Auditory-vocal “mirror” neurons in songbirds: circuit mechanisms, the role of experience, and links to learning and communication

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Imitation is an essential engine for propagating human culture, enabling people to transmit art, music, speech, and language from one generation to the next. The young child’s ability to vocally imitate the speech of parents and peers is arguably one of the most essential forms of learning for human societies, because it provides the foundation for spoken language. The sensorimotor interactions that underlie human speech learning and communication remain poorly understood. An emerging idea is that sensorimotor neurons selectively active during both the execution and observation of specific gestures (i.e., mirror neurons) could play an important role in the learning, perception and production of speech and language. Given that non-human primates do not learn their vocalizations, an important goal is to develop a suitable animal model in which to search for auditory-vocal mirror neurons and explore how they function to enable learned vocal communication. Songbirds afford two great advantages in attaining this goal. First, they are one of the few non-human animals to communicate using learned vocalizations. Second, the neuronal circuitry for singing and song learning, known as the song system, is well described and amenable to cellular and synaptic level analyses. These features render the songbird an exceptional organism in which to search for auditory-vocal mirror neurons, to explore their involvement in learned vocal communication, to analyze the synaptic and circuit mechanisms that give rise to their complex sensorimotor properties, and to explore how experience shapes the functional properties of these neurons. Our group has used chronic recordings in freely vocalizing wild songbirds to identify individual neurons that display a systematic auditory-vocal correspondence, reminiscent of mirror neurons. Through field studies, we have forged a link between the auditory response properties of these neurons and song perception. Using intracellular recordings made in brain slices, anesthetized and even singing birds, we have begun to uncover synaptic and circuit mechanisms that give rise to these complex neural properties. Finally, we have used in vivo multiphoton imaging methods to explore how auditory experience affects the structural and functional properties of these neurons, and are using optogenetics to explore how the activity of these neurons contributes to song learning. In addition to discussing the results of these experimental studies, consideration will be given to how the activity of auditory-vocal mirror neurons is likely to be harnessed for vocal learning and communication.