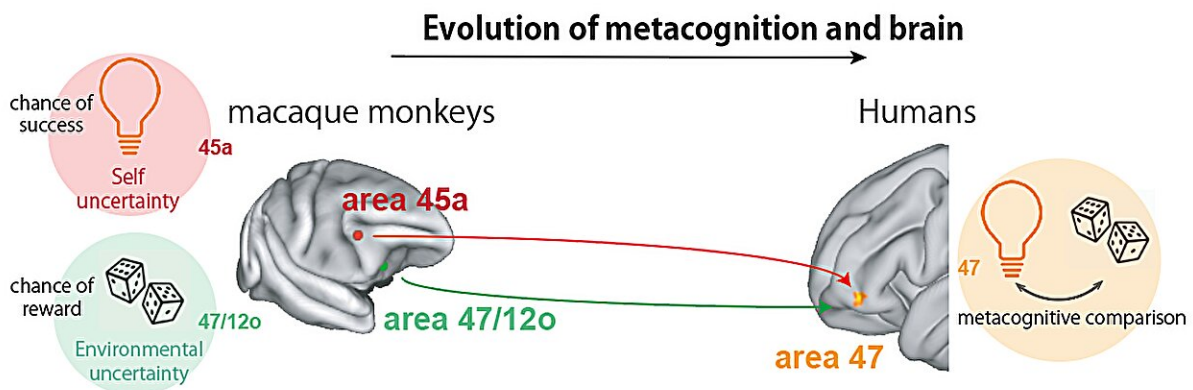


# Macaques plan ahead, offering clues to origins of human foresight

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The evolution of metacognitive abilities for future imagination and planning. Credit: Kentaro Miyamoto (2026).

When humans are planning their future actions and decisions, they typically imagine situations or issues they could encounter and predict how they would respond in these imagined scenarios. This imaginative process is highly advantageous, as it allows humans to prepare for specific situations without having to physically act out different scenarios in advance.

Imagining our own responses in future scenarios is rooted in metacognition, the ability to monitor, evaluate and predict one's own mental processes and actions. Past studies suggest that this ability is

more advanced in humans than in other primates, such as monkeys and apes.

Researchers at the University of Oxford and RIKEN Center for Brain Science in Japan set out to further explore how macaque monkeys plan their future decisions and actions. Their findings, [published in \*Nature Human Behavior\*](#), suggest macaques also simulate future decisions in their minds, identifying brain regions that could have evolved to enable the more advanced metacognition observed in humans.

"For example, when planning how to travel to a theater in an unfamiliar town, we need to consider probabilities, or degrees of certainty, that arise from both ourselves and the environment," Kentaro Miyamoto, first author of the paper, told Phys.org.

"If we drive, we need to estimate whether we can accurately choose the best route and arrive at the venue within the limited time available; this is self-derived certainty. If we take a bus, we need to estimate whether a bus that is often delayed is likely to arrive on time; this is environment-derived certainty. To arrive in time for the start of the performance with greater certainty, we must accurately estimate and compare these two forms of certainty and choose the appropriate means of transport."

## **Assessing how monkeys plan future decisions**

While conducting earlier studies involving human participants, Miyamoto and his colleagues identified a specific brain area that appears to be involved in the monitoring and evaluation of one's own thoughts about the future, also known as prospective metacognition. This is area 47 in the anterior lateral prefrontal cortex, a small section of the brain that was implicated in high-level mental capabilities, as well as the processing of memories and emotions.

"Area 47 is evolutionarily novel, and monkeys do not possess an anatomically corresponding brain region," said Miyamoto. "We therefore sought to uncover the evolutionary origins of prospective metacognition by examining whether monkeys, which lack area 47, are capable of imagining future states, and, if they are, how the neural mechanisms underlying this ability differ from those in humans."

To shed light on how monkeys plan their future actions and decisions, the researchers developed a new task specifically designed to assess the animals' prospective metacognition. This task required the animals to predict the probability that a future perceptual judgment they would make would yield a positive result.

"We then examined the evolutionary origins of the ability to imagine and plan for the future by measuring whole-brain activity in monkeys using functional MRI," explained Miyamoto.

"The future-planning situation we recreated required monkeys to complete a [random-dot motion](#) direction discrimination task. Specifically, we developed a prospective metacognition task in which monkeys compared two options and selected the one that was more likely to yield a reward."

The first option available to the monkeys would yield a reward only if they correctly judged the average direction of motion of the dots in front of them. As the dots moved randomly and telling them apart was difficult, this was a challenging task for the monkeys.

The second option they could pick was to complete the same task, but with the dots moving coherently, which made guessing the direction in which they were moving much easier. If they picked this option and made a correct judgment, however, they would not necessarily receive a reward. Whether they received a reward depended on the number of dots

they were seeing.

"When monkeys performed this task, they were able to compare the two probabilities and choose the optimal option, although their performance was not as high as that of humans," said Miyamoto. "These findings indicate that monkeys also possess, to some extent, the ability to imagine and plan for future states."

## **Tracing the evolutionary roots of human metacognition**

The findings gathered by the researchers suggest that macaque monkeys are also capable of imagining future scenarios and states, yet their metacognition-related processes appear to be less advanced than those of humans. The brain activity recordings collected by the team also offered some indication of what brain areas support prospective decision-making in monkeys.

"This study revealed why humans alone were able to develop an intelligence based on metacognition and future imagination, abilities that are much less developed in other animals, focusing on the efficiency of neural circuits centered on human area 47," said Miyamoto.

"We found that area 47, an evolutionarily novel region unique to humans, did not emerge as an entirely new brain area. Instead, it developed by incorporating the connectivity patterns of 45a and 47/12o, two evolutionarily older frontal regions that are also present in macaque monkeys, a closely related primate species."

Essentially, these findings suggest that area 47 in the human anterior lateral prefrontal cortex evolved from two areas in the monkey brain, known as 45a and 47/12o. When the researchers disrupted activity in

these two regions, they found that the monkeys' performance in the prospective decision-making task worsened.

"The network of human area 47 and the comprehensive network formed by two evolutionarily older prefrontal regions in macaques showed highly similar patterns," explained Miyamoto. "The only notable difference was that, in macaques, the connectivity with the anterior end of the brain, known as frontopolar area 10, was not as strong as in humans."

The team's efforts led to interesting new insights about the possible evolutionary origins of planning and metacognition, uncovering specific primate brain circuits that could have preceded area 47. Miyamoto and his colleagues are now planning to explore the circuits they identified in more depth, specifically focusing on area 10 and its connection to area 47 in the human brain.

"[Area 10](#) is known to be involved in exploring and evaluating novel possibilities," explained Miyamoto. "The connection between areas 47 and 10 may be related to human creative imagination, and we would like to continue investigating the evolutionary origins of what makes humans uniquely human by focusing on the relationship between these two regions."

**More information:** Kentaro Miyamoto et al, Brain activity, disruption and connectivity comparisons identify origins of human metacognition in other primates, *Nature Human Behaviour* (2026). [DOI: 10.1038/s41562-026-02473-w](https://doi.org/10.1038/s41562-026-02473-w).

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