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■ Cognition

Domestic Dogs Use Humans as Tools

Dogs live sympatrically with humans across the entire globe, but what has allowed dogs to live together so successfully with humans? Recent research focusing on the problem solving abilities, or cognition, in dogs suggest that part of the answer lies in how dogs are able to utilize humans in solving problems. Dogs excel, relative to other animals, at using human behaviors to learn about the world and modify their own behavior. Many dogs can even be characterized as human tool users because they intentionally elicit help from humans if they are unable to solve a problem by themselves. Comparative experiments on social problem solving, or social cognition, in wolves, dogs, and foxes demonstrate that dogs acquired these unusual problem solving abilities during domestication. Therefore, this research supports the hypothesis that dogs have been successful in living with humans not only because of changes in their social behavior during domestication, as many have previously suggested, but also because of changes to their social cognition as well.

Making a Puzzle Out of the Making of Man's Best Friend

Dogs were the first species that began living together with humans, and today hold a position in many cultures as a favored companion. In some cases people even raise dogs in lieu of having their own human children. The very earliest archeological evidence of dogs living with humans is from Germany, Israel, and Iraq and indicates that the commensal relationship between humans and dogs began between 12,000 and 14,000 years ago.

For anyone who has owned or interacted with a dog for any amount of time, the fact that dogs were the first domesticated animal to live with humans may not be surprising. Dogs raised by humans can thrive in human company. In fact, many dogs grow to love humans so much that they can suffer from symptoms of anxiety and depression if they are not in visual contact with a human at all times. Moreover, humans enjoy spending excessive amounts of time with and money on dogs. Many people find dogs to be unavoidably attractive playmates, spending hours with dogs on anything from fetch to dress up games. In the United States the obsession with canine companions leads to an annual expenditure on dog food that exceeds 10 billion dollars.

However, although it may seem clear to any dog lover why modern dogs are a favored companion, it is less than obvious how this interspecific mutualism might have originally been fostered. We know from genetic studies that the closest relative of the domestic dog (*Canis familiaris*) is the wolf (*Canis lupus*). By comparing the DNA of wolves and various breeds of dogs, geneticists have been able to determine that all dogs are likely to have originated from a population of Asian wolves that lived somewhere between 40,000 and 15,000 years ago. This population of evolving dogs then underwent explosive expansion, spreading as far as the western United States sometime as early as 9,000 to 10,000 years ago.

Initially scientists argued that, much as people breed dogs today, prehistoric humans must have adopted wolves and, over many generations, intentionally bred them for traits that made them more dog-like. However, today's scientists realize there are problems with this idea. If dogs originated from wolves after generations of intentional breeding by humans, how can this be reconciled with the fact that humans of most cultures, at least in recent history, typically fear and persecute wolves—a persecution that has almost led to their extinction? How could it be that people living tens of thousands of years ago, having no modern weapons, did not find wolves terrifying, but instead found them to be appealing fireside companions? Puzzling yes, but even more so when you realize that adult wolves make horrible human companions. Although beautiful, gregarious, and incredibly intelligent animals, as wide ranging pack hunters, wolves are also free spirited, stubborn, and emotionally reactive. There is a strong dominance hierarchy within wolf groups that is maintained through dominance displays and overt aggression. Although normally gentle and peaceful, adult wolves, even those raised by humans, can easily cause serious injury to any human foolish enough to attempt to force his will on it (i.e., it would be ill advised to attempt training an adult wolf how to sit!). Finally, the origins of our relationship with dogs is further clouded by the fact that, even today, it is far from universal for humans to view dogs as celebrated inhabitants of their communities. Instead, in many cultures dogs are seen as pests that must be tolerated or even eradicated. Therefore, with the knowledge that dogs evolved from a feared predator into a species that many humans shun, it is no longer obvious how dogs evolved from wolves and successfully spread across the entire globe in concert with humans. Thus, if we are to understand why dogs have been so successful as a species, it becomes important to understand what changes occurred during the domestication

of dogs from wolves, while also understanding how these changes might have occurred. It is only with such information that we will gain insight into exactly what it is about dogs that has made them so successful at living with humans for so long and in such varied circumstances.

