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Quantifying sound change from speech dynamics

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Many types of phonetic sound change emerge from a restructuring in speech dynamics, including those that are due to coarticulation (Ohala, 1993) as well as vowel shifts resulting in diphthongisation. Quantifying dynamic relationships in speech production is inherently difficult and for this reason is typically not explicitly incorporated into modelling sound change. Here we address this issue using functional principal components analysis (FPCA: Gubian et al., 2015) applied to two sound changes: firstly, to the change of pre- to post-aspiration in Andalusian Spanish (Ruch & Harrington, 2014; Ruch & Peters, 2016) in which e.g. /pa^{h}ta/ → [pat^{h}a] ('pasta', Castilian Spanish: /pasta/); secondly, to the merger of the falling diphthongs in New Zealand English by which pairs such as 'beer/bear' have become almost or completely homophonous in the last 50 years (Maclagan & Gordon, 1996).

For the first of these, FPCA was applied to pairs of curves, namely the probability of voicing and the magnitude of high frequency energy in /V_1sCV_2/ sequences in which C = /p, t, k/ and in which /s/ was realised as pre- and/or post-aspiration in isolated words produced by 24 younger and 24 older speakers of Andalusian Spanish. The results suggest that the ongoing sound change is associated with a shift in how the closure is phased with respect to voicing. The results also point to a trading relationship – which is often implicated in sound change (e.g. Beddor, 2009) – between the amplitude of pre- and post-aspiration. For the New Zealand English merger, FPCA was applied to the first two formant frequencies in stressed falling diphthongs extracted from a database of read speech produced by 36 younger and 36 older speakers. Consistently with other studies (Hay et al., 2006; Rae & Warren, 2002), the merger was greater in younger than older speakers. The sound change was shown to involve a