ADVANCES IN MODELING SPEECH PRODUCTION AS STATE FEEDBACK CONTROL

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For several years now, our lab has been examining how well state feedback control (SFC) models the control of speaking (Houde and Nagarajan, 2011). In brief, speaking involves changing the dynamical state (the position and velocity) of the vocal tract articulators and in SFC, speech is controlled by maintaining a running estimate of this dynamical state. Importantly, this state estimate is maintained entirely within the CNS, with sensory feedback exerting only a corrective influence on this internal estimate.

Our prior work has shown how SFC accounts for many of the behavioral phenomena associated with the role of sensory feedback in speech production as well as many of the neural phenomena associated with sensory processing during speaking (Houde et al., 2014). We are now examining how SFC accounts for the abnormal speech feedback processing seen in various neurological conditions. We have found that many conditions are associated with abnormally large compensatory responses to unexpected pitch (16p11 autism, Alzheimer's disease, and cerebellar ataxia) and formant (cerebellar ataxia) feedback perturbations, as well as abnormally small adaptive responses to sustained formant feedback alterations (16p11 autism, cerebellar ataxia). These results suggest a degree of independence between the mechanisms mediating long-term sensorimotor adaptation and the mechanisms generating immediate compensatory responses. In cerebellar ataxia in particular, simulations with our SFC model have led us to hypothesize that cerebellar damage principally only affects the internal predictive models governing sensorimotor adaptation, and that the large compensatory responses we observe result from a subsequently-learned over-reliance on sensory feedback.

Most recently, we have also begun to develop a hierarchical extension of SFC by combining it with the Task Dynamics (TaDA) model of speech production (Ramanarayan et al., 2016). In the combined model, gestural scores of the TaDA model drive the state feedback control law governing utterance production, and current vocal tract state is expressed in terms of task (constriction) state, which is estimated from both somatosensory and auditory feedback. The resulting model combines the strengths of both TaDA and SFC: it accounts for the sensitivity that speakers exhibit to changes in sensory feedback (including auditory feedback), and it is able to generate a more complete range of speech output.

References

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