Clever creatures

The brains of the smartest animals seem to work remarkably like our own, finds **David Robson**

BARELY a month goes by without a new tale of animals behaving brightly. There are orangutans that craft umbrellas out of plant leaves, and chimps that employ stones as hammers with a technique that is uncannily similar to one seemingly used by our Stone Age ancestors. In Bali, long-tailed macaques steal from tourists and then exchange their swag for edible rewards – and they have learned to target high-value items as if they appreciate the basic principles of economics. Hyenas employ the art of deception, with low-status individuals sounding an alarm call that scares their rivals away from a tasty carcass. In one UK zoo, several parrots curse copiously, apparently to entertain visitors. Pigs have been taught to play video games, rats can learn the rules of hide-and-seek, and let's not forget the golfing bees.

Superficially, these behaviours certainly seem smart. But what do they really reveal about animal intelligence? The human mind is remarkable for its innovation and problem-solving across many different domains. Do other animals have the same sort of brains, or are their headline-grabbing antics no more than party tricks that require little complex reasoning?

BRETT RYDER

Scientists have begun devising elaborate tests to tackle this question. Like our own IQ tests, they allow researchers to assess the capacity of an animal's mind, compare the mental abilities of different individuals and identify factors that lead to superior performance. The findings have been a revelation. They provide some fascinating insights into the anatomy of intelligence. And they may even shed light on the evolutionary origins of our own minds.

Our current understanding of human intelligence was born in the early 20th century, when psychologist Charles Spearman noted that children's performances in school subjects as diverse as French, mathematics and music were often correlated with each other. Using sophisticated statistical techniques, Spearman was able to identify the shared element that apparently reflected someone's general intelligence, dubbing it "g". He saw it as a form of "mental energy" serving all kinds of problem-solving and learning, and noted that some people had it in greater abundance than others.

> **"Our general intelligence is thought to give us our unique flexibility of thinking"**

The subsequent development of IQ tests, with their measures of memory, vocabulary, processing speed and non-verbal reasoning, aimed to capture differences in that general intelligence. Over the years, these tests have come under some criticism. Nevertheless, long-running studies show that they can predict some important outcomes in life, like someone's academic success and their performance in various professions.

Because our general intelligence is considered to give us our unique flexibility of thinking, many scientists believed that it must have emerged relatively recently in evolutionary terms, in our ancestral lineage. Other animals, they suggested, had evolved more modular minds, with each skill existing independently from the others. That being

the case, there would be no point in even attempting to measure an animal's g. "Non-human animals were thought to have evolved very specific solutions for very specific small problems," says Judith Burkart, an evolutionary anthropologist at the University of Zurich in Switzerland.

The idea of a modular mind fitted with the belief that animals behave mostly through instinct without much underlying "thought". It also made sense in terms of efficiency and reliability: evolving small, additional modules was considered to be less costly than general intelligence, which was assumed to need disproportionate amounts of brain tissue. "It is intuitive to think that you can evolve something by simply adding a little brick of Lego," says Burkart. In reality, however, this modular mind idea doesn't tally well with our knowledge of brain structure. And the growing recognition that the same neural areas often serve many different skills led some, including Burkart, to question the basic premise.

The first evidence of non-human general intelligence came from studies of mice and rats in the late 1990s and early 2000s. Like the human IQ tests, these experiments included a battery of tasks assessing different skills. One test measured how quickly the rodents learned to associate a sound with an electric shock. Another featured tasty snacks placed in three cups marked by different odours. In only one – the cup with a minty smell – was the food accessible to the rodent, and the researchers timed how long it took for each animal to learn this rule. In a third and fourth task, the animals had to navigate different kinds of mazes.

Rodent reasoning

If the rodent mind were built from many different modules, you wouldn't expect an individual to have a similar aptitude for the different tasks. Yet each one did: the researchers identified a common g factor that seemed to reflect a general, underlying cognitive ability. What's more, g appeared to account for around 40 per cent of the difference in individual performance across the tasks – very similar to the proportion seen in human intelligence tests. Even more striking was the distribution of the scores among the group, which followed the famous bell-shaped curve, with most clustering around the mean performance and much fewer at the high or low extremes. It is exactly the same distribution that is seen in human IQ.

