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Editorial overview: Comparative cognition

Jessica F Cantlon and Benjamin Y Hayden

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Jessica F Cantlon

Benjamin Y Hayden

Brain and Cognitive Sciences, Center for Visual Science, and Center for the Origins of Cognition, University of Rochester, Rochester, NY 14627, United States
e-mail: jcantlon@rcbi.rochester.edu

Jessica Cantlon is an associate professor of Brain & Cognitive Sciences at the University of Rochester, NY. Her lab is interested in the evolutionary and developmental origins of concepts, with a focus on numerical and spatial computations. Her research takes an integrative approach by comparing behavior and patterns of neural activation across species and stages of development, with the goal of understanding the shared and distinct principles of conceptual organization in humans and other animals.

Benjamin Hayden is an associate professor of Neuroscience and in the Center for Magnetic Resonance Research at the University of Minnesota. His lab is especially interested in the how we value influences our foraging decisions. They approach this question from the converging perspectives of

Animal cognition is a venerable field of inquiry, with antecedents in the nineteenth century, and in ethology, and evolutionary anthropology, psychology, and field biology. The field has a rich tradition of providing elegant causal explanations of behavior at multiple levels of analysis. Some researchers seek to discover the mechanistic and computational bases of behavior [1,2]. For others, the scientific goal is to understand the proximate and ultimate causes of behaviors by systematically comparing cognition in species with shared versus distinct phylogenies and environmental pressures [3]. And for still others the scientific goal is to understand the natural history of human cognition, and its evolutionary foundations [4]. Beyond these bases, many scholars seek to understand the behaviors of model organisms for neuroscience, and as models of psychiatric disease [5]. All of these pursuits are interrelated, and each is necessary in order to explain the complex causes of behavior, and determine how human minds are built.

The role of animal cognition research in modern science is ever more critical as scientists adjust to new technologies for measuring the neural bases of behavior. New molecular techniques are revolutionizing neuroscience, neural networks are transforming artificial intelligence and cognitive science, futuristic imaging techniques are enhancing psychology, and robotics seems tangibly close to self-driving cars. But despite the excitement, these areas are experiencing a crisis of confidence. These fields are bumping up against hard limits on their interpretations of the data, and many discoveries are proving to be sterile, because we lack a sophisticated understanding of behavior (see discussion in [6,7]). As a consequence, advocates of those fields have recently taken a turn toward understanding behaviors, and the situations in which they arise. And that in turn means understanding animals in their environments, including humans in our ancestral environment.

In our view, then, animal cognition forms the foundation of neuroscience, psychology, and artificial intelligence [8]. It always has been central to those endeavors, but its importance has taken on a renewed vigor because of the critical importance of behavior to advances in new fields. At the same time, comparative cognition is also, not coincidentally, undergoing a renaissance. It has taken new ideas from its adjacent fields and built on them, and has continued to evolve internally in exciting new directions (e.g. [9–13,19]). Furthermore, new technologies are improving the ability to measure behavior precisely, even in the wild (e.g. [14,15]). As such, comparative cognition is experiencing a renewed vigor and growth, as old mysteries are resolved or reframed, and new questions are being asked. These puzzles have taken on a new importance as the foundation for new types of inquiries, but remain fascinating in their own right.

neuroscience and comparative psychology in rhesus macaques. He is particularly interested in how decisions are affected by natural contexts by how uncertainty, and curiosity, and self-control influence choices, and how evolution shapes decision-makers' minds and brains.

Using laboratory and field observations, and tools from psychology, biology and neuroscience, animal cognition researchers have examined the mechanisms and computations underlying a variety of behaviors, often with surprising results. Seemingly complex behaviors can be explained by simple cognitive processes and heuristics, and solutions that non-human animals devise can differ from those of humans, but can sometimes be more efficient or elegant. Insights from animal research reveal that the underlying causes of behavior are often counter to our human intuition (e.g. [16–18]).

One area of growth has been the development of novel model organisms. Scientific ideas that were developed to help understand the most well-studied species are now sufficiently established that insights from those species can be used as a foundation to understand other, less well-studied species. Our special issue highlights some of these new frontiers. Wilkinson et al. explore reptile cognition (Wilkinson), Mather and colleagues look at cephalopods (Mather et al.), Range et al. review canine cognition (Range et al.). Chittka considers cognition in honeybees (Chittka et al.) and Brown examines cognition in fishes (Brown et al.). And, finally, Hopper and colleagues consider advances in animal cognition research from the perspective of the rich resources that zoos offer (Hopper).

Other authors take on issues beyond the domain of animal cognition, but made possible by its recent successes. For example, Yorzinski considers the ability of individuals to recognize each other (Yorzinski). Beck shows the mutually informative insights that are drawn by comparing the cognition of children and animals (Beck et al.). And Marshall looks at a very new and exciting research area, collective decision-making (Marshall et al.). Other scholars in our issue probe the intersection of animal cognition and applied fields: urbanization (Griffin et al.), animal welfare (Mills et al.), and conservation (Marzluff et al.). In all three cases, authors reveal how advances in animal cognition provide new perspectives on these real world problems.

Finally, a number of authors take a look at some more classic problems in comparative cognition, but look at how they have been improved and developed by new scientific insights. For example, Sulikowski looks at the psychology of foraging decisions (Sulikowski et al.), Heilbronner considers the effects of risk and uncertainty of decision-making (Heilbronner), and O'hara looks at avian problem-solving (O'hara et al.). Likewise, Lee considers an area that has fascinated psychologists for a hundred years, the mechanisms of spatial cognition, and integrates recent empirical discoveries under a deepening theory of spatial representation (Lee et al.). Morand-Feron presents new insights into the origins of associative learning (Morand-Feron et al.) and Nieder compares the mechanisms and neural bases of numerical cognition in corvids and primates, a research area that has advanced significantly over the past 20 years (Nieder). On the hardware side, two anatomists look at the comparative evolution of animal brains (Herculano Houzel) and human brains (Sherwood et al.). Finally, Gunturkun examines links between cognition and brain size across species (Gunturkun et al.).

The contributions to this special issue represent the many levels of analysis and explanation available for the study of behavior. All of these approaches have been incubated and refined by animal researchers, with cognition at the nexus between brain and behavior. The rich theoretical and methodological traditions of comparative cognition research will be an important bridge between behavior and the interpretation of neural signals. The study of animal cognition will tell us how various species (including humans) behave in ways that are well adapted to their environments, while also retaining robust flexibility. These endeavors are central to answering three essential questions in modern science: how behavior is caused, how it is implemented by the brain, and what it means to be human.

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