Do Dogs Have Unusual Abilities to Solve Social Problems?

How can we explain the origin of man's best friend if it is no longer clear how or why dogs evolved from wolves and came to live together with humans. In order to uncover clues regarding the origin of dogs and our relationship with them, researchers have gathered information from as many sources as possible, including dog genetics, morphology, physiology, and the archeological record. Additionally, some researchers have studied dog behavior. Recently these efforts have focused on examining how the problem-solving behaviors, or cognitive abilities, of dogs might differ from other species of animals, and how these differences might help explain the evolution of our relationship with them.

In 1998 two different comparative psychology laboratories, one in the United States and one in Hungary, published research on how dogs solve social problems. Independently, these two teams of researchers came to the same conclusion. Dogs seem to be skillful at using human social cues, or signals, to learn things about their environments. Both groups of researchers used the same experimental paradigm, or methodology, to study the cognition of dogs. The paradigm was similar in some ways to the famous shell game that many street magicians use to entertain audiences. Thus, while a dog watched from a few feet away, food was hidden by an experimenter in one of two opaque cups that were spread several feet apart. The trick was that, although the dog knew the food was hidden in one of the two cups, there was no way for the dog to see which cup the food was hidden under (the experimenter handled both cups the same way although he only hid food under one cup). However, unlike the street magician, the human experimenter, after hiding the food, tried to help the dog find the food by providing some conspicuous signal to indicate its location. For example, the experimenter might tap on the cup where the food was hidden, point to the correct cup, or simply look toward the correct location. Then the dog was allowed to search for the hidden food. If the dog touched the correct cup first, it received the food reward, whereas if it did not choose the correct cup first, it did not receive the food. Indeed, both groups of researchers found that dogs were excellent at finding the hidden food using any of the signals the experimenters provided. However, a good experimenter should not be convinced quite yet. Dogs are known for their keen sense of smell. Is it possible that the dogs were successful, not because they used the human signals, but instead used olfactory cues (i.e., the scent of the food) to choose the correct cup? To control for this possibility, a test was run that replicated the exact procedure described above, with the exception that the experimenter did not provide any cue to the location of the hidden food. In this controlled situation the same dogs who found food when human signals were available could no longer find the food. Therefore, the failure of dogs to find hidden food in these control conditions demonstrates that dogs find hidden food using human signals.

Perhaps, as someone who interacts with dogs often, you are wondering why this result is interesting. Is it not obvious that dogs use gestures and other social cues provided by humans in all types of situations? Actually, it is not so obvious. The skill dogs show in using human

signals is quite impressive in light of work with other members of our own taxonomic group—the primates. Universally, primates are very poor at using signals from humans to find hidden food—even using the exact same experimental methodology just described. Whether it is a capuchin monkey, baboon or even our closest living relative the chimpanzee (sharing in common with us 98.6% of our genetic code), nonhuman primates are totally unsuccessful at finding hidden food if it requires using gestures or signals from humans. This is not to say that primates are not capable of learning how to use human social cues to find food. Primates can learn to use human signals, but only after they have played the game several dozen times. Surprisingly, however, once primates have had enough experience to learn how to use one cue, they do not typically generalize this skill to a new cue or signal. For example, chimpanzees were trained to use a human pointing gesture to find food, but once proficient, they were unable to use the same gesture if the experimenter simply stood several meters away from the two hiding locations. In addition, primates are not skilled at using static cues. When primates do learn to use human signals to find food, they simply rely on the directionality, or motion, involved in making the cue. For example, chimpanzees who are proficient at using a pointing cue are no longer capable if they did not actually see the human extend their arm toward the hiding location. Finally, primates need tremendous experience to learn how to use any type of cue that is novel or arbitrary to them. For example, if instead of using a body part to indicate the location of the food, an experimenter places a wooden block on top of the correct cup, it takes chimpanzees dozens of trials to learn to use the block as a reliable indicator of the food's location.