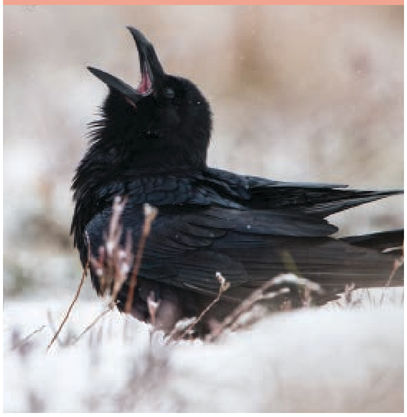
"Rodent IQ follows a bell-shaped curve – the same distribution that is seen in human IQ"

By the early 2010s, primatologists had started to take a keen interest in the findings, with some devising a battery of tests to explore chimpanzee intelligence. To show their spatial memory, chimps had to remember the location of food, after it had been hidden. For a test of causal reasoning, a peanut was concealed in one of two boxes. Then, based purely on the sound – whether it rattled – a chimp had to pick which container held the treat. Other tasks tested communication, by seeing whether a chimp would respond to a human pointing at a particular object, and tool use, by seeing whether a chimp could choose an appropriate object to retrieve food that was out of reach.

Testing 99 chimps in this way, neuroscientist William Hopkins at Georgia State University in Atlanta and two of his colleagues found evidence of a g factor that could explain the correlations in the performance of individuals across the tasks. Once again, the variation followed a bell-shaped curve. Many of the chimps were related and, by comparing the individual performances across their family trees, the researchers were able to explore how much of that intelligence was inherited. Overall, they found that around half of the variability was due to genes, which is amazingly consistent with the studies of human intelligence. "I was fairly stunned," says Hopkins.

Using similar experiments, scientists have now identified g in the cognitive abilities of a range of animals, including orangutans, cotton-top tamarins, bowerbirds and magpies. "The science is still in a very early stage," says Rosalind Arden at the London School of Economics, who in 2016 determined that border collies have g. As a result, she and others who have found g in animals are cautious about interpreting their findings. It will be important, says Arden, to show that the measured differences in intelligence actually

A raven's performance on IQ tests is similar to that of primates



SVEN ZACEK/NATUREPL


NATURE PICTURE LIBRARY/ALAMY

Thieving macaques seem to understand basic economics

correspond to meaningful outcomes – in the same way that IQ scores predict academic and professional achievement. For a border collie, for example, you might compare the measured differences with their performance in dog training classes. For an animal in the wild, it may be their overall survival.

Even with more research, Arden is sceptical of the idea that we will ever be able to quantify the differences in intelligence between species. “The problems facing a cat are different from the problems facing a capuchin or camel,” she says. In other words, two species may show a g factor underlying their individual skill sets but have evolved different strengths or weaknesses based on what was most necessary for survival. For example, dogs and octopuses are both highly intelligent creatures but, depending on the particular tasks used to test them, each could look either very smart or very stupid. And, purely at a practical level, different species may not be physically capable of the same tests: a dolphin, for example, lacks hands, so it cannot manipulate objects in the way a primate would.

Corvid cognition

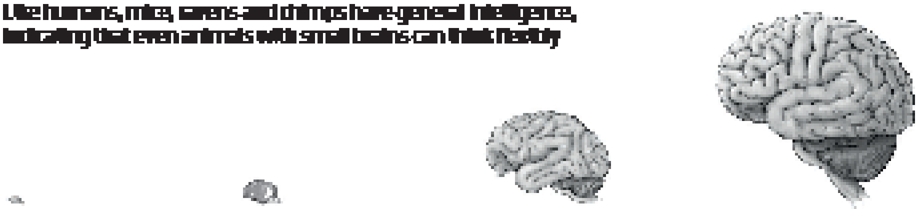
It may not be possible to rank the overall intelligence of different species, but other researchers believe that general comparisons could be enlightening. Simone Pika at the University of Osnabrück, Germany, is one of them. She and her colleagues recently tested ravens on a battery of cognitive tasks that was originally designed for primates. Members of the corvid family – crows, magpies, jays, ravens and the like – have long been known for their sophisticated behaviours, which include tool use and deception. They are even thought to exhibit metacognition, or the capacity to assess their own knowledge and exhibit self-doubt. Given these findings, it is tempting to wonder how their minds compare to those of apes, especially given that the anatomy of bird and mammal brains is so different.

