Gradient change in lingual gestures acquired during speech therapy

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In selection-coordination theory, adult hierarchical phonological representations and the non-isomorphic structures used for speech production planning both emerge and mature through developmental transitions in gestural coordination starting in infancy, mediated by the internalization of sensory feedback [1]. The family of gestural and attractor-based models to which this developmentally-orientated, emergent and partially non-deterministic account of hierarchical structure belongs have always been characteristically plastic enough to account for some types of phonetic variation in adulthood, including allophony, lenition, and even speech errors [2], though genuinely categorical or segmental variation such as epenthesis, sandhi, or variation in lexical incidence are more of a challenge (in part on purpose), along with morphophonemic alternations and indeed highly stable errors.

Non-infant acquisition also occurs, and a great deal of research has focused on L2 acquisition in later childhood or adulthood. Clinically-mediated acquisition is far less studied, but is a phenomenon of equal theoretical value. In the treatment of school-aged children with persistent or intractable Speech Sound Disorders (SSDs), changes to the phonological inventory (and structure) and to speech production are both caused by speech therapy. The purpose of therapy is to add segments, alter phonotactics, modify speech production or remove (perhaps atypical) segmental mergers. To achieve these aims, the therapist works with multiple levels of phonetic and phonological structure, and uses varied forms of explicit and implicit positive and negative feedback. Such feedback might refer to the immaturity or deviance of the speech production per se, or to the linguistically incorrect contrastiveness of the child's output, or to ineffective categorical perception. Feedback ranges from the metalinguistic and functional, to real-time biofeedback (of acoustics or articulation), and typically blends these holistically to help develop effective introspection that the client can use independently outwith the therapeutic context to guide themselves towards stable, mature, functional productions. The intention is usually to remove incorrect articulatory patterns, introduce new gestures and gestural targets, alter coordination, or to increase stability if there is non-functional variation.

We have recorded children's lingual articulations with high-speed ultrasound before, during and after such therapy, in at least five sessions, over a period of months, to create a unique articulatory dataset of clinically-mediated acquisition. The children received therapy for a wide range of persistent primary SSDs including merger of velar and alveolar stops, cluster reduction, coda deletion, and the phonetic distortions of /s/ among others.

In this paper, we focus on the remediation of /k/=/t/ mergers in seven children. (The details of the therapeutic model and its efficacy appear elsewhere [3].) We demonstrate the varied nature of the gradient pathways of longitudinal change seen during these cases of clinically-mediated acquisition. Qualitatively, the emergence of the velar/alveolar contrast can be seen in mid-sagittal ultrasound data clearly. We report the magnitude of the dorsal velar gesture in each session using linear and area-based differential measures between /t/ and /k/ tongue surface splines, which is compared to child and adult norms (Figure 1). The spatial and dynamic nature of /k/ is reported in a more qualitative manner (Figure 2).

We discuss the relevance for selection-coordination theory. While velar fronting in children with persistent SSD is probably not identical to the typical developmental process seen in much younger children, clinically-mediated acquisition is of interest. Feedback leads to new gestures, which are gradually reorganised. These changes need not align with audible moments of acquistion: some development is covert. Moreover, children may initially undershoot (Figure 1) or overshoot (Figure 2) before mature output is gradually mastered.

