previous success at a box. If they had waited a while but not received any pellets, they waited even longer before pressing the next time. However, if they were not rewarded too many times in a row after pressing the button, they moved to the other box. They had apparently decided that this food box was not worth the wait and it was better to look elsewhere.”

To analyze the underlying neuronal processes, the researchers wirelessly recorded the activity of 96 neurons in the prefrontal cortex. This brain area is involved in the control of goal-directed behavior and is activated in many aspects of the foraging task, for example in the evaluation of options, the expectation of a reward, the preparation of actions, and the perception of the outcome.

“However, characterizing the activity patterns of individual neurons does not always reveal the whole story when we study complex decision-making processes,” Shahidi explains. “Complex behaviors consist of different components that are sometimes processed simultaneously in the same brain area.” To separate these components, the researchers developed a mathematical model that first identified components of neural activity, mainly consist of groups of neurons that were more strongly active when the animals waited longer before pressing a button or when the button has been more rewarding in last few presses. Since the animals cannot know in advance whether a button press will be rewarded, the researchers assume that these neurons represent the animals' subjective expectations.

The researchers also tested whether the neuronal activity could be used to predict when the animals would press the button and whether they would decide to switch between the boxes. “We were surprised at how well our model could predict what the monkeys would do in the next few seconds,” says Shahidi. “Our results show not only how the development of wireless recording technologies can improve our understanding of brain mechanisms in natural movement scenarios, but also how advances in data science are transforming neuroscience by extracting the computational components of the brain from the collective activity of neurons. We hope that in the long term, such advances will help to better understand abnormalities in cognitive processes such as self-pacing in Parkinson's or self-initiating actions in apathy” says Shahidi.

Original publication

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The German Primate Center GmbH (DPZ) – Leibniz Institute for Primate Research conducts biological and biomedical research on and with primates in the fields of infection research, neuroscience and primate biology. The DPZ also maintains four field stations in the tropics and is a reference and service center for all aspects of primate research. The DPZ is one of the 96 research and infrastructure facilities of the Leibniz Association.

Images with captions

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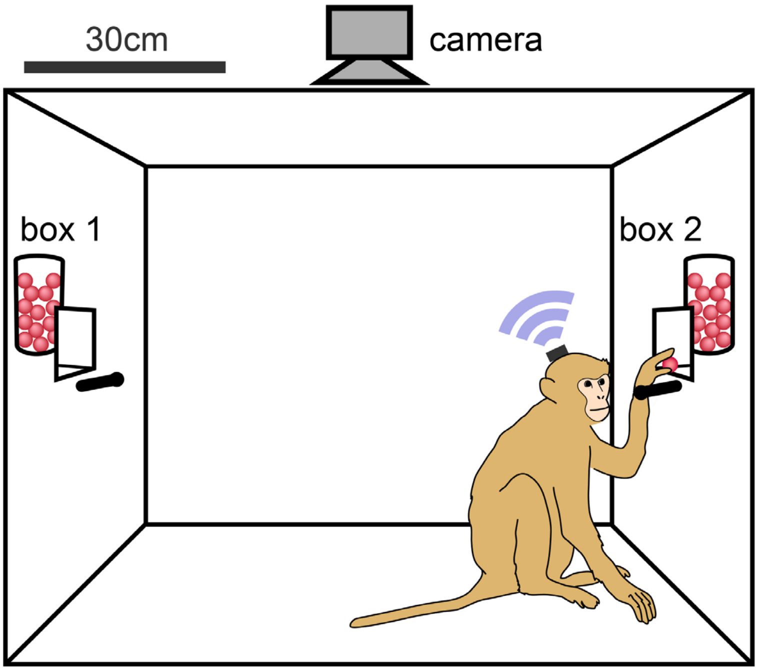

A rhesus monkey retrieves food pellets from a food box in an experimental room. Illustration: Neda Shahidi, Xaq Pitkow


Rhesus macaques in the animal husbandry at the German Primate Center. Photo: Magrit Hampe


A rhesus macaque in the animal husbandry at the German Primate Center reaching out for the snow, a natural action similar to the action of the monkeys in the experiment reaching out for the food pellets. Photo: Karin Tilch


Dr. Neda Shahidi is junior research group leader at the Collaborative Research Center 1528 at the University of Göttingen and the German Primate Center in Göttingen. Photo: Karin Tilch