Pika and her team put the ravens through a range of tests from causal reasoning and quantity appreciation – whether they would choose a plate with more pieces of food, for instance – to communicative and social skills, such as whether a raven could follow an experimenters’ gaze to find hidden food. For most of the tasks, the ravens’ abilities were remarkably similar to those of chimps and orangutans. The big difference was that they emerged at a much younger age – surprisingly young, even given that their lifespan is far shorter than that of primates. “The ravens’ performance was already really striking at just 4 months,” says Pika. At this stage, the young still depend on their parents, but they have started to find their own food, giving them many opportunities to put their reasoning and social skills to use, she says.

Comparing the brains of apes and ravens hints at some common qualities that appear to give rise to greater general intelligence. The advanced abilities of primates are thought to have come from the rapid growth of the neocortex, the folded outermost layers of the brain. Indeed, there is some evidence that primates with bigger neocortices are smarter. Bird brains are much smaller and lack these layers, which historically led some people to take a dim view of their abilities. ›

Brain size isn't everything

Like humans, mice, ravens and chimps have general intelligence, indicating that even animals with small brains can think flexibly



Mouse	Raven	Chimp	Human
0.4g	10.2g	380g	1350g
71 million neurones	1.2 billion neurones	28 billion neurones	86 billion neurones

SOURCE: [illegible]

“The conclusion was that, without this neocortex, there’s not enough brain material to make higher cognition possible,” says Pika. However, recent research suggests that corvids make up for this with efficient packing: the neurons in their forebrain are arranged so densely that the total number of cells equals or even exceeds that in primates with much bigger brains. The neural wiring, linking different regions, is also similar in both groups. “It seems that if you want to be smart, you really need to have a high number of neurons and they should all be very well connected,” says Pika.

KRISTINA BLOKHIN/ALAMY

The clever antics of rats aren’t merely party tricks

Why be smart?

As well as giving an insight into the anatomy of brainpower, g tests in non-human animals may also help us understand the evolutionary forces that lead to more flexible thinking. If greater general intelligence does require more brain growth and maintenance, as many researchers believe, then it must offer some big advantages to offset the costs. There are a few competing ideas. One is the cognitive buffer hypothesis: the idea that greater general intelligence allows an animal to cope with an unpredictable environment – improving, for instance, its capacity to forage for food in varied climates. Another, the Machiavellian intelligence hypothesis, considers competition between individuals as the driving force. For animals that live in big groups with complex hierarchies, it is important to keep track of allegiances and to outsmart rivals, all of which is thought to require greater brainpower.

Related to both of these ideas is the cultural intelligence hypothesis, which concerns the sharing of social information between individuals. A solitary animal may be able to find new ways of foraging, for example, but animals that live in a group can capitalise on the innovations of others without putting in that individual effort. “Using social information is much more efficient than trial and error,” says Burkart. The higher an animal’s general intelligence, the better it is likely to be at taking advantage of advances made by others. According to this hypothesis, greater general intelligence should therefore evolve in animals with plenty of opportunities for social learning. When Burkart and her colleagues examined the evidence for general intelligence in non-human animals, they concluded that the cultural intelligence idea is a promising explanation for general intelligence.

Some early evidence for this assertion comes from comparisons of Sumatran and Bornean orangutans. The two species are thought to have diverged around a million years ago. Although their habitats today are very similar, the Bornean apes are solitary and dispersed, whereas the Sumatran ones tend to live in denser populations, which should give more opportunities for social learning. Observations in the wild show that young Sumatran orangutans do take advantage of this: juveniles spend more time watching others than their Bornean counterparts do. The result is a broader repertoire of socially learned behaviours. They use leaves as a type of glove to handle spiny fruit, for example – a behaviour not typically seen among Bornean orangutans.

“This may help us understand the evolutionary forces that lead to more flexible thinking”

According to the cultural intelligence hypothesis, the potential exchange of social information should have driven the evolution of a quicker and more flexible brain that is more adept at all kinds of problem-solving. Sure enough, Burkart’s colleagues at the University of Zurich have found that Sumatran orangutans performed better on a range of cognitive tasks, such as extracting food from a puzzling contraption, which would require higher general intelligence. Their brains are also slightly bigger than those of the Bornean orangutan, supporting the notion that higher general intelligence requires greater reserves of neural tissue.

Human evolution would, of course, exemplify the cultural intelligence hypothesis of brain evolution. From the first stone tools to today’s books, computers and smartphones, our lives have depended on our ability to exploit the advances of others. However, when we fully explore the extent of animal intelligence, we may find that many other creatures are on a similar path. ▮

David Robson is the author of *The Intelligence Trap: Revolutionise your thinking and make wiser decisions.* Follow him on Twitter @d_a_robson