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Biologic and physiologic foundations of speech motor control

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Our still-incipient understanding of speech motor control relies heavily on decades of expertise in a wide range of related disciplines. Sponsored jointly by the American Speech-Language-Hearing Association and the National Institute on Deafness and Other Communication Disorders, four internationally recognized leaders in orofacial motor control, sensorimotor integration, speech development, and effects of aging on speech production, came together at the 2005 15th Annual Research Symposium. The four articles in this issue were generated directly from these presentations. Researchers in orofacial neurophysiology (James Lund), oromotor development (Steven Barlow), speech motor control (Anne Smith), and cognitive neuroscience (Frank Guenther) synthesize research in their labs with respect to the functional framework for speech production, ranging from brainstem mechanisms to cortical influences, from neuropathology to normative physiologic changes across the lifespan. These scientists have built the bridge between the lab and the clinic, describing how well-understood physiologic mechanisms can influence clinical approach.

James P. Lund, Dean of the Faculty of Dentistry, McGill University, addresses the persistent question of the relationship between speech and such well-modeled behaviors as respiration and mastication. Respiration and mastication are primitive but complex movements that are both rhythmic and highly variable. The rhythms are produced by brainstem central pattern generators (CPGs) under the control of higher centers and sensory feedback. Feedback control of the respiration is overridden during speech, while mastication must be suppressed to allow intelligible speech. The incompatibility of speech and mastication is clearly physical, but it is also likely that that speech commands to facial, tongue, and jaw muscles pass through the masticatory CPG. Lund describes the intrinsic and circuit properties of the CPG, and roles of primary afferents in masticatory patterning.

Steven M. Barlow, Professor and Director of the Communication Neuroscience Laboratories, University of Kansas, discusses early emerging patterned orofacial movements (e.g., mastication and sucking) with respect to the emergence of other complex orofacial motor behaviors. These patterned behaviors in humans are numerous, varying across the lifespan in their complexity and dynamics. Of particular clinical and scientific interest are the emergent characteristics of orofacial motor control and sensorimotor integration in premature neonates and infants, and in a range of other populations including: children

undergoing surgical reconstruction of the lower face, young and older healthy adults, and individuals with progressive neuromotor disease. Control dynamics of patterned behaviors are also described in this paper, which summarizes the experimental results of probes delivered using external mechanical loads.

Anne Smith, Distinguished Professor and Head, Speech, Language, and Hearing Sciences, at Purdue University directly addresses some of the essential questions in the development of speech motor control. How do children learn to control the complex sequences of movements that are required to produce speech? Do boys and girls learn speech motor skills at the same rate? How do speech movements, sculpted in time and space by the nervous system, “attach to” units of language? In developmental speech and language disorders, do problems in the language domain affect the speech motor system, and conversely do problems in the speech motor domain affect language processes? The answers to these questions are far-reaching, influencing the most basic models of speech production as well as day-to-day treatment decisions.

Frank Guenther, Associate Professor of Cognitive and Neural Systems, Boston University, describes a model of speech motor control that hypothesizes a feedforward control system, involving premotor and primary motor cortex and cerebellum, working in concert with auditory and somatosensory feedback control systems involving auditory and somatosensory cortical areas as well as premotor/motor cortex. This description is extended to new speech sounds as they are learned by first storing an auditory target for the sound, then using the auditory feedback control system to tune feedforward commands for producing the sound with practice. The model accounts for a remarkably wide range of kinematic, acoustic, and neuroimaging data.

Taken as a collection, these papers provide a remarkably broad perspective on speech motor control. A relatively well-understood neural infrastructure can be brought to bear using complex models of learning and impairment; interactions of higher level cognitive and linguistic function can be used to explicate the constraints and influences imposed by related systems; and development is shown to provide a window to the patterned behaviors that may influence speech production.

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