What are the minds of non-human creatures really like?

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Credit: University of Cambridge

It is often talked about as the ultimate prize of artificial intelligence: a machine that can think like a human. But human minds are only one example of the kinds of minds on earth. So what are those other minds like? How do they work and how can we understand them? Suppose we do create human level cognition in artificial intelligence (AI), does that widen the 'space of possible minds' to include AI alongside humans and animals?

Dr Kathelijne Koops (St John's 2006) is not a chimpanzee, but she says that, sometimes, she thinks like one. That's because when she's not in her office in Zurich, she is in Guinea's Nimba Mountains where for the past 13 years she has studied chimpanzees.

"When you spend lots of time with them, you begin to think a bit like a chimpanzee," she says. "You start to pay attention to which trees are fruiting, and when they start travelling in a particular direction you remember the amazing fig tree they're heading for."

This meeting of minds comes in handy when wildlife camera crews wanting to find chimps call on Koops. More importantly, it has helped her investigate what drove humans to become such supreme tool musers: "We can't go back in time to study our ancestors, so another way of doing this is to study our closest living relatives."

Studying animals in the wild is challenging – but essential. "You have to study the forest too, because if you don't understand the forest, you will never understand chimpanzees. You need a good knowledge of the ecology to interpret their behaviour, and you can't study tool use if you don't understand how their resources are distributed."

Her research has revealed that ecology is an important influence on tool use, and that for chimpanzees, opportunity – not necessity – is the mother of invention. Food shortages had no effect on chimps' tool use, she found, whereas the more often they encountered ants or nuts, the more likely they were to invent tools to exploit them.

More recently, Koops has compared chimps' tool use with that of bonobos, which – despite being closely related and living in the same forests – use almost no tools. By watching youngsters at play, she discovered striking differences between intrinsic motivation of the two species. "At all ages, chimpanzees manipulate objects more – they are just more busy with objects – than bonobos," she says.

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Given the limitations of using our own mind to study the minds of other species, a less anthropocentric view of the 'space of possible minds' is vital, Koops believes: "Defining intelligence or culture in a way that is restricted to humans makes no sense in the grander scheme of evolution. Once we widen these definitions to include other animals, we find culture in other primates, tool use, and incredible intelligence in corvids."

That we know so much about corvids – birds such as crows, magpies, rooks and ravens – is largely down to Nicola Clayton, Professor of Comparative Cognition in the Department of Psychology, who after many years working with these so-called 'feathered apes' firmly believes there is more to intelligence than how a human mind thinks about the world.

"If you want to understand how a computer works, you need to know how a Mac – as well as a PC – works. They seem to do the same thing and produce similar products, yet they use different operating systems," she says. "Similarly, if we limit ourselves to the human mind, it's difficult for us to know how it works, and what is exceptional."

Fascinated by cognition in corvids – in particular memory and mental time travel – she sets the scene for her research by talking about digger wasps. The female wasp digs a burrow, collects caterpillars to provision the nest, and finally lays her eggs. "It's clearly future-orientated behaviour, but is it planning ahead?" says Clayton. "Is the wasp envisaging a future, imagining various scenarios and then opting for the one she thinks most appropriate?"

It turns out that like a washing machine moving through its cycle, the digger wasp is pre-programmed, and if you intervene experimentally to remove the caterpillars, for example, the wasp cannot adapt its behaviour. Corvids on the other hand are extremely flexible: they really can imagine the future and act accordingly.

To learn more about the mental mechanisms at work in one species of corvid, the western scrub-jay, Clayton devised an experiment called 'planning for breakfast'. For six days, the birds live in three interconnected rooms, and each evening were locked in one of the two end rooms. On waking each morning, they find that in one room breakfast is served, but in the other it's not. For the remains of the day powdered food is freely available in all the rooms. On the final evening, after spending three nights in the breakfast room and three in the hungry room, the birds are given seeds which they can cache in trays in either of the end rooms.

