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

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

required to respond to the shape of an object, such as a triangle or a star, even when the object is altered in size or brightness. In other words, sea lions and a host of other animal species can classify stimuli according to physical attributes along dimensions such as shape. Even though many animals can sort things according to similar physical dimensions, can they classify stimuli that do not share common physical characteristics? Can they classify items and events that are connected by a common location, timing, or purpose? Can they integrate and classify information coming from different sensory channels? The answer to these questions is a very definite "yes" even though classifications according to physical dimensions may be more powerful than those based on more abstract dimensions.

There are many examples from the animal behavior literature on cognition and communication demonstrating that animals can extract meaningful or functional relationships from an assortment of different stimuli. These types of abstract classifications are called *equivalence relations*. To illustrate the importance of equivalence relations in animal behavior, let's go through the following widely different examples and determine what they have in common:

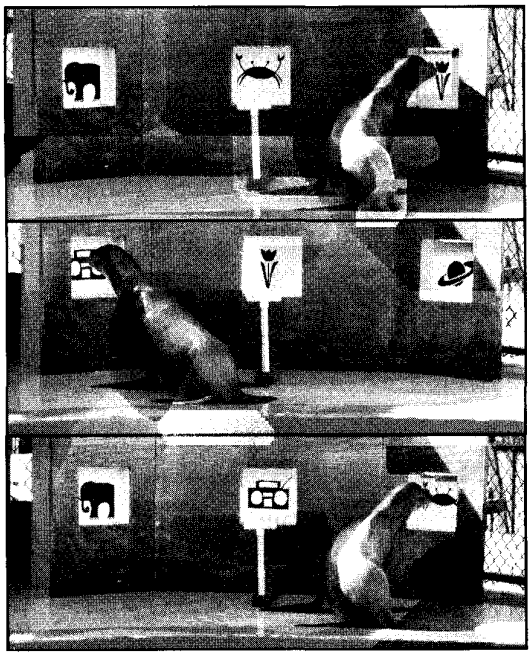
1. Dolphins *echolocate* in murky waters by emitting a train of pulsed sounds or clicks, bouncing the clicks off an object and listening for the returning echoes. In this way they can not only locate underwater objects, but they can also recognize an object echoically and differentiate it from other objects. Following echoic recognition of an object, a dolphin that is allowed to inspect objects visually but not echoically can readily learn that the previously reflected sound cues correspond to the currently reflected light cues from that same object. In other words, despite the dramatic perceptual differences in the stimuli perceived, the dolphin can learn that visual images can substitute for echoic images and vice versa because they refer to the same object. We might say that the echoic stimuli and the visual stimuli have become equivalent in terms of their meaning.

2. Alarm calls that signify particular predators are highly developed in groups of vervet monkeys living in Kenya. Large cats, including leopards, elicit loud "barks" from the monkeys; raptors elicit "coughs"; and snakes, including pythons, elicit "chutters." After recognizing a predator, a vervet gives a predator-specific alarm call, and the other monkeys in the group respond in a predictable way: Leopard calls result in listeners running and climbing into trees, raptor calls result in listeners looking up into the air and then running into thick bushes, and snake calls result in listeners standing up on their hind legs and looking down into the grass. This phenomenon has been investigated experimentally by manipulating the vervet monkeys' vocal communication system by playing sound recordings back to them from hidden loudspeakers. Researchers have concluded that the communication system is language-like in that the monkeys can substitute the predator-specific call for the sight of the predator, and vice versa, and respond appropriately to either cue. The system is analogous to referentiality in human language, where the printed or spoken word functions as a substitute for the object. Just as the spoken words "cup," "cat," and "car" invoke the meaning, or the physical embodiment, of those objects, the barks, coughs, and chutters of vervet monkeys are equivalent to the predators they are associated with.

3. Monkeys and baboons can learn to sort members of the same matriline together because genetically related individuals often share a history of common spatial, temporal, and functional interactions. Thus, when an adult female hears a juvenile scream, she will often

respond by orienting to the juvenile's mother. This behavior implies that the female has learned about the connection between the juvenile and its mother and can respond to one in the absence of the other. There is additional evidence that monkeys can differentiate both their own close companions and those of other individuals. Investigators have found that female subjects can recognize other individuals by their calls, and that they can classify the callers according to matrilineal kinship. Some monkeys can even be trained to match pictures of mothers in their social group with pictures of their offspring. This type of performance demonstrates that these animals have the capacity to classify individuals on the basis of such abstract properties as "mother–offspring pairs" or "matrilineal kinship." This capacity for abstract classification is clearly illustrated in the case of kin-based redirected aggression in vervet monkeys. If an individual in one matriline threatens an individual in another, then the relatives of those individuals may later fight with one another, acting as if they recognize that the relationship between their relatives is equivalent to their relationship with each other.

4. Male common chimpanzees acquire strong group identities, with all members of their social grouping being treated similarly. In contrast to the vervet monkeys just described, in which individuals learn to sort members of the same as well as other matrilines, group cohesion in chimpanzees frequently occurs among large groups of related males. The members of these groups share communal ranges, and these males live their entire lives within the group where they were born. Bonding between members of these patrilineal alliances is cemented by extreme cooperation and solidarity, which includes events such as mutual grooming, food sharing, the sharing of female consorts, and the exchange of other reinforcers. While interactions between members of an alliance are generally positive and aggression is tempered, the interactions between the members of different alliances can escalate into unusually hostile and violently aggressive attacks by the more numerous and stronger of the two groups. Over a period of many years, such violent attacks are known to have resulted in the complete annihilation of chimpanzee communities consisting of male groups and the females and offspring associated with them. Even inanimate objects associated with a particular group may elicit



The above photographs show an animal performing a matching-to-sample procedure, in which the subject observes the stimulus shown in the center panel (the sample) and then selects corresponding match to the sample from one of the two alternatives on either side. In this experiment, the sample and the correct match do not look physically similar so the subject must make a selection based on its previous experience with the objects shown. For example, to demonstrate the formation of an equivalence relation, a sea lion may be taught two conditional rules; following learning of these rules, the sea lion is tested to determine if other logical relationships emerge without further training. In the series of photos shown, the sea lion is trained to perform the discriminations "given crab . . . select tulip" *(top) and* "given tulip . . . select radio" *(middle). The logical inference* "given radio . . . select crab" *is tested in the final step (lower). Performance based on the equivalence of the connected stimuli predicts successful performance in the absence of additional training.*

Courtesy of Ronald Schusterman.