With the inability of primates to use human signals in mind, the abilities of dogs to use the same type of information skillfully seems quite remarkable. However, how do dogs fair on some of these more difficult tests that were used to uncover how inflexible primates are in using human social cues? Almost without exception, dogs are skillful in the same tasks that primates have previously struggled to understand. First, many adult dogs are able to use various human gestures or signals on their very first try; they do not require dozens of trials to learn how to use each new social cue. Second, dogs do not simply rely on the motion provided by the cue. Dogs can use cues even when they are provided statically. Perhaps most impressively, dogs are not tricked when someone provides a false cue that is in the direction of the food, but is not actually directed at the correct location. Dogs will choose the cup a human is looking at, but will not choose the cup if the human is only looking above it. Finally, dogs are also capable of spontaneously using a range of novel and arbitrary cues to find hidden food. Unlike primates, many dogs, on their first trial, will choose a cup on which a human has placed a wooden block. Taken together, these results are very similar to those obtained with young children, and suggest that dogs have an unusual understanding of human communicative signals and gestures relative to that of other animals.

Both teams of scientists studying problem-solving behaviors in dogs have discovered that dogs have unusual abilities for comprehending communicative gestures and signals provided by humans. Could this unusual ability have played a role in helping dogs succeed in living with humans and spreading across the planet? Indeed, it might seem that skill at using various human social cues could have been extraordinarily advantageous to any animal living in proximity to humans. First, by attending to human gestures and signals, dogs have access to information about the location of things such as danger or food to which they otherwise would not—especially since human vision is far more acute than that of dogs. But perhaps most importantly, a dog that was able to read human social cues flexibly could predict how best to behave across a variety of novel situations in order to avoid making humans angry or perhaps even to find a way to please them. If true, then perhaps the

ability to read social cues was an important reason why dogs were able to quickly and successfully spread across the planet with humans.

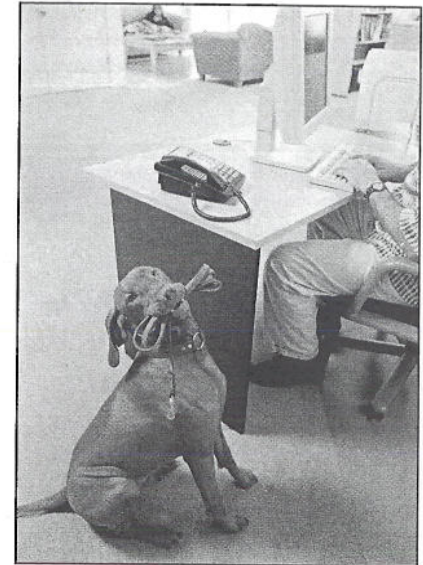
Did Dogs' Social Cognition Change during Domestication?

Dogs are more skillful than primates at using human gestures and other signals in a number of settings. This suggests the hypothesis that these problem-solving abilities may have played an important role in allowing dogs to survive together with humans, and therefore evolved during domestication. However, while comparisons between dogs and primates suggest this interesting hypothesis, these same comparisons cannot fully test whether it is correct. With the hope of testing whether dog cognition evolved or changed during domestication, both laboratories studying dog cognition have extended their comparisons to include wolves, while also studying how the ability to read human social cues develops in dogs.

If the ability to read human gestures evolved during domestication, then dogs should be more skilled than wolves in reading human social cues. Although a possibility, it is not clear if this is the case. It is also possible that dogs simply inherited their skill at reading social cues from their canid ancestry. Wolves are cooperative hunters who most probably rely heavily on behavioral cues of group mates and prey alike while working together to bring down their quarry. Therefore, it could be that dogs simply inherited their unusual skill for reading subtle interspecific social cues. If true, this would rule out the possibility that this ability played a central role in facilitating the relationship between dogs and humans.

