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Animal Cognition

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Animal cognition comprises the mental mechanisms through which animals acquire, process, and use information to generate adaptive responses. Typically, researchers use animals' observable behavior to infer their mental processes. A basic function of cognition is to enable animals to use information in a flexible, goal-directed manner.

History

Using anecdotes from many species, [Romanes \(1882\)](#) concluded that intelligent thought could be found in almost every animal species. However, [Thorndike \(1898\)](#) rejected Romanes's anecdotal approach and conducted systematic experiments that upheld his view that animals learn by trial and error. Soon afterwards, [Köhler \(1925\)](#) argued that trial and error alone could not fully explain chimpanzee problem-solving in spatial and tool-using tasks, arguing that insight is also required. The stage was set for the clash of two psychological systems that would dominate most of the 20th century: *behaviorism* and *cognitivism*.

Behaviorists such as [Watson \(1913\)](#) and [Skinner \(1938\)](#) argued that behavior is reflexive and shaped by external reinforcement. Cognitivists like [Tolman \(1948\)](#) argued that animals are capable of mental representation and inference. Since then, the lines between the two schools have blurred: most researchers accept that animals form representations, but there remains disagreement on the relative importance of representations and associative processes. Animal cognition expanded significantly in the late 20th Century, encompassing subfields such as social intelligence (see, e.g., [Premack & Woodruff, 1978](#)) and language and communication (e.g., [Cheney & Seyfarth, 1985](#)) [see [Animal Culture](#)].

Core concepts

Cognition confers flexibility to organisms. There are five key concepts that foster this flexibility.

Representation is the process of encoding and, in many cases, storing information. Representation allows animals to make decisions beyond the information they currently perceive, such as holding expectations about a particular outcome based on previous experience.

Association, crucial for various forms of learning, entails establishing and storing connections between stimuli and possible responses for the positive or negative consequences these stimuli may confer.

Inference consists of connecting and recombining disparate stimuli and representations to make predictions. This is important for problem-solving, enabling animals to reason and reach novel conclusions.

Abstraction denotes the formation of representations, or concepts, applicable to distinct exemplars despite their differences in basic features. Underlying abstraction are the *relations* between stimuli, which can be first order ($A = A$ or $A \neq B$) or second order ($AA = BB$ or $AB \neq BB$).

Questions, controversies and new developments

Most controversies in animal cognition revolve around the nature of the representations underlying behavior or the processes supporting the production of novel responses. For instance, in tasks to investigate whether animals represent other individuals' mental states, some authors maintain that animals use behavioral rules based on observable behavior ([Povinelli & Vonk, 2003](#)), while others assert that some species go beyond this, representing other individuals' psychological states (e.g., goals) ([Call & Tomasello, 2008](#); [Krupenye & Call, 2019](#)) [see [Theory of Mind](#)].

Another set of controversies contrasts cognitive and non-cognitive processes. For example, some authors have argued that animal vocalizations lack intentionality and are solely tied to internal emotional states, whereas others proposed that vocalizations refer to external entities ([Graham et al., 2019](#)). Although it is now widely accepted that some vocalizations have a referential component, there is disagreement about its nature.

Some controversies center around the taxonomic distribution of a particular ability. For instance, some authors maintain that only great apes exhibit mirror self-recognition, while others argue that elephants, dolphins, and some birds show it too ([Gallup & Anderson, 2020](#)). At the core of this controversy lie the different methods used across species. Although there is agreement on the necessity of adapting methods to achieve a broad comparative scope, there is much argument over what constitutes a valid method or a diagnostic response.

One new development is social network analysis: the study of groups as a function of the relationships between individuals. This method is based on the axiom that the role an agent plays within its social sphere and the links between this agent and others will be determinants of the agent's behavior and evolutionary fitness ([Freeman, 2004](#)).

Another contemporary topic is metacognition—the monitoring of one's own cognitive states—which first appeared in comparative circles in the 1990s and has since experienced a boom in research interest. Since researchers cannot use verbal self-reporting to study metacognition in animals, they have devised other methods including the uncertainty-response task ([Smith et al., 1995](#)).

Traditional data collection methods have now been complemented with technologies such as thermal imaging to study animal arousal ([Barraault et al., 2022](#)) and eye tracking to study attention ([Lewis and Krupenye, 2022](#)). There are also novel ways of coding data—for example, DeepLabCut, a system that uses neural networks to analyze animal poses, is being used to code gestural communication automatically ([Wiltshire et al., 2023](#)). Artificial intelligence is also at the forefront of research in other ways—for instance, dynamic compositional strategy models are used to analyze observed behavior patterns.

Broader connections

Animal cognition is related to multiple disciplines in the natural, social and technological sciences. The connections with evolutionary biology and developmental psychology are particularly strong; cognition, after all, is often involved in the production of adaptive responses during evolution and ontogeny. These disciplines often share conceptual frameworks and methods.

Connections with social sciences have been strengthened in recent years, particularly with linguistics and economics. Some linguists are interested in what kind of communication is possible without language and what are the evolutionary building blocks of language ([Amphaeris, Shannon, & Tenbrink, 2021](#)). Comparative researchers have adapted paradigms originally developed by economists to investigate how animals make decisions and what are the evolutionary roots of human economic decisions ([Wood, Kim & Li, 2016](#)).

Finally, the study of the relationship between biological and artificial cognition is gaining momentum. Artificial intelligence researchers are building computational models of animal behavior, using artificial agents to simulate behavior and contrasting the outcomes of their simulations against the responses of biological agents. Moreover, the neuronal architecture of animal intelligence offers an excellent springboard to develop artificial algorithms ([Hassabis et al., 2017](#)).

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