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Introduction to the Special Issue on Neuroethology

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This special issue highlights some recent advances in neuroethology based on research presented at the 13th International Congress of Neuroethology and associated satellite symposia in Brisbane, Australia, on July 15–20, 2018. The discipline of neuroethology combines methods and concepts from ethology with those from neurobiology to develop a comparative analysis of the mechanisms of behavior that takes into account a species' ecology and evolutionary history. In his 1951 book *The Study of Instinct,* Nobel Prize winner Niko Tinbergen called on ethologists and neurophysiologists to join forces to search for mechanisms of motivated behaviors. He used the term "ethophysiology" to describe this integrative research approach, which he felt was crucial for developing a full understanding of behavior in all its complexities. At that time, "the ethologists were as naive about the neurophysiological significance of their findings as the neurophysiologists were about the behavioral implications of theirs" (Hoyle, 1984, p. 371). To rectify these limitations and to move forward, some of the earliest neuroethological research focused on understanding cellular mechanisms underlying the ethological concepts of releasers (sign stimuli) and fixed action patterns in species such as locusts and toads (Ewert, 1980; Hoyle, 1984). The breadth of neuroethological research soon expanded to include many other species, particularly those with distinct sensory or motor specializations (echolocating bats, electric fish, barn owls; Ewert, Capranica, & Ingle, 1983), as well as to understand neural mechanisms of more "general" behaviors, such as learning, memory, navigation, and communication. Molecular genetic, anatomical, and computational approaches are also part of the neuroethologist's toolbox.

The overarching goal of a neuroethological approach, regardless of the particular species studied and the particular tools used, is to take advantage of evolutionary solutions to biological problems to identify both behavioral adaptations and underlying cellular and genetic mechanisms. Contributions to this special issue emphasize that a neuroethological perspective, combining behavioral, neurobiological, and computational tools, can contribute to major advances in behavioral neuroscience.

Much early work in neuroethology focused on motor control, and in this light the special issue begins with an analysis by Montgomery and Perks (2019) of common principles in the organization and operation of the cerebellum throughout vertebrate evolution. The computational role of the vertebrate cerebellum as an array of adaptive filters has its origins in the cerebellar-like structures found in the hindbrains of jawless fish. Montgomery and Perks describe conserved features in these cerebellar-like structures and in the cerebellum per se, and model how these features operate in sharks and in electric fish to cancel reafferent noise generated by the animal's movements and facilitate the processing of environmental stimuli. Finally, they propose that the same principles of cerebellar noise cancellation identified in these aquatic species can be applied to understanding adaptive motor patterns for song production in songbirds and speech production in humans. Montgomery and Perks's interweaving of evolutionary and computational data to address the control of basic motor behaviors highlights valuable insights to be gained from a comparative, neuroethological approach.

Continuing the discussion of electric fish as a model neuroethological system, Milam, Ramachandra, and Marsat (2019) focus on the sensory side, and attempt to identify common principles in how the nervous system localizes sensory signals of biological importance. As they argue, "comparing solutions across modalities and species can reveal core principles of a mechanism and key adaptation permitting new functions" (p. 282). Indeed, mechanisms by which the weakly electric knifefish form a spatial image of their environment have strong analogies with spatial localization in the vertebrate visual system (by use of topographic mapping) and auditory system (by means of computing differences in inputs from bilateral sensory receptors).

Electroreception is an active sense in which an electric organ produces discharges that are transmitted into and modified by the environment, then picked up by electroreceptors on the fish's body and processed to determine the identity and location of objects in its surroundings. The third article in this special issue, by Shriram and Simmons (2019), discusses another active sensing system: echolocation. Big brown bats emit ultrasonic signals through their larynx and sense their environment by processing the returning echoes using time-domain codes. Echoes are not exact replicas of the transmitted sound but are modified by the properties of the ensonified object. These modifications are called echo highlights,

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or target glints. The features of echo highlights allow them to serve as signatures for particular objects. Shriram and Simmons probe with psychophysical methods how bats identify and classify these glints. Their results suggest that big brown bats use a processing scheme to classify target glints that is similar to that for another echolocating mammal, the bottlenose dolphin, despite the vast differences in the ecologies of these animals and in how they produce echolocation sounds. This is an example of how a comparative neuroethological approach can reveal a common principle in evolutionarily diverse species.

The next three contributions consider vocal communication from a neuroethological perspective. Bats not only echolocate but also use acoustic signals for social communication. Salles, Bohn, and Moss (2019) review the behavioral and neurophysiological literature on acoustic communication in different bat species. Most bats live in social groups and use sounds to communicate distress, stress, and aggressive intent. Infant isolation calls may contain a vocal signature to allow the mother to identify her offspring within a large roost. It is interesting that like songbirds, bats adapt their calls in response to what they hear and show evidence of vocal learning. Echolocating bats can therefore serve as a new mammalian model to address conceptual questions regarding the extent to which animal acoustic social signals may function as rudimentary communication systems as well as to address mechanistic questions of how complex sound sequences are encoded and retrieved in the brain.

Like bats, marmoset monkeys are social and highly vocal, using sounds to communicate affiliative or aggressive intent, as well as location. Dohmen and Hage (2019) report data from an interactive playback experiment designed to examine the extent to which marmosets take turns when producing contact calls. Turn-taking in human conservation requires precise timing and cooperation between speakers, and understanding this behavior in animals can shed light on the evolution of vocal flexibility. Dohmen and Hage show that in marmosets, some features of turn-taking are stable whereas others vary across behavioral contexts. They suggest that turn-taking is affected by internal arousal and the external context but also is under some degree of cognitive control.

Of particular importance in neuroethological research is the refinement of noninvasive techniques suitable to studying whole-brain function in a variety of species. One such technique is manganese-enhanced magnetic resonance imaging (MEMRI). This imaging technique has better spatial resolution than does functional MRI, and because it reduces the confound of high background scanner noise, it is advantageous for studying auditory pathways. Ringler, Coates, Cobo-Cuan, Harris, and Narins (2019), for the first time, use MEMRI to identify areas of the leopard frog brain that differentially respond to the male's advertisement call. Consistent with prior invasive neurophysiological research, they find that the auditory midbrain is specialized for processing these conspecific sounds; further, they also show that areas involved in reward also differentially activate to these same stimuli. Widespread use of the MEMRI technique can help address theories of brain function and behavior using longitudinal designs or in rare, exotic, and endangered species.

The articles in this special issue of *Behavioral Neuroscience* offer a broad selection of modern perspectives and research findings in the field of neuroethology. These articles not only highlight exciting recent discoveries in neuroethology but also point to important open questions, which serve to inspire new lines of investigation for scientists working in the field of behavioral neuroscience.

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Correction to Simmons and Moss (2019)

In the article "Introduction to the Special Issue on Neuroethology," by Cynthia F. Moss and Andrea M. Simmons (*Behavioral Neuroscience*, 2019, Vol. 133, No. 3, pp. 265–266, http://dx.doi.org/10.1037/bne0000327), the order of authors was reversed. The correct order of authors is Andrea M. Simmons and Cynthia F. Moss. The online version of this article has been corrected.

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