The same researchers from the United States tested this hypothesis by comparing the ability of seven wolves and seven dogs for their ability to use various gestures in locating hidden food, using the same shell game described previously. The wolves lived at a wildlife sanctuary, but were all raised for several months as puppies by their human caretaker. In addition, as adults, the wolves interacted with people every day—whether it be a familiar caretaker or groups of school children visiting the sanctuary. However, for the tests, to help minimize the chances that the wolves would perform poorly with an unfamiliar experimenter, all of the shell games were performed by their favorite caretaker who had raised them since they were puppies. What happened when the experimenter hid the food from the wolves and then tried to tell them where it was? Regardless of whether the experimenter pointed to, pointed and gazed at, or even tapped on the correct container, the wolves did not find the hidden food using the human cues. Meanwhile, all of the dogs were able to find the hidden food using at least one of the cues that the experimenter provided.

The researchers from Hungary also compared the ability of a different group of wolves and dogs to use human social cues in the shell game. Importantly, the four wolves tested had not only been raised in a human family as puppies, but also had continued to live together with a human family into adulthood. These wolves had the same amount of exposure to



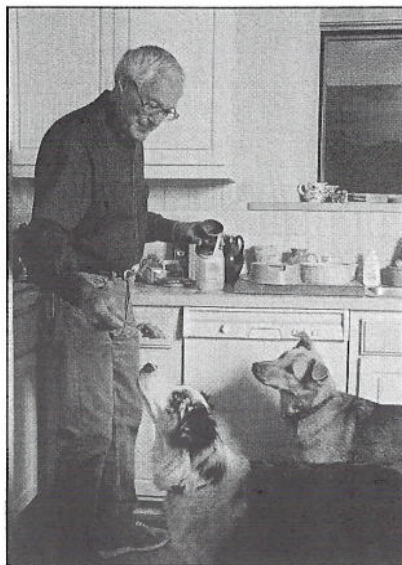
Dogs have subtle, and not so subtle, ways of communicating and learning signals.

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humans as the four dogs with whom they were compared (the dogs were raised by the same people as the wolves). Again, even after carefully controlling for exposure to humans, the four wolves were not as skillful as the dogs in using social cues that humans provided for finding hidden food. However, this research team did not stop there. They also conducted a second and perhaps even more impressive study in which they tested how often dogs and wolves would request help from humans in solving a problem they themselves were unable to solve. First, the wolves and dogs were shown that they could easily access a bowl of highly desirable food if they simply removed an obstacle between themselves and the food. Both the wolves and dogs easily solved such a problem. However, the trick was that after the subjects had learned how to obtain the food reliably, the problem was altered so that it was impossible to remove the obstacle. While the wolves worked tirelessly to access the food, continually trying new strategies for the duration of the test, the dogs instead almost immediately gave up and either approached, barked at, or stared at the experimenter—as if requesting help. This finding corroborates previous research showing that dogs will direct humans to hidden objects that they wish to obtain, such as toys or food, while showing that this ability is also not inherited from wolves. Overall, the comparisons of wolves to dogs in the various cognitive tasks used by these two teams of researchers support the hypothesis that dogs' unique abilities to use human social cues evolved during domestication and were not inherited from wolves.

However, there is one more hypothesis that could easily account for the unusual ability of dogs and rule out the possibility that domestication effected the cognitive abilities of dogs. It is possible that dogs acquire their ability to read human gestures and signals during intense exposure to humans as they grow up as puppies in human families. All the dogs tested and

compared to primates and wolves were raised in human families. They had interacted with humans for countless hours. Therefore, it is likely that the dogs that participated in the various shell games had been directed to food in their normal interactions with humans on countless occasions before they were ever tested. This would mean that just like primates and wolves, dogs also require dozens of exposures to human signals before they become proficient at utilizing them. If true, the only thing that is unusual about dogs is their intense exposure to humans and not their abilities at reading human social cues. This hypothesis predicts that dogs with little exposure to humans will show less skill at using human cues than dogs with intense exposure to humans. In addition, it also predicts that puppies' skills at using human social cues will improve dramatically as they grow older and have gained more experience with humans. However, neither of these predictions were supported when puppies were tested in the same shell game that had been used with adult dogs. Puppies who were reared in a kennel awaiting adoption by a human family were as skillful at using human social cues as those that had lived with a human family since birth and were attending obedience classes. In addition, when the performance of puppies from different age groups were compared, the youngest puppies performed as well as the oldest puppies.



