Feature

Elements of consciousness in animals

Consciousness is still a subject that divides scientific opinion on philosophical grounds. Does it exist in separation from cognitive processes? Are there different types and levels of consciousness? Does it exist in animals, and how can we tell? More and more features that we used to consider unique hallmarks of the conscious human mind are now also being recognised in animals ranging from chimpanzees to corvids. This opens up opportunities to study aspects of the conscious mind in animal models. **Michael Gross** reports.

Temple Grandin, who shot to global fame as the titular heroine of Oliver Sacks' case collection *An Anthropologist on Mars*, has had a highly successful career in academic studies of animal welfare, in spite of being diagnosed with autism. Combining insights from her work with animals and from her experience with autism, she has come to the conclusion that the autistic mind may be a step closer to that of non-human mammals, such as cattle, than the neurotypical human mind.

Grandin has successfully used her closeness to animals in both directions. Observing animals helped her understand her own mind, and her personal experience helped her to design animal handling facilities that are now widely used. She first brought up this topic in her book *Thinking in Pictures* in 1995. Most recently, she has summarised her thoughts on these matters in the book *Animals in Translation*, co-authored with Catherine Johnson and published in 2005. An HBO biopic, with Claire Danes playing Grandin, was released in 2010.

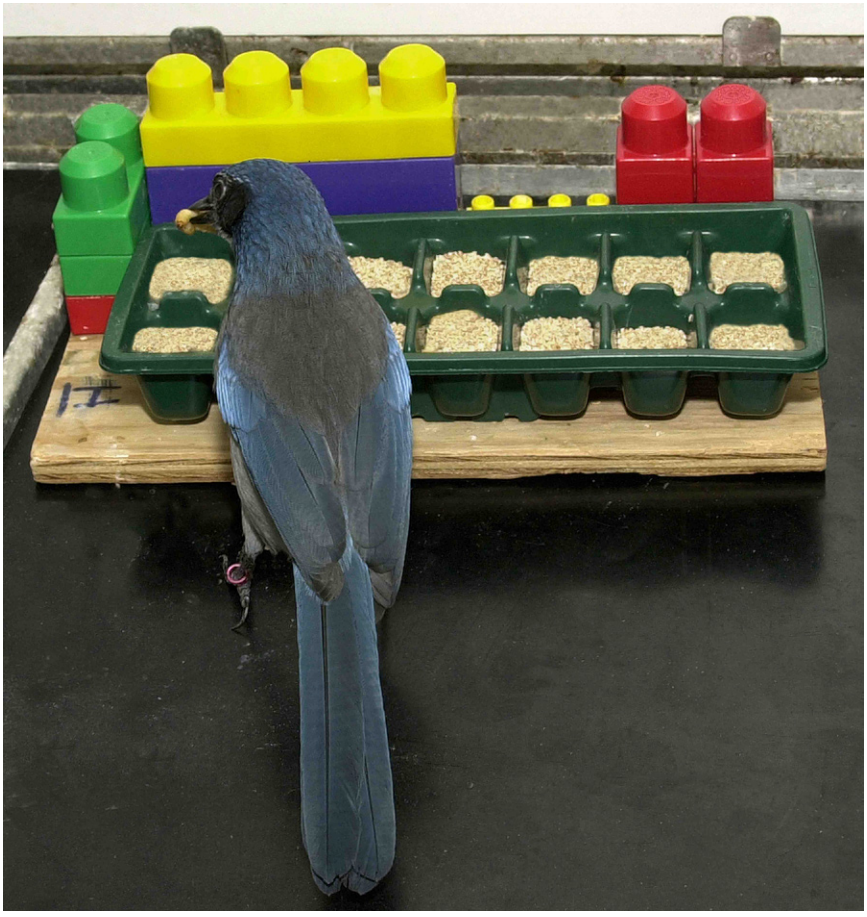
In an earlier essay on consciousness, published on her website in 1998, Grandin attempted to describe her particular type of consciousness, which does integrate input from all her sensory inputs, but does not lead to integration through language or connection with emotion. She argues that her consciousness is on the second level in a hierarchy of four steps, including: 1) consciousness within one sensory system; 2) consciousness integrating all sensory systems; 3) consciousness linking all sensory systems with emotions; and 4) translating all this into thoughts processed in a symbolic language. Thus, in contrast to neurotypical humans, Grandin maintains that her perceptions, while fully integrated across sensory modes, do not connect to emotions and are not automatically translated into language. She has also described her consciousness as "thinking in pictures".

Given the philosophical divisions over consciousness, people may disagree with her analysis, but breaking the problem down into different levels of connectivity between sensory signals, emotional states, and mental representations offers a useful handle by which to grasp the thorny question of whether and to what extent animals possess consciousness.

