Scrub-jays (left) store food for future consumption, and can remember what they have cached as well as where and, given its perishability, how long ago.

Memories of Tomorrow

BY NICOLA CLAYTON

Do animals remember the past and plan for the future? Studies of scrub-jays dispute the notion that humans are unique in the ability of their minds to travel in time.

Animals, it is claimed, are stuck in time and live in an extended present. They can't go back in time to reminisce about the past, nor can they think about the future and imagine various kinds of scenarios. However, the western scrub-jay, a member of the crow family, provides evidence against the belief that animals are stuck in the present.

Canadian neuroscientist Endel Tulving argues that episodic memory, which involves 'remembering' specific personal past experiences as opposed to acquiring and storing other kinds of 'factual' information, is universally familiar in human beings, or at least in healthy human beings. He also says that this ability is unique; that although other members of the animal kingdom can learn and benefit from experience and solve problems, make decisions and so on, they cannot travel back into the past in their own minds.

More recently, this viewpoint has received endorsement from Thomas Suddendorf and Michael Corballis at the universities of Queensland and Auckland. Their 'mental time travel hypothesis' states that this ability to travel in the mind's eye is unique to humans, and therefore constitutes a discontinuity between humans and other animals.

Why do many people assume that humans alone possess such an ability? Perhaps it is because the way in which we assess these things is language-based. There are three features to consider.

First, when we think about the past it is accompanied by a feeling of re-experiencing a specific past event – a bit like rewinding the videotape in your mind. Second, the thought is accompanied by an awareness that the event happened in the past. Third is a realisation that these are one's own memories – each person is the author of their own memories and has a unique perspective of a given event.

Given that animals cannot talk to us, assessing whether or not animals have a feeling of re-experiencing the past is difficult. It is by talking that humans assess this in one another. In trying to find a way to test these abilities in animals, I have tried to come up with a definition based on the behaviour of scrub-jays.

These birds display a behaviour called food caching. They hide all kinds of food, including invertebrates such as worms that degrade over time. These birds have very accurate, long-lasting memories about the locations of their caches, even if it is just based on one trial. (Remember that part of the definition of episodic memory is what happened, where and when, on the basis of a single past experience.)

Scrub-jays were a good candidate because they clearly remember where their food was cached. The question was whether they could also remember what types of food and, given its perishability, how long ago. (The birds only like worms when they are fresh.) We thought we could also look at the prospective component because the whole point of caching food now is for future consumption.

Scrub-jays will readily cache in captivity. We gave them food items that they love to eat and will readily hide, and 'caching trays' comprising an ice cube tray filled with sand or corn kibble. We make each one distinct using Lego Duplo bricks.

We conducted an experiment that focused on their memory of 'what, where and when' by using two kinds of foods: peanuts and worms. The worms degrades over time, while the peanuts stay fresh.

The idea behind the experiment is that the birds get to cache both peanuts and worms, and on some days they get their trays back 4 hours later, in which case they can recover the peanuts and the worms while both are still fresh. They have a slight preference for recovering the worms, but they eat the peanuts as well.

However, sometimes we left a 124-hour gap between caching and recovery – at the same time of day but 5 days later plus 4 hours, at which point the worms have degraded. The birds don't like them and will spit them out, and should instead recover their peanuts. What they are being trained in is how long the worms take to decay.

We contrasted this group of birds with a control group that also get to cache their peanuts and worms. However, for this group we replenish their caches so that the worms never decay.

What happened when we then suddenly gave both groups a test trial of memory in which we let them cache as normal but then remove all the food prior to recovery so they can't use olfactory cues to detect where the food is? If they can remember how long ago they cached their peanuts and worms, and where they hid them, then the birds in the 'degrade' group should preferentially search for the worms at the short interval of 4 hours. At the long interval, if they can remember that the worms will have degraded, they should search instead for peanuts. The 'replenish' group, however, should continue to search preferentially for worms at both intervals.

That indeed is what we observed. The 'replenish' group showed a consistent preference to search for worms, while the 'degrade' group did not. They searched for worms when there was a short gap between caching and recovery, and switched to peanuts if the worms would have degraded.

We argue that this demonstrates that the jays remember caching these worms and peanuts in terms of what happened, where and when.

Food perishability isn't the only consideration that scrub-jays need to make when caching. Scrub-jays are social creatures – they don't only hide their food but they also steal food from other birds'. As a result they go to great lengths to protect their caches from thievery. We capitalised on that to ask a second question about their episodic-like memory: could they keep track of who was watching?

A scrub–jay in the act of caching.

We set up an experiment involving two caching events. The caching bird hides worms in Tray A in the presence of a second bird (Observer A) in another cage. Observer A can have a good look but can't actually get to the caches.

In a separate event, the caching bird hides food in another tray (Tray B) in front of a different bird (Observer B). So, Observer A and Observer B each watch a different caching event.

What will our caching bird do at recovery? Will it bother to protect its caches?