Two domestic dogs waiting to be fed by their "master."

Courtesy of Corbis.

Therefore, there is no support for the hypothesis that dogs' unusual ability to use social cues is a product of intense exposure to humans during ontogeny.

Taken together, the comparisons of wolves with dogs and between various dog puppies provide no support for either of the two major hypotheses that might have potentially explained the skill dogs show in using human gestures and signals. By default, this suggests that dogs underwent evolution during domestication that effected their social cognition. The evolution not only enhanced the abilities of dogs to attend to interspecific social cues, but also has facilitated their propensity to request help from humans when they encounter an unsolvable problem. In other words, dogs could have as easily earned the nickname "the human tool user" opposed to the title of "man's best friend" if only people had known exactly why dogs are unusual relative to other animals.

What Is Domestication and Can It Cause Cognitive Evolution?

The comparisons between adult dogs, wolves, and puppies of various ages and rearing histories, suggest by default, that the ability that enables dogs to excel at reading human social cues evolved during domestication. However, these same comparisons provide no direct support that domestication might have caused the changes in the social problem-solving abilities observed in dogs. In the hope of testing the domestication hypothesis directly, these comparisons were again extended to include a population of experimentally domesticated foxes for whom all the details of their domestication were known.

First, what is meant by domestication? This might sound like a question deserving of a straightforward answer, but until a Russian geneticist named Dimitri Belyaev began experimentally to domesticate various species of mammals living on a farm in Siberia, it was unclear exactly how animals became domesticates once living in association with humans.

Before the work of Dr. Belyaev, the only certainty was that, without exception, domesticated mammals from cats to cows share a suite of changes from their wild ancestors that seemed to be a result of their association with humans. Domesticates show sweeping changes in physiology, morphology, and behavior. For example, all domesticated mammals have lower levels of stress hormones, show a -20% reduction in brain size, and have a reduction in fear response to novelty. In addition, many domesticates have higher rates of floppy ears, spotted or multicolored coats, smaller teeth and bones, and in some species even curly tails. Although all domesticated mammals seem to have experienced changes in some or all of these traits, it was long a mystery as to how this phenomenon might be explained. Is it that, over history, humans intentionally bred animals that had some combination of these traits? Or alternatively, was it that somehow all of the documented changes were actually correlated with each other: If one changes they all change as an accidental byproduct.

Luckily, the work of the late Dimitri Belyaev has helped in putting this mystery to rest. In 1959, Dr. Belyaev and his colleagues began one of the longest continuing experiments in history with the goal of experimentally domesticating foxes for the purpose of studying the behavioral genetics of domestication. Two separate populations of foxes have been maintained for the entirety of the experiment. Each year the members of the control population have been bred randomly while those of the second population have been selectively bred based on their behavior toward humans. In the selected population, only individuals who were attracted to a human experimenter, as opposed to those being afraid or aggressive, were allowed to breed.

After only 20 generations, the selected fox population began showing all the universal signs of domestication. Not surprisingly, the selected foxes became tame toward humans and

even began wagging their tails and barking at the sight of a human. However the selection didn't effect just behavior. Just as with many domesticated mammals, successive generations of selected foxes began having a higher prevalence of curly tails, floppy ears, and reduced tooth and bone size even though none of these traits were selection criteria used by the experimenters. Therefore, Dimitri Balyaev's work with the foxes demonstrated that the suite of changes associated with domestication were all correlated and incidental byproducts of selection against aggressive and fearful behavior. It is only as a result of this work that we now know that domestication is the process by which the least aggressive and fearful animals in a population survive and reproduce at higher levels when living in association with humans.