Corvids and children

Another scientist who compares the minds of animals and humans is Nicola Clayton, who holds positions at the psychology and zoology departments at the University of Cambridge, where she works with children and birds, respectively. Studying social cognition in corvids (including jays, crows and rooks), the groups of Clayton and of her husband Nathan Emery identified behaviours that are typically associated with self-awareness and theory of mind in the development of young children.

For instance, jays hiding their food take into account whether others may have been able to observe them doing



Theft prevention: When jays realise that they have been observed while hiding their food, they come back to the cache to hide it elsewhere. This is particularly common in jays who have themselves been food thieves, suggesting that they can take the perspective of the thief. (Photo: Nicola Clayton.)

Free hugs: Juvenile bonobos will readily offer body contact to comfort peers in distress. In this photo taken at Òlola ya Bonoboó in the Democratic Republic of Congo, one juvenile embraces another who has just lost a fight. (Image courtesy of Zanna Clay.)

so. If they conclude that another jay has knowledge of their cache, they come back after the observer has gone and retrieve their food to hide it in a different place. They are most likely to do so if they have experience of stealing food themselves. It takes a thief to know a thief, even among birds.

This behaviour requires the ability to take the perspective of another individual, something that is clearly an element of consciousness. Psychologists often investigate this ability in children using the Sally-Anne experiment, which children only master at an age of four years on average. Only recently have researchers begun to implement this ability in humanoid robots (Curr. Biol. (2013), *23*, R821–R823).

Christoph Teufel, Clayton, and James Russell at Cambridge have analysed the role of experience and theory of mind in two-year-olds and found that, even when they understood from their own experience that another person was unable to see (through a coloured mask), they did not correctly infer the knowledge state of that person (J. Cogn. Devel. (2013), doi:10.1080/15248372.2012.664591).

In some experiments that involve prediction of physical changes, such as the crows throwing pebbles into a pitcher to raise the water level and reach floating food, average children only match the intelligence of the corvids at age seven (PLoS One 2012, 7, e40574; see also: Curr. Biol. (2011), *21*, R905–R907). While it may seem surprising that most children learn to predict another person's mind earlier than the much simpler system of a jar of water, Clayton suggests that there may be cultural effects involved that still have to be investigated.

In any case, food-caching corvids clearly display behaviours that we tend to identify as symptoms of consciousness in human infants, thus have to be conscious to a certain extent. "The jays seem to be socially aware, given their experience projection skills that are a hallmark of theory of mind," Clayton explains. "They also have episodic-like memory and can plan for the future. Such mental time-travel abilities also rely on awareness, i.e autonoesis and chronesthesia," she says, referring to an earlier study from her group showing that jays can plan their breakfast for the next morning (Curr. Biol. (2007), *17*, 856–861).

Evolutionary biologists like to link these achievements in birds with the requirements of essential natural behaviours, for instance by assuming that using a stick as a tool would come more naturally to birds that collect sticks to build their nests. However, this interpretation has been somewhat undermined by a report from Alice Auersperg and colleagues, who observed spontaneous tool innovation in a captive Goffin's cockatoo (*Cacatua goffini*). These birds roost in natural tree holes and have not been known to use tools in the wild (Curr. Biol. (2012), *22*, R903–R904). Intelligent planning may be an ability even more widespread among birds than we realise now.

In December 2010, Clayton was awarded the Jean-Marie Delwart prize in Comparative and Evolutionary Neuroscience by the eponymous foundation, which then proceeded to hold a symposium on *The Emergence of Consciousness in Animal and Human Behaviour*, setting Clayton's work in the context of studies with other species. The meeting was held at Brussels in October 2013.

Social canids

Most other researchers in the field of animal consciousness restrict themselves to mammals. Dogs and their wild relatives are particularly popular. Family dogs can easily be recruited for non-invasive psychology experiments, whereas the social consciousness of their wild relatives can be inferred from natural pack behaviour in the wild.

At the Brussels conference, Marc Bekoff from the University of Colorado at Boulder, USA, presented insights into perceptions of fairness among canids from his long-running field studies of coyotes in the Grand Teton National Park, near Jackson, Wyoming, US. When young coyotes or wolves play, they use various strategies to ensure fairness. They may limit their own strength, e.g. restrict the force of their bite, or even reverse roles, meaning that a dominant animal may roll over and expose its unprotected underside. This suggests that they, too, can to a certain extent explore what it's like to be somebody else.

The fundamental rules of fairness in coyotes' playtime are: "Ask first, be honest, follow the rules, and admit you're wrong." Bekoff's observations suggest that animals that fail to play by these rules will usually fail to form strong social bonds and will leave the pack when they grow up. As these lone animals are exposed to higher mortality rates, Bekoff suggests, the ability to engage in fair play has a direct advantage for evolutionary fitness.