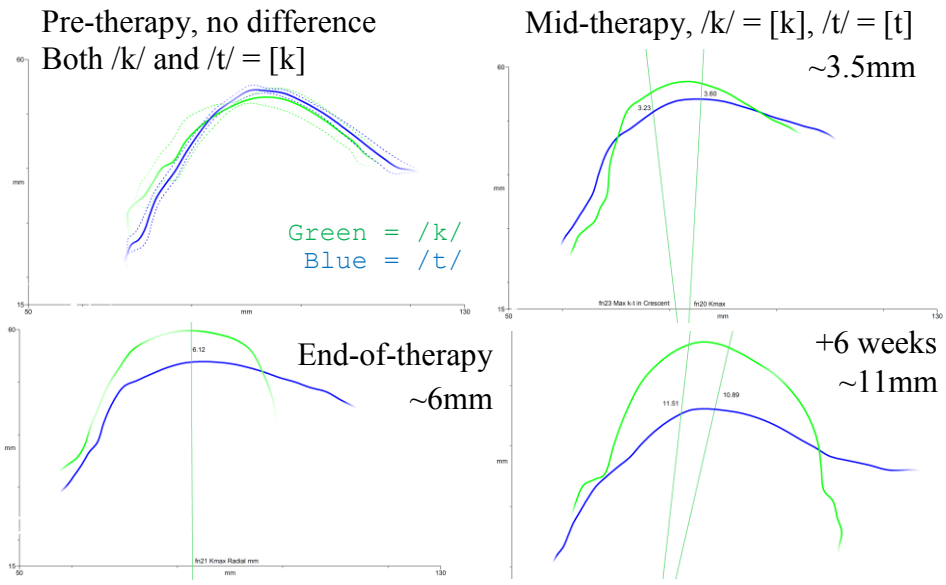

Figure 1. *Speaker 07F, anterior to right. The panels show longitudinal gradient emergence of canonical [k] for /k/ against /t/ as [k] was mastered. /k/ and /t/ had been merged as [t] pre-therapy (top-left). /k/ was transcribed as correct mid-therapy (top-right) but the contrast is under-achieved, with < 4mm maximal dorsal crescent width, and tip raising. The maximum dorsal crescent width increased post-therapy (bottom-left) and reached typical 11mm in post-therapy maintenance (bottom-right).*

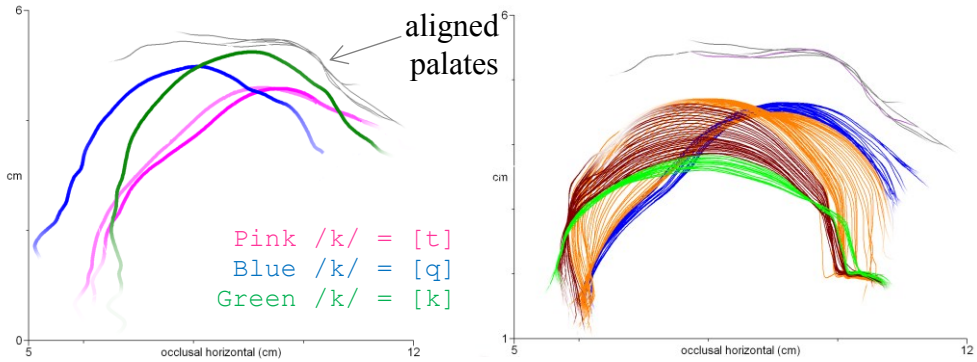

Figure 2. *Speaker 01M, anterior to right, sessions aligned via hard palate. Left panel: Longitudinal development in /k/. Pre-therapy (pink), fronting of /k/ to [t] (merged with /t/, not shown) occured in two sessions. Mid-therapy (blue) there was overshoot to [q]. Post-therapy (green), /k/ was canonically velar. Right panel: Articulatory dynamics in one of 01M's very first distinguishable /k/ tokens. Blue splines (8ms intervals) are in a stable pre-speech phase. Movement towards (orange) and during (brown) the stop closure show a velar gesture then overshoot. The stop release burst and post-release transition (green) are uvular-pharyngeal (cf. the mean [q] in the left panel). The token was also poorly coordinated with the following vowel and over-long.*

[1] Tilsen, S. 2016. Selection and coordination: the articulatory basis for the emergence of phonological structure. *Journal of Phonetics*, 55, 53–77.

[2] Browman, C. & Goldstein, L. 1992. Articulatory Phonology: an overview. *Haskins Laboratories Status Report on Speech Research*, SR-111 / 112, 23–42.

[3] Cleland, J., Scobbie, J.M. and Wrench, A.A. 2015. Using ultrasound visual biofeedback to treat persistent primary speech sound disorders. *Clinical Linguistics and Phonetics* 29(8-10), 575-559.