Groupthink. Social living may have fostered the evolution of intelligence.

A new generation of experiments reveals that group-living animals have a surprising degree of intelligence

Social Animals Prove Their Smarts

A Fox observed a Crow in a tree with a piece of cheese in her mouth. Hungry for the cheese, he thought up a ruse to get it. He said, "What a noble bird I see above me! Her beauty is without equal. If only her voice is as sweet as her looks are fair …"

The Crow was greatly flattered, and to show the Fox that she could sing, she opened her mouth and gave a loud caw. Down came the cheese. The Fox, snatching it up, said, "You have a voice, madam, I see: What you want is wits."

—Retelling of a fable by Aesop

In Aesop's time, it was common to endow animals with qualities of the human mind. In addition to the flattering fox, Aesop told of a deceitful eagle that lured a turtle to its death and a compassionate lion that exchanged favors with a shepherd. But although folktales often feature scheming or generous animals, scientists have spent most of the past few centuries thinking of other species as "dumb," or at least driven by innate behaviors. Even when biologists, anthropologists, and psychologists finally began to appreciate the complexity of animal cognition in the 1950s, they tended to focus on the mental advantages that still separated humans from the rest of the animal kingdom.

Even 10 years ago, most researchers considered the intellectual chasm between humans and animals too broad for even primates to begin to bridge. A few claimed that animals have advanced cognitive skills, but early studies were chiefly anecdotal and convinced few hard-core experimental biologists, says Michael Tomasello, a developmental psychologist at the Max Planck Institute for Evolutionary Anthropology in Leipzig, Germany. "From a scientific point of view, most of the evidence [for higher cognition] was not very good," he says.

In the past decade, however, the field of animal cognition has taken off, galvanized in part by a once-obscure idea that the development of social skills drove the evolution of general intelligence (see sidebar, p. 1737). The thinking is that the need to remember and track peers sharpened social animals' ability to do other useful cognitive tasks, such as remembering where and when particular fruit trees were ripe for the picking, or learning tool use from a particularly creative peer. From this perspective, abilities such as remembering the identity of dominant individuals are crucial steppingstones to the most advanced cognitive abilities, such as learning how to interact with those dominants for personal gain—something scientists assumed only humans could do.

Of course, humans are masters of social intelligence. We judge friend from foe and head honcho from underling by the raising of an eyebrow. We scheme, deceive, and sometimes help others with no gain to ourselves. But it turns out that other animals can do these things too, at least to some degree. Researchers using rigorous tests of such abilities in animals are finding numerous examples. Crows deceive each other, as do apes; hyenas keep track of social hierarchies. There are enough parallels that now "everyone is interested in

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discovering the similarities between animals and humans," says Bennett Galef, an emeritus animal behaviorist at McMaster University in Hamilton, Canada.

Together, the new studies, particularly those of apes and birds, are providing provocative evidence that perhaps humans aren't as special as we might like to think, says Brian Hare, a biological anthropologist also at the Max Planck Institute for Evolutionary Anthropology. What was once considered a sharp line separating humans from all other animals is becoming a blurry gray area, with various animals possessing certain parts of the set of skills that we consider advanced cognition.

In large part, that's because we're not the only species that has evolved to cope with the demands of living in groups, says Nicola Clayton, who studies animal cognition at the University of Cambridge, U.K. People in villages, chimps in troops, ravens in flocks, and hyenas in packs all need to be able to size each other up and modify their behaviors as needed.

Not all researchers are impressed with animals' newly demonstrated social ingenuity, and there is disagreement about its implications. All the same, says Marc Hauser of Harvard University, for cognitive scientists the research questions have changed, from what sets humans apart, to what animals reveal about the building blocks of higher cognition.

Tool savvy. An eager student learns how to retrieve a treat from outside its cage (*left*), while another ape takes a "grape-retrieval" tool to save for later use (*right*).

