

INSIGHTS



PERSPECTIVES

COGNITION

A raven's memories are for the future

Ravens can plan for expected future events based on past experiences

By **Markus Boeckle** and **Nicola S. Clayton**

The human brain stores memories of past events to guide decision-making about current and future events. Researchers long assumed that animals do not use memories in this way but rather exist in a constant stream of present needs, unable to plan for the future (1). Studies on nonhuman primates and cor-

vids challenge this view and show that some species can plan for the future at least as well as 4-year old children (2, 3). These results suggest that planning for the future is not uniquely human and evolved independently in distantly related species to address common problems (4). On page 202 of this issue, Kabadayi and Osvath (5) show that ravens anticipate the nature, time, and location of a future event based on previous experiences. The ravens' behavior is not merely prospective, anticipating future states (6); rather, they flexibly apply future planning in behaviors not typically seen in the wild.

Although some corvids make and use tools as part of their ecological predisposition, ravens are considered a non-tool-using corvid and are not known for trading items for food. However, they are known to cache food in nature and can use tools in experiments (see the photos). In their study, Kabadayi and Osvath test ravens' abilities to plan for future tool use and trading, rather than for food caching (a behavior that might be considered as an adaptive specialization to gather food in order to eat it at a future date). They thus provide compelling evidence against the argument

Department of Psychology, University of Cambridge, Cambridge, UK. Email: markus.boeckle@gmail.com; nsc22@cam.ac.uk

that future planning in corvids is a cognitive ability that can only be used during food caching or some other specific evolutionarily selected adaptation. The study provides evidence that future planning can flexibly serve different behaviors not only in humans but also in nonhuman animals.

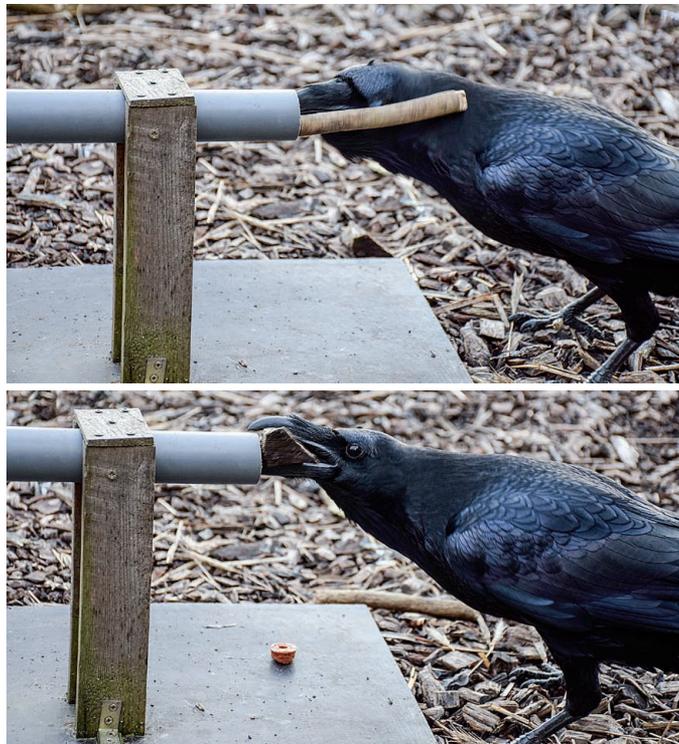
The authors presented five ravens with a choice of objects. Only one of these objects was a functional tool, which could be used to retrieve food from a puzzle box. The ravens chose correctly not only when they were offered the box but also when they had to store the tool and plan for the next day. In another experiment, the ravens were trained to exchange tokens for food. When the ravens knew that trading would only happen on the next day, they chose and stored these tokens as soon as they were offered to them. By manipulating tool choice, time, and trading opportunities, the authors controlled the value of the items at choice in relation to current as well as future interactions.

The results from the two experiments show that ravens take temporal distance between item choice and reward into account, exercise self-control, and make decisions for predicted futures rather than arbitrary ones. Thus, the birds opt for a more distant but higher gratification rather than an immediate but lower gratification and do so flexibly across behaviors.

