Internal estimation for speech control

Dr. Xing Tian, xing.tian@nyu.edu; Prof. David Poeppel, david.poeppel@nyu.edu
Department of Psychology, New York University

Optimal control of speech production requires a process of internal estimation to predict the auditory consequences of planned action/articulation (Guenther, 1995; Guenther et al, 1998, 2006; Hickok, 2011; Hickok et al, 2012; Houde & Najarajan 2011; Price et al, 2011; Rauschecker & Scott, 2009; Tian & Poeppel, 2010, 2012). We present three MEG studies - using mental imagery of speech as a model - to demonstrate the computational architecture of internal estimation during speech production. Our findings suggest that internal estimation during speech production is a sequential process, in which, initiated by a motor plan (reflected in pre-motor and parietal activation patterns), an initial somatosensory estimation (parietal activation) is followed by the auditory estimate of a target (temporal activation) (Exp. 1, Tian & Poeppel 2010). We show that common neural substrates in auditory regions underlie both auditory estimation and perception; and we demonstrate that the auditory estimation derived from the internal simulation of articulation increases the sensitivity of auditory responses to subsequent perception (Exp. 2; Tian & Poeppel, in press). The results of the comparison between auditory estimation and feedback are expressed as changes in the magnitude of early auditory responses, and such comparisons are constrained by the differences in spatial and temporal features (Exp. 3, Tian & Poeppel, under review). In summary, internal estimation and internal-external interactions provide the neurocomputational foundations for the temporally precise monitoring and finely graded online control of speech production.

Guenther, F. H. (1995). Speech sound acquisition, coarticulation, and rate effects in a neural network model of speech production. *Psychol. Rev., 102*(3), 594-620.

Guenther, F. H., Ghosh, S. S., & Tourville, J. A. (2006). Neural modeling and imaging of the cortical interactions underlying syllable production. *Brain Lang., 96*(3), 280-301.

Guenther, F. H., Hampson, M., & Johnson, D. (1998). A theoretical investigation of reference frames for the planning of speech movements. *Psychol. Rev., 105*, 611-633.

Hickok, G. (2012). Computational neuroanatomy of speech production. *Nat. Rev. Neurosci., 13*(2), 135-145.

Hickok, G., Houde, J., & Rong, F. (2011). Sensorimotor Integration in Speech Processing: Computational Basis and Neural Organization. *Neuron, 69*(3), 407-422.

Houde, J. F., & Nagarajan, S. S. (2011). Speech production as state feedback control. *Front. Hum. Neurosci., 5*(82). doi: 10.3389/fnhum.2011.00082

Price, C. J., Crinion, J. T., & MacSweeney, M. (2011). A Generative Model of Speech Production in Broca's and Wernicke's Areas. *Frontiers in Psychology, 2*(237), doi:DOI: 10.3389/fpsyg.2011.00237

Rauschecker, J. P., & Scott, S. K. (2009). Maps and streams in the auditory cortex: nonhuman primates illuminate human speech processing. *Nat. Neurosci., 12*(6), 718-724.

Tian, X., & Poeppel, D. (2010). Mental imagery of speech and movement implicates the dynamics of internal forward models. *Frontiers in Psychology, 1*(166), doi:DOI: 10.3389/fpsyg.2010.00166

Tian, X., & Poeppel, D. (2012). Mental imagery of speech: linking motor and sensory systems through internal simulation and estimation. *Front. Hum. Neurosci., 6*(314). doi: 10.3389/fnhum.2012.00314

Tian, X., & Poeppel, D. (in press). The effect of imagination on stimulation: the functional specificity of efference copies in speech processing. *J. Cogn. Neurosci.*

Tian, X., & Poeppel, D. (under review). Dynamics of self-monitoring and error detection in speech production: evidence from mental imagery MEG.