Understanding understanding

Throughout history, researchers have swayed back and forth on the question of animal intelligence. In the 1600s, nonhuman animals were considered little more than breathing machines. But after Darwin implied that differences between humans and other species were a matter of degree, dozens of examples of "smart" animals came to light, only to be subsequently debunked. During the 19th and early 20th centuries, the prevailing idea became that most animals, primates included, didn't reason but instead had sets of rules that dictated their behavior. And animal-cognition researchers avoided inferring states of mind from an animal's behavior. They took their cues from 19th century psychologist C. Lloyd Morgan, who argued that complex behaviors don't necessarily require complex thought, and that researchers should look for simple, mechanistic explanations for even the most complex animal behaviors.

But starting in the late 1970s, some researchers went against the grain. In 1976, psychologist Nicholas Humphrey of the London School of Economics stirred the pot by suggesting that getting along with others required more brainpower than other aspects of daily life, and that social animals might have humanlike smarts. "It was very much at odds with what everyone was thinking at the time," Humphrey recalls.

Two years later, psychologists David Premack and Guy Woodruff of the University of Pennsylvania proposed that chimpanzees might be able to think about what they are doing and to understand what others are thinking, an ability they called a "theory of mind." Even as children, humans can read each other's minds at least to some degree. Maybe chimps could as well, if we could only find a way to communicate with the apes, Premack and Woodruff proposed. And in the late 1980s, Andrew Whiten, an evolutionary psychologist at the University of St. Andrews in Fife, U.K., and his colleagues suggested that the relatively big brains of humans and other primates evolved not to see, smell, or fight better but to recognize and deal with social dilemmas.

Telling tales. Aesop's talking animals may not be true to life, but he might have been right about their intelligence.

But "it took a while for people to start thinking about these ideas," says Clayton. Today, psychologists recognize "theory of mind" as a critical cognitive skill, underlying teaching, deception, and perhaps even language (*Science*, 16 May 2003, p. 1079). It's also seen as a steppingstone to consciousness, or thinking about one's own thoughts—often considered the ultimate in higher cognition (*Science*, 25 June 1999, p. 2073).

Yet scientists disagree on exactly what theory of mind is, and the literature is filled with conflicting reports about its existence in animals. As recently as 6 years ago, Hauser argued that chimps didn't have even the basics of a theory of mind. Today, "the field has been completely turned upside down," says Hauser. "The provocative question is not do they have a theory of mind; it is thinking about the components that are going into theory of mind."

Reading the primate brain

Corporate meetings, playground games, and bargain shopping all require complex negotiation skills and a keen sense of who one's allies are. It makes sense that apes, our closest kin, should be political as well, but it has taken decades for scientists to come to grips with the idea that apes have street smarts akin to ours. Beginning in the 1960s, field researchers such as Jane Goodall were reporting sophisticated politics among

CREDITS: (TOP, LEFT TO RIGHT) ANDREW WHITEN; JOSEP CALL/MAX PLANCK; (BOTTOM) TIME LIFE PICTURES/GETTY IMAGES

Hide, no seek. Ravens (*inset*) turn away from each other to keep secret the location of their buried food.

chimps, for example, but controlled experimental evidence was rare.

Apes rarely did well on self-awareness, memory, gaze-following, gesture, spatial learning, and other tests at which even young children excel. For example, children will follow another person's gaze, showing that they are aware that the tester is in fact looking at something. But chimps confronted with humans with or without blindfolds on their heads didn't discriminate among who could see—and therefore deliver a reward—and who couldn't.

Then 6 years ago, Hare and his colleagues showed that under the right circumstances, chimps could pass some of these tests with flying colors. The secret was that chimps are exquisitely tuned in to their competition, particularly when food is involved, and will do everything they can to get a treat.

In one experiment published in 2001, Hare, Tomasello, and their colleagues paired a dominant chimp with a subordinate and manipulated the two apes' view and access to food. If both could see the food, the subordinate deferred. But if the dominant chimp couldn't see the treat, the subordinate quickly snapped it up.

The experiment, coupled with a related but simpler one published a year earlier, was revolutionary. "There was a big change in perspective," says Clayton, and a flurry of more ecologically appropriate experiments—geared to what motivates chimps in the wild—followed. For example, in a new study in *Cognition*, Hare and his colleagues designed another competition over food. They had chimps go head-to-head against a human who pulled food out of reach as a chimp went to grab it. If the chimps were given the option, they sneaked up behind a barrier to get to the food instead of approaching it directly. Thus, the chimps demonstrated not only that they knew what the human could see but also that they knew how to manipulate the situation to stay out of sight. Other studies have shown that chimps can recognize when a human is imitating them.

