Brain evolution of complex behavioral traits: vocal learning and spoken language

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Understanding the evolution and mechanisms of how brain pathways for complex behaviors evolve has been mysterious. One such trait is vocal learning, which is critical for song in song learning birds and spoken language in humans. Vocal learners have forebrain to brainstem vocal control systems, whereas vocal non-learners only have brainstem vocal systems. We found that the specialized song learning systems of song-learning birds (songbirds, parrots, hummingbirds) are embedded within an ancient vertebrate motor system that controls limb and body movements. The song learning and adjacent motor systems share many features in common, including motor-driven gene expression networks, and an anterior pathway necessary for motor learning and a posterior pathway necessary for production of learned movements. In addition, the song and speech learning pathways show convergent expression changes in axon guidance molecules and other genes in song-learning birds and humans. To explain these findings, I propose a motor theory of vocal learning origin, where ancient brain systems used to control movement and motor learning gave rise, by brain pathway duplication, to brain systems to learn and produce song and spoken language. The duplicated motor system is connected to muscles of the vocal organ to control a specialized form of learned movement control - song and speech, which has specialized changes in genes involved in neural connectivity and neural activity. The auditory-motor connectivity of the vocal learning system in turn influences the adjacent motor system to allow vocal learners to synchronize their body movements to rhythms in sounds heard, to learn to dance. In this manner, the evolution of brain pathways for vocal learning have evolved independently of a common ancestor, but dependent on a pre-existing motor learning pathway scaffold that then diverged.

References:

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