If domestication is the result of selection against aggressive and fearful behavior, is it then possible that this type of selection during dog evolution is directly responsible for the unusual social problem-solving abilities in dogs? One way to test this hypothesis is to test the experimentally domesticated foxes in the ubiquitous shell game. If the experimentally domesticated foxes are as skillful at using human social cues as domestic dogs are, then this would suggest that selection for domestication can cause enhanced problem-solving abilities in canids. This type of evidence would provide direct support for the hypothesis that dogs' unusual social cognition is a direct result of domestication.

Experiments have now shown that the experimentally domesticated foxes are as skillful as dogs and more skillful than the control foxes at using human gestures and signals when attempting to find hidden food. Therefore, it seems likely that the enhanced social cognitive abilities witnessed in domestic dogs are simply another incidental byproduct of domestication. Given that domestication caused a change in the problem-solving abilities as a result of the transition from wolf to dog, it is likely that reading human social cues played a large role in assuring the success of dogs in living together with humans. Dogs who were not aggressive and fearful toward humans were also more skilled at using their gestures and signals to predict human behavior while modifying their own behavior to the satisfaction of their human groupmates.

Summary of Research on Dog Social Cognition and Domestication

Humans and dogs have an ancient and unusual relationship. Today, in many cultures, dogs enjoy a special position in society as friends or even colleagues. At first glimpse, it seems that this interspecific relationship was all but an inevitable product of human history. However, upon closer inspection, the origin of our commensal relationship has become an evolutionary puzzle. Scientists across a number of disciplines have been working toward understanding how, why, and when dogs became so successful at living with humans. Recently, a new area of research has developed which has focused on studying the ability of dogs to solve social problems. This research has revealed that dogs have an unusual ability to read human gestures and signals in order to solve problems that would otherwise be unsolvable. Comparisons between dogs and chimpanzees dramatically illustrate how gifted dogs really are at comprehending human gestures and signals. This initial finding suggested that dogs may have been successful at spreading across the globe in part because of their unusual abilities to communicate with humans. If true, then the unusual abilities of dogs should have evolved during domestication. Therefore, a number of studies were designed to examine whether dog social cognition was effected by domestication. Comparisons between dogs and wolves demonstrate that the ability of dogs to communicate with humans is not a general ability of canids that has been inherited through common descent. In addition, studies on

dog puppies suggest that dogs do not require intense exposure to humans in order to develop their abilities at reading human social cues. Finally, a population of foxes that have been experimentally domesticated share with dogs their unusual ability to read human social cues. Taken together, these comparative and developmental studies show that dog social cognition evolved during domestication and support the hypothesis that these new abilities provided dogs with an important skill in surviving together with humans. As dogs evolved from wolves, those individuals who were less aggressive and fearful while at the same time better at predicting the behavior of humans using human social cues were the most successful at surviving and reproducing. Thus, it maybe that dogs should not only have the title of "man's best friend" but also "the human tool user."

See also Cognition—Social Cognition in Primates and Other Animals

Communication—Vocal—Referential Communication in Prairie Dogs

Domestication and Behavior

Domestication and Behavior—The Border Collie, A Wolf in Sheep's Clothing

Further Resources

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Brian Hare

Cognition Equivalence Relations

Like a computer, an animal's brain can be used as a powerful tool to bring meaning to a jumbled and disorganized array of information. One way the brain simplifies the world is through classification, or the placement of items into categories. True classificatory behavior depends on the learned equivalence or grouping of stimuli. It is well known that many animal species, including chimpanzees, monkeys, dolphins, sea lions, and some birds are capable of organizing their experience along abstract lines. They are able to respond to a certain constant dimension of an object despite variation in other dimensions. This cognitive skill is called concept formation. For example, a sea lion can do very well when