They can also sense the motives of others. A study a few months ago showed that chimps kept track of partners who best collaborated in retrieving inaccessible food and chose that same partner again in the next trial (*Science*, 3 March 2006, p. 1297). New experimental designs are helping to demonstrate chimp smarts outside the social realm, too: Studies show that they can reason about the movement of things they cannot directly see and plan for the future by taking account of past experiences.

Meal planning. Western scrub-jays remember where and when they buried wax worms in ice cube trays.

In parallel, other researchers are demonstrating that social primates are smart enough to help their cause through teaching and learning. Chimps apparently learn tool use from one another, and communities in different regions of Africa develop what some researchers consider cultural differences in tool use. The idea is still controversial, but field and, more recently, lab work are strengthening the case.

Last year, Whiten and his colleagues demonstrated "social learning" of traditions in two groups of captive chimpanzees. The researchers trained one female from each group either to pull or to lift a stick tool to retrieve a reward. After watching the female for just 20 minutes a day, each group learned its respective technique within a week. Not only were the chimps able to copy the lifting or the pulling, but lifters also almost never tried to pull or vice versa, suggesting a strong tendency to conform to the local norms, Whiten suggests.

Taken together, this work shows striking parallels with human abilities, says Hare. But do chimps have a theory of mind? They lack the most advanced skill identified by Woodruff and Premack: the ability to realize that another individual is thinking something wrong, or that it has a false belief, points out cognitive scientist Daniel Povinelli of the University of Louisiana in Lafayette. In his view, to have a theory of mind, a species must pass the false-belief test. And so far, chimps fail it. "People who [keep] insisting that 'It's got to be there, at least a little bit,' in dogs, cats, chimpanzees, my cousin Ned's horse are really missing the point," Povinelli says.

But Hare argues that theory of mind is "a whole suite of abilities." The new results indicating that chimps can judge what others are thinking, manipulate others through deception, and so on "are shooting down the all-or-none hypothesis about theory of mind," he says.

He adds that the false-belief test is so challenging that it foils children up to about age 4. In one test, for example, a child and a companion watch a tester put candy in a box. When the companion leaves, the candy is moved into a bucket. Because the child doesn't yet have a sense of false belief, she thinks the companion will know to look in the bucket, whereas an adult realizes that the companion still thinks the candy is in the box.

Hare argues that experimenters simply haven't found a good way to figure out where a chimp expects the companion to look for the

CREDITS (TOP TO BOTTOM): THOMAS BUGNYAR; PHOTO COURTESY OF NICOLA CLAYTON

Man's Best Friend(s) Reveal the Possible Roots of Social Intelligence

When a chimp sneaks a banana behind another chimp's back, it's showing social intelligence. So is the crow that buries worms behind a bush to prevent bystanders from spotting the location of its stash. Recent controlled experiments show that some social animals have evolved the flexibility and intelligence to deceive and benefit from others and even predict what their peers may do (see main text).

But why did these and related abilities evolve? In the 1970s, Nicholas Humphrey, now of the London School of Economics, proposed that natural selection favored the ability to distinguish anger from acceptance and to respond to changes in the moods of one's companions. Individuals with these kinds of social skills had advantages in gleaning food and mates—and avoiding violence, he suggested. But such evolutionary scenarios are hard to test. Now Brian Hare and Michael Tomasello of the Max Planck Institute for Evolutionary Anthropology in Leipzig, Germany, and their colleagues are gleaning some clues from studies of domestic dogs and their wild cousins, wolves and foxes.

Even as puppies, canines are adept at taking cues from their owners—more adept than chimps, who are rarely able to follow a human's eyes or hands to hidden food. That indicates a genetic component to this skill. For decades, anthropologists have hypothesized that this behavior began when dogs and humans were able to tolerate each others' company without aggression. Togetherness fostered dogs' social skills, helping ensure their access to food and other resources without having to resort to violence. Dogs better at reading human minds were favored by selection, leading to a cycle of interaction and cooperation.

