

# Discovering task dynamics for tongue shape

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What is the nature of the laws that govern articulatory control? A widespread approach is to propose simple dynamical models that capture the temporal evolution of articulatory variables, such as simple articulatory signals (e.g. tongue tip movement) or tract variables (e.g. tongue tip constriction degree) (Fowler 1980; Kelso et al. 1986; Browman & Goldstein 1992). The fundamental goal in this enterprise is to identify the hypothesized ‘laws of speech’ that govern the control of abstract linguistic events.

While early research proposed simple linear dynamical models (Saltzman & Munhall 1989), these do not show good quantitative fits to empirical articulatory data. This has led to a number of proposed adaptations, including time-varying activation (Byrd & Saltzman 1998), nonlinearity (Sorensen & Gafos 2016; Stern & Shaw 2025), under-damping (Kirkham 2025a), physical scaling (Kirkham 2025b), and entirely non-autonomous models (Elie et al. 2023). Despite their differences, these approaches share a common assumption: speech involves the control of low-dimensional variables, such as tract variables or simple articulatory dimensions. This assumption underpins a widespread hypothesis in human motor control (Bernstein 1967), yet dimensionality reduction is often presupposed rather than directly evidenced. In this study, I take a different approach: rather than assuming low-dimensional control by focusing on one-dimensional articulatory signals, I instead investigate whether we can discover hypothesized low-dimensional control signals for whole tongue shape dynamics directly from data.

I extend a data-driven model discovery algorithm previously applied to single fleshpoints and tract variables (Kirkham 2025a; Kirkham & Strycharczuk 2025) to time-varying ultrasound tongue contours. Preliminary results reveal that a simple linear model captures 2–3 dimensions governing the spatiotemporal dynamics of tongue shape variation, with interpretable parameters including stiffness, damping, and phonetically-relevant tongue shape targets. This stands in contrast to single-point analyses, where nonlinear terms are required in approximately one third of cases (Kirkham 2025a). The observation that articulatory dynamics simplify in shape space suggests that nonlinear control of movement may not be cognitively specified as part of phonetic planning. Instead, nonlinear movement characteristics emerge from the projection of a high-dimensional biomechanical system onto a low-dimensional measurement, highlighting the fundamentally embodied nature of articulatory control (Perrier et al. 2003; Šimko & Cummins 2010; Gick & Stavness 2013).

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