"We find they spontaneously hide food in the hungry room. They don't know which room they will sleep in, but plan ahead for the eventuality that if they end up in the hungry room, they won't go hungry," she explains. "It's a huge step up from learning by trial and error – like the difference between making a mark on paper and writing Shakespeare."

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Her work has overturned previous assumptions that animals are stuck in the present, unable to remember the past (aside from experiential learning) or plan for the future. "That's important because it suggests that intelligence evolved independently in very distantly-related animals with very different brains," she says. "We shared a common ancestor over 300 million years ago, and whereas our brains are layered, crows' brains are nuclear – they both contain neurones but have a different architecture." Hence the original analogy between a Mac and a PC.

Clayton is one of several biologists involved in the new Leverhulme Centre for the Future of Intelligence. Its academic director, Bertrand

Russell Professor of Philosophy, Huw Price, thinks that as well as considering animals within the space of possible minds, we should be less biocentric.

"There is no reason to think that what we are trying to categorise is one type of thing," he says. "It seems multidimensional, so it is more helpful to think of intelligence in terms of skills or capabilities – and that includes those of machines."

Both Dr Fumiya Iida, of the Department of Engineering, and Dr Sean Holden, from the Computer Laboratory, are doing just that. An expert in AI, Holden is developing machine learning algorithms for automated theorem proving and to help biochemists make better predictions from their protein databases, which are vital for drug discovery.

Despite the fact that AI is often represented fictionally and in the media in human form, most machine learning research does not use biology as its starting point, says Holden. Artificial neural networks and human brains both have neurones, but for the most part, the former are massively simpler than ours.

Partly as a result, today's AI is brilliant at very narrow competencies, whereas humans are good at pretty much everything, as Holden explains. "Most AI researchers don't try to solve the whole problem because it's too hard. They take some specific problem and do it better," he says.

"That's not to say that the way humans think isn't useful to AI, but working out how brains do things is hard. And there's a difference in scale. Brains are doing things that are in some senses quite different from what AI researchers are currently attacking – I'd be ecstatic, for example, if I could build a robot that could put on a duvet cover."

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In the Department of Engineering's Biologically Inspired Robotics Laboratory, researchers are widening still further the space of possible minds by questioning not just anthropocentrism and biocentrism, but challenging the prevailing brain-centric view of intelligence.

"In the Middle Ages, people thought intelligence was in the blood. Today, we think it's in the brain, but who knows if that's the end of the story," says Iida. "As roboticists, our standpoint is that it comes from the body – what we call 'embodied intelligence'."

By viewing intelligence as connected with behaviour and motion, Iida rejects the notion of the body as being simply a slave to the brain. There are many ways in which the brain is controlled by the body, he argues, and good reasons why this should be the case. "We have hundreds of thousands of muscles in our body, so how can the brain control this? A computer can't," he says. "Every fraction of a second you have to co-ordinate hundreds of muscles just to grab a cup, for example."

To explain this, developmental robotics focuses on the fact that brains and bodies develop together, figuring out first how to accomplish simple tasks such as focusing the eye, before beginning to tackle more tricky tasks such as walking.

"That's the starting point for our robotic research," Iida explains. "We do a lot of work on leg locomotion, because it's the interface between the brain and the real world. Walking is very difficult. If you miss a step, you fall, so it's critical. And every step is different, it's not like conventional robotics because robots are meant to do the same thing fast and efficiently – that's why leg robots are very difficult to build."

But while they may be difficult to build, there is also a huge amount to be gained in the attempt, because not only is it helping roboticists to build better robots, it's also helping them understand the fundamental principles of what makes systems autonomous, intelligent and adaptive.

"We are trying to take robots and build them to the level that we can treat them as another species – the 'life as it could be'," he concludes. "Because even though robots are not the direct outcome of the evolutionary process, we could think about them as a new species – with a new mind."

Provided by University of Cambridge

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