That hypothesis is backed up by Hare's studies of foxes bred for the past 45 years to be comfortable with humans. These foxes understand human gestures—for example, when a human points to food—but untamed foxes don't, even after extensive efforts to train them, Hare and his colleagues reported in 2005. Studies done in 2002 and 2003 reveal "the exact same difference between dogs and wolves," says Hare. Selecting foxes for "togetherness" with humans also facilitated the evolution of the ability to understand their two-legged caretakers.

A similar cycle of tolerance leading to increased communication may have spurred the evolution of social intelligence within a species, says Hare. As social tolerance increased, group members could get close enough to an innovative, tool-using peer to imitate the behavior. Selection could also favor even more congenial relationships, say for cooperative food gathering or childcare, to the benefit of all involved.

Fellowship. Foxes bred to be tame are keenly tuned in to human behavior.

And the limits of social tolerance may partly explain differences in intelligence among species, says Tomasello. For example, chimps have competitive strategies down cold and can be quite sneaky. But they don't cooperate very effectively, at least not intentionally; they would have come to a bad end in Aesop's fable about the lion and the shepherd who traded favors. In contrast, although humans too are competitive, we also possess the capacity for more empathetic social skills. "We lie, but we can also cooperate and coordinate planning," says Tomasello. "It's not that humans have greater individual brainpower, it's that they have the ability to pool their cognitive resources and benefit from what others have learned."

This evolutionary scenario sounds reasonable, but it will be difficult to prove. Hare plans to compare higher cognition between bonobos and chimps, which exhibit different levels of social tolerance, to see whether the connection between sociability and cognition holds up. Bonobos are quite tolerant; when they meet strangers, they have sex, whereas chimps often wage war, he points out.

Even before these studies are done, other researchers are taking notice—although they have yet to be convinced. "Evolutionary modification of fearfulness and aggressive tendencies might be a critical precursor to the evolution of social intelligence," says ethologist Kay Holekamp of Michigan State University in East Lansing. "But I would certainly be surprised if that were all there were to [it]." **–E.P.**

treat, and that therefore we don't know yet whether chimps pass or fail this test. "We have not been able to come up with a convincing experiment with nonhumans," he says.

Picking bird brains

So far there's no evidence—and no good tests—of understanding false belief in birds. But contra the opinion of the fox in Aesop's tale, Clayton and her colleagues have found that crows and their relatives, including ravens and scrub-jays, have social intelligence on par with primates, apparently deceiving others in order to win more food. In Clayton's studies, she takes advantage of the natural tendency of many birds to stash surplus food in anticipation of lean times, and for other birds to steal those caches.

She and her husband Nathan Emery have recreated this behavior in her lab at the University of Cambridge, providing captive birds with sand-filled trays in which to bury wax worms. Sometimes the duo switches the food after it's been hidden; in other cases, they allow another bird to witness the burial. "They are putting birds in different situations and showing that the birds do all sorts of flexible things," says Hare.

Using this approach, Clayton and her Cambridge colleague Anthony Dickinson have shown that western scrub-jays remember what they have buried, and when and where they buried it, a phenomenon called mental time travel. They retrieve perishable food before it rots, for example, while waiting longer to retrieve nonperishable items. Many animals can remember where food has been placed, but rarely have researchers demonstrated that an animal can keep track of when an event occurred and use past events to figure out what to do in the future. This ability was demonstrated in bonobos and orangutans only recently, in an experiment published online in *Science* last month (16 June, p. 1662). The study showed that these primates could select the proper tool for a task even though they wouldn't need it until the next day. And in this week's issue of *Current Biology*, other researchers demonstrated that mangabeys, a primate found in Uganda, will take note of unripe fruit and come back to pick it after a few sunny days.

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For birds, anticipating the future enables them to realize when they must take evasive action to protect stashed food. Working with Joanna Dally, then a graduate student, and Emery, Clayton showed in another experiment that western scrub-jays that see a potential thief will hide food far away from the other bird and sometimes move their supplies several times. In other cases, they wait to stash food until the onlooker is distracted. The jays take none of these precautions if no other birds are in sight. "There's flexibility at multiple levels," says Clayton.

