Constructing Animal Cognition
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Cognition refers to processes that define and operate on the relations between environment and behavior. The current study of animal cognition varies from emphasis on the specialized to the general. Scientists interested in a particular species often focus on complex cognition particular to that species. Thus, students of temperate zone songbirds are interested in song learning and migration. Other scientists are primarily interested in how closely the cognition of nonhuman animals approaches that of humans, as in the case of language (Savage-Rumbaugh et al. 1998). Still others are interested in cognition characteristic of a wide-range of species, as in the case of scalar timing and conditioning (Gallistel and Gibbon 2000). This paper considers an approach to animal cognition compatible with this range of interests, an approach based on constructing the mechanisms, function, and evolution of cognition a species at a time.

Constructing cognition in this view requires tools and information from a variety of sources. Three sources have roots in the 19th century: Ethology, learning psychology, and the physiology of perceptual-motor relations. A fourth contributor is a modern version of the art of creating artificial animals, now based in computers and robots (Taylor, this volume). The final contributor is the ancient human practice of using experience-based knowledge to view the world as though one were, in fact, a particular animal. I will call this practice theromorphism (taking the animal's view) to distinguish it from the more common anthropomorphic practice of presuming that the cognition processes of human and nonhuman animals are fundamentally the same, and from the even more common idiomorphic practice of presuming that cognition processes of other beings, regardless of species, are identical to one's own. In what follows I briefly outline what each source potentially contributes to the study of animal cognition.

Ethology

Ethologists grounded animal cognition in careful observation of the development, control, and vigor of naturally occurring behavior. Influenced by naturalists like von Uexküll (1957), they were also concerned with the animal's view of the world. In an influential paper on the "umwelt "of an animal, von Uexküll (1957) combined his personal observations with information on the physiology of receptors to create pictures of the sensory world of animals ranging from mollusks to flies and dogs. Ethologists like Tinbergen (1951) created more dynamic scenes by carefully observing naturally occurring sequences of behavior, dividing them into interlocking sets of perceptual-motor units (critical releasing stimuli and species-typical responses). By manipulating characteristics of the releasing stimuli, they explored mechanisms controlling the occurrence and intensity of responses. For example, after carefully illuminating the courtship dance of male and female sticklebacks (a small temperate zone fish), Tinbergen (1951) performed experiments using artificial "models" of males and females to clarify mechanisms underlying perceptual-motor organization.

Based on both observations and experiments, Tinbergen (1951) summarized the reproductive behavior of male sticklebacks in a hierarchical, motivational model. This model divided the perceptual-motor units into repertoires associated with different motivational states (feeding, migrating, territory defense, courtship, and parental behavior), which were determined by the current stimulus conditions and previous state. Though he did not extend his modeling efforts beyond this example, other investigators developed motivational systems of fear, aggression, parental behavior, and feeding (see Eibl-Eibesfeldt 1975).

In short, ethology established the importance of careful observation of naturally occurring behavior and showed the value of experimental manipulation of critical stimuli in clarifying the control of perceptual-motor units. Based on observation and experiment, ethologists developed functional models relating stereotyped responses, stimulus filters, and motivational states. Finally, ethologists showed how classical evolutionary comparisons