On some days the caching bird is allowed to recover worms from the trays in front of Observer A; sometimes in front of Observer B; sometimes in front of a naïve individual that didn't witness either caching event; and sometimes in private. Does its behaviour differ in each case?

When the cacher recovers its caches with no other birds present it will eat about half of the food it has hidden and then re-cache the rest of it. If one of the observers is present it will protect the cache that the observer saw it hide (e.g. Tray A for Observer A). If a naïve bird is present it will essentially withhold information, re-caching very little of the food from either tray.

At this point we thought it would make sense for the cacher to re-hide food if it had been watched, and then come back in private so that the observer wouldn't know the new location. Indeed they put the items in new sites, and each item was moved just once to that new place.

However, when an observer is present they are just as likely to re-hide the food in the old cache sites that the observer has already seen. In fact each item is moved up to six times.

We think that this strategy is a bit like the Shell Game. It is a way of protecting caches because it is very difficult to know where the caches end up. Since the worms are not visible in the beak it is not even clear whether the bird has actually moved a worm from that site or not.

We think that this is a way of protecting their caches, making it much less certain that the observer will know the final destination of the cache. At any rate it shows that the birds do keep track of who was watching, and when.

The whole point of this re-caching is that it is geared towards the future. After all, there is no benefit in re-hiding food that is never going to be retrieved. So to what extent might caching actually engage planning behaviour?

Three things are needed to establish behavioural criteria for future planning in animals. First, the behaviour must be flexible and not simply a pre-programmed response.

According to the mental time travel hypothesis, the point about future versus current needs is that animals, it is claimed, "cannot anticipate future needs ... and are therefore bound to a present that is defined by their current motivational state". So the second thing was to check that the scrub-jays are actually caching for the future.

Third, the caching shouldn't just be because the anticipatory act has been reinforced. In other words, it is not just through learning.

We gave the scrub-jays a series of trials in which the worms were always degraded. We wanted to see whether they were sensitive to past recoveries and would learn to stop caching the worms. We found that they learned this quite rapidly.

To compare current and future motivational needs, we used the idea of specific satiety, or the dessert principle. This is the idea that, having eaten one type of food until you are satisfied, you don't want any more of that food but you will quite happily eat a new one. After all, most of us manage to find room for a dessert after a main course!

To explore this, scrub-jays were pre-fed one of two powdered foods (to prevent caching) for 3 hours, followed by a 10-minute period when both foods were available unpowdered for eating and caching. Thirty minutes later the jays received a second 3-hour feeding period on one of the powdered foods, followed by the opportunity to recover the food they had previously cached.

The jays were separated into two groups. The 'same' group was given the same food (e.g. powdered pine seeds) in both 3-hour feeding periods. When this group was allowed to recover their caches they were expected to preferentially eat and cache the food that had been unavailable to them (e.g. kibble) according to the dessert principle.

In contrast, the 'different' group was given one food (e.g. powdered pine seeds) in the first 3-hour feeding period and a different powdered food (e.g. kibble) in the second 3-hour feeding period. If they are stuck in time they should emulate the 'same' group and continue caching kibble, but if they can plan for the future they should continue eating kibble but start caching pine seeds so that they can eat something different in the next 3-hour feeding period.

As predicted, both groups preferentially ate kibble, but while the 'same' group continued to cache kibble, the 'different' group switched to caching pine seeds. This behaviour suggests they are doing this for a future need at the next recovery rather than their present need at caching.

Putting it all together in terms of forethought, we tested if the scrub-jays could plan for tomorrow's breakfast. In this experiment the birds had no opportunity to cache during training, so they could not learn about good and bad places to cache. They were given powdered food so that they couldn't cache it – there is nothing for them to grab hold of or fly off with.

During 6 days of training, the birds explored three little chambers and ate the powdered food. On some mornings they woke to find themselves in one of the outside chambers. Sometimes they ended up in one compartment and breakfast was served. On other days they woke up in the other compartment and had to go hungry.

On the evening of the sixth day we gave them items to cache. If you can plan for breakfast, then having learned that in one room you get breakfast and in one room you don't, and given that you don't know which room you will wake up in, you should put most items in the no-breakfast room. And that is what they did.

Finally, we tested whether the birds could plan what and where to cache for breakfast, based on the idea of specific satiety. Rather than having breakfast in one room and no breakfast in the other, the birds would get different breakfasts. On some days they end up in one room and they get powdered peanuts for breakfast; on other days they end up in the other room and they get powdered kibble. They don't know which room they're going to end up in.

If they can plan but don't know whether they will end up in the peanut room or the kibble room, they should put food in both but they should put predominantly kibbles in the peanut room and peanuts in the kibble room. After all, in the kibble room they will get as much kibbles as they want in the morning, so what they want is the other food.

And that is what they did. In both rooms they place more of the different food than the food usually found in that room.

Taking these results together, I am arguing that scrub-jays are sensitive to the past, present and future. They remember the what, where and when of the specific caching episodes. They will cache for a future motivational need, independent of their current needs. And they can anticipate future conditions on the basis of past recoveries, from protecting their caches from potential pilfering thieves to planning for breakfast.

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