Furthermore, birds who have been thieves themselves are more likely to take these evasive actions than birds who have not been so nefarious. The jays' behavior implies that they are aware of the onlooker's intentions and are using their past experience to predict the future actions of the potential thief, says Clayton.

In addition, like apes, the jays track the social status of their competitors and change their behavior accordingly. In the lab, scrub-jays try hard to hide food from dominants but not from breeding partners, whose pilfering is tolerated, Clayton's group reported. All this hints that jays do have elements of a theory of mind, says Clayton.

Lab work on ravens supports this idea. In most cases, a raven poised to grab another raven's stashed food doesn't hesitate to act when bystanders might beat them to it, Thomas Bugnyar and Bernd Heinrich of the University of Vermont in Burlington reported in 2005. But if the stash belongs to a dominant member of the flock, the thief will briefly search elsewhere, as if to allay suspicion. Such actions seem intentional and suggest that the thieves understand what other birds are seeing, says Bugnyar. "There's no question that birds are more intelligent than anyone thought they would be," Tomasello says.

But researchers still don't agree on how to interpret these results. Cognitive ethologist Marc Beckoff of the University of Colorado, Boulder, sees little difference in social prowess between humans and other species, and he suggests that animals should be treated more like humans.

Other researchers still draw a line separating the minds of humans and animals, even other social species. The new experiments highlight how "various species have remarkable cognitive skills for the problems they must solve," but they stop short of showing a theory of mind or other advanced cognitive skills, says Povinelli. Humans, by virtue of having language, have a fundamentally novel cognitive system, he points out. Tomasello agrees, noting that humans excel at many skills: They are better teachers, for example.

Furthermore, what looks like humanlike cognition may not be. Dogs, for example, seem to know what their owners are thinking. But "they are not reading people's minds but our behavior," cautions Clive Wynne, a psychologist at the University of Florida, Gainesville. For example, those ravens avoiding the wrath of dominant birds could be picking up on subtle behavioral cues that humans can't read, he says.

To resolve whether external cues or internal decision-making underlie seemingly intelligent behavior, researchers need to expand their studies to include more species, Wynne says. "We're only studying a tiny, tiny fraction of animals," he says. "We really don't know what's out there."

Those studies are beginning, and by looking across the animal kingdom, researchers are gleaning the conditions that predispose a species toward social intelligence. For example, Kay Holekamp, an ethologist at Michigan State University in East Lansing, has observed hyenas for 18 years and concludes that these scavengers can recognize not just their own status relative to the pack leader but also the status relationships of other pack members. Other researchers are trying to measure social intelligence, albeit often in indirect ways, in ungulates, elephants, and dolphins. And in this week's issue of *Current Biology*, researchers demonstrated that fringe-lipped bats learn to listen for unfamiliar prey from fellow bats.

All these studies suffer from the same limitation, however. Researchers still can't read the minds of their subjects, warns behavioral ecologist Anne Engh of the University of Pennsylvania: "Until we can come up with creative methods of testing, we won't know whether complex behaviors are the result of animals actually knowing what they are doing or whether they are able to do complex things using cognitive short cuts."

Galef is particularly skeptical of researchers who have concluded that chimps respond to peer pressure, that wolves and capuchin monkeys have a sense of fairness, or that jackdaws are the avian equivalent of the Good Samaritan. "It's gotten a little out of hand," he complains. And not one species has yet passed the false-belief test, he points out.

But does that matter? "It's not clear to me that you need [a complete] theory of mind to be very skilled socially," says Hare. And for much of the animal kingdom, those skills are good enough. Just ask Aesop.

–ELIZABETH PENNISI

Keeping track. Hyenas remember the players—and their relatives—when bickering breaks out.

CREDIT: LAURA SMALE

Additional Reading

- J. Dally *et al.*, "Food-caching western scrub-jays keep track of who was watching when." *Science* **312**, 1662 (2006).
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- N. Emery and N. Clayton, "The Mentality of Crows: Convergent Evolution of Intelligence in Corvids and Apes." *Science* **306**, 1903 (2004).

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