Peter Pongrácz from Eötvös University at Budapest, Hungary, reported sociocognitive research with dogs conducted with Ádám Miklósi. In a recent paper, Miklósi's group examined the response of dogs to behavioural interactions from other species by using robots as well as human partners in their experiments, in order to separate responses to the social behaviour as such from those to its physical embodiment. The experiments showed that the dogs soon began to form expectations regarding the behaviour of the robots, and that they recognised certain social aspects of it (PLoS One 2013, 8, e72727).

Bonobo comforts

The animals that are genetically closest to our species, bonobo and chimpanzee, are also strong candidates for consciousness research. Zanna Clay and Frans de Waal from Emory University in Atlanta, Georgia, USA, studied the consolation behaviour in young bonobos at a sanctuary in the Democratic Republic of the Congo (Proc. Natl. Acad. Sci USA (2013), doi: 10.1073/pnas.1316449110).

Having previously established that juvenile bonobos are more likely to comfort others than are adults and adolescents, the researchers have now found that those juvenile individuals who are good at controlling their own emotions will also be more likely to comfort peers in distress after a tantrum or after losing a fight. As the sanctuary where they studied bonobo behaviour harbours large numbers of juveniles orphaned by bushmeat hunters, the researchers could also establish that good emotional control and the ability to comfort others were more likely to occur in juveniles brought up by their own mothers than in orphans rescued and reared by humans.

The link between emotional control and sympathetic concern is well-established in children. Finding it in bonobos as well, the authors argue, shows that we share important parts of our socio-emotional behavioural framework with our animal relatives.

At the Brussels symposium, de Waal put this research into the wider context of his research on empathy in primates and presented what he calls a 'Russian doll' model of how animals perceive others. Their perception, de Waal explained, ranges from a core mechanism of emotional linkage arising from a direct mapping of another's behavioural state onto the subject's representations. This Perception–Action Model, according to de Waal, provides the basis for higher levels in which there is an increasing distinction between self and other, so that the other is recognized as the source of felt emotions.

Closing the Brussels symposium, Daniel Dennett from Tufts University warned of the dangers of drawing sharp lines between some animals that are conscious like we are, and others that are just zombies. He suggested that consciousness emerges from the massive interconnectivity of complex brains.

Frans de Waal summarises the experience: "Most of the participants at the meeting approached consciousness by evaluating capacities in animals that we associate with consciousness, such as mirror self recognition, time travel, insight learning, empathy and perspective-taking, and so on. So, instead of trying to demonstrate consciousness per se, we were looking for circumstantial evidence assuming that, if certain capacities engage consciousnesses in humans, then they probably also do in other species. We reviewed evidence from invertebrates and fish to birds and mammals, truly across the spectrum."

These considerations seem to suggest that there is a consciousness spectrum, even more finely graded than the four steps that Temple Grandin suggested in the 1990s, on which various animals may display distinct features of consciousness.

Rather than searching for a whole consciousness package, which may be as futile as earlier attempts at finding the seat of the soul, it may prove worthwhile for researchers to study those features separately, in the hope that they will later fit together into a meaningful understanding of human consciousness.

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Q & A

György Buzsáki

György Buzsáki obtained an MD degree from the University of Pécs, Hungary in 1974, followed by his Candidate of Science (~PhD) degree in 1984. Following postdoctoral fellowships with Eduardo Eidelberg in San Antonio, Texas and Cornelius Vanderwolf (a student of D.O. Hebb) at the University of Western Ontario, Canada, he returned to Pécs as an Assistant/Associate Professor in Physiology; at that time he was also a visiting scholar in Anders Björklund's lab at University of Lund, Sweden, and the Nenski Institute, Warsaw, Poland. In 1986, he became a J.D. French Foundation Fellow and subsequently an Associate Professor-in-residence at the University of California at San Diego, a rewarding and fruitful collaborative epoch with Fred Gage. After spending 20 years at Rutgers University, as Professor and Board of Governors Professor, he moved to New York University where he is currently a Biggs Professor of Neuroscience and Physiology. He is an elected member of AAAS, Academia Europaea and the Hungarian Academy of Sciences. His honors include the 2011 Brain Prize, ISI Highly Cited, Krieg Cortical Discoverer Award, The Pierre Gloor Award, Henry Neufeld Memorial Award, Distinguished Scholarship at Rutgers University and Collége de France Distinguished Professor. He sits on the editorial boards of several leading neuroscience journals, including Science and Neuron. His primary interests are brain oscillations, sleep, memory and associated diseases. His main focus is 'neural syntax' — how the segmentation of neural information is organized by the numerous brain rhythms to support cognitive functions. His book Rhythms of the Brain *has received numerous accolades.*

Why did you choose to study biology in the first place? I did not. I wanted to become an electrical engineer. As a young radio ham my goal was to establish effective Earth–Moon–Earth radio communication; but, given the expense of studying