What are the selective pressures that led to complex cognition and enabled future planning to evolve? The answer to this question may be best understood by investigating convergent evolution among distantly related species such as corvids and primates (4). In the 1990s, scientists discovered that mammals and birds share homologous forebrain structures, the neurobiological foundation for complex cognition (7). On the basis of this evidence, corvids and parrots were tested for cognitive abilities to explore the evolutionary development of cognition. There are two main hypotheses to explain the evolution of intelligence. According to the physical intelligence hypothesis, complex cognitive capabilities evolved according to the physical demands of the environment, such as the need to memorize location, time, and availability of food or how it can be extracted with tools. The social intelligence hypoth-

esis focuses on the social environment and the requirement to anticipate and manipulate the behavior of individuals from the same and other species. These mechanisms need not be mutually exclusive and might interact with phylogenetic heritage and developmental constraints (8).

The evolution of future planning in corvids may provide a good example of how these selective pressures are entwined. Corvids commonly cache perishable foods, which they only consume while still fresh. They must therefore understand the physical



Tool-using raven. In a separate experiment, a raven involved in the Kabadayi and Osvath study uses a stick to poke for food in a tube (first photo). She succeeds in pushing the stick into the hole (second photo), but handling the stick is tricky for her. She then invents a new way of solving the problem: She fills the tube with bark pieces (third photo) and thereafter pecks at the bark until the food falls out.

features of what they cached and when and where they did so. On the other hand, these birds are social; they can follow the gaze of others, remember where others have cached, and use their observational memory to pilfer those caches later. They also tactically deceive conspecifics who try to pilfer their food caches. Ravens cache food from ephemeral but temporarily and locally highly abundant carcasses. They use several tactics to protect their caches from being stolen by others as well as pilfer those that others have cached and anticipate their competitors' behavior (9). Corvids thus evolved complex cognitive abilities to deal with the social and physical environment but use their intelligence flexibly across situations.

Future planning in corvid food caching seems to be controlled by two different motivational systems: a feeding system and a caching system. One of us (N.S.C.) has studied these systems in an experiment in which individual corvids were fed with peanuts, powdered peanuts, and/or peanut-sized stones (10). Subsequently, the birds were presented with whole peanuts or stones, and their caching behavior was observed. Only a combination of motivational changes due to feeding as well as caching in the previous stage explained later caching of stones and peanuts. Food storing thus seems to be controlled by the relatively independent caching system interacting with the feeding system, jointly controlling the motivation to cache and plan for the future.

In humans, multiple motivations are at work when planning for the future. Kwan *et al.* have argued that there are two simultaneous but different cognitive processes involved in future planning in humans; one is directly related to the value of a future reward and the other to imagining the experience of a future reward (11). "Never go shopping when you are hungry" is a common advice, but overbuying might be reduced when specifically imagining oneself in the future. By dissociating current and future value, adequate performance in future planning increases (11). Ravens and other food-caching corvids might similarly use two potential routes for future planning—namely, orienting to the value of future reward and/or imagining themselves retrieving food caches in the future. For ravens just as for humans, memories are thus more for the future than for the past. ■

REFERENCES

1. T. Suddendorf, D. R. Addis, M. C. Corballis, *Philos. Trans. R. Soc. B* **364**, 1317 (2009).
2. J. Redshaw, T. Suddendorf, *Front. Psychol.* **4**, 404 (2013).
3. C. R. Raby, D. M. Alexis, A. Dickinson, N. S. Clayton, *Nature* **445**, 919 (2007).
4. N. J. Emery, N. S. Clayton, *Science* **306**, 1903 (2004).
5. C. Kabadayi, M. Osvath, *Science* **357**, 202 (2017).
6. N. S. Clayton, T. J. Bussey, A. Dickinson, *Nat. Rev. Neurosci.* **4**, 685 (2003).
7. E. Jarvis *et al.*, *Nature* **6**, 151 (2005).
8. K. E. Holekamp, *Tr. Cogn. Sci.* **11**, 65 (2007).
9. T. Bugnyar, S. A. Reber, C. Buckner, *Nat. Commun.* **7**, 10506 (2016).
10. N. S. Clayton, A. Dickinson, *Anim. Behav.* **57**, 435 (1999).
11. D. Kwan *et al.*, *Hippocampus* **22**, 1215 (2012).

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