Gradient co-activation of articulatory phonological representations in speech errors

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Recent studies based on phonetic measurements of speech errors show that there is gradience in speech errors. Specifically, the acoustic and articulatory properties of speech errors reflect a gradient combination of the intended target and the error outcome (for recent reviews, see Goldrick et al. 2011; Pouplier & Goldstein, 2010).

The question that this study aims to address is what mechanisms give rise to gradience in speech errors. Previous studies have suggested several possible explanations, including a low-level feedback mechanism leading to partial correction during articulation (Pouplier & Goldstein, 2010), partial transition from less stable gestural couplings (i.e., alternation of two consonants in a tongue twister) to more stable coordination modes in a coupled oscillator system (Goldstein et al. 2007), and gradient coactivation of target and error representations during production (Goldrick & Blumstein, 2006; Pouplier, 2007; McMillan et al. 2010).

This paper explores this third mechanism – gradient coactivation. We consider this phenomenon within the framework of Articulatory Phonology (AP; Browman & Goldstein, 1986 et seq.). AP models utterances as a set of articulatory goals (gestures) which are coordinated with one another. Using an AP-based computational model of speech motor control (Nam, Goldstein, Saltzman & Byrd, 2004), we model two cases of speech errors. Simulation results show that coactivation can account for the observed phonetic properties of speech errors.

<u>Case 1: Independent gestures.</u> Pouplier and Goldstein (2010) explored speech errors induced by quick repetitions of *cop top*. Within AP, these onsets differ in terms of independent gestures (tongue tip vs. tongue dorsum closure). They found that in many onset errors, articulatory gestures of both the target and the intruding consonant were present. However, the intruding consonant was of lesser spatial magnitude than corresponding cases of intended production and the intruding gesture had a shorter duration than the intended target. We model the gradient coactivation as superposition of a partially activated intruding gesture onto the intended target. This model can account for the observed magnitude and relative timing patterns.

<u>Case 2: Distinct coordination relations.</u> Goldrick et al. (2011) examined tongue twisters that induced errors on initial voiced and voiceless stops (e.g., *pin bin bin pin*). AP assumes that these onsets differ in the coordination relation between (a) the closure gesture for the onset consonant and (b) the gesture for the aspiration between the onset and the vowel. We show that a voicing continuum can be modeled as reflecting a weighted average of voiced and voiceless targets. Thus, modeling gradient coactivation as a weighted average of target and error coordination relations successfully accounts for the observed properties of these errors.

<u>Conclusions</u>. The models implemented in our study are the first to generate the precise articulatory and acoustic predictions of a gradient coactivation account of speech errors. These models successfully predict empirically observed gradient properties of speech errors, demonstrating that a gradient coactivation account provides a plausible theory of the phonetics of speech errors. A low-level feedback control mechanism is therefore not necessarily the dominant source of gradience in speech errors. Rather than resulting from corrective motor actions during articulation (Guenther et. al. 2006), gradience could in fact reflect the nature of inputs to the articulatory planning system. Differentiating between these two accounts (feedback control vs. gradient coactivation) would require further comparison of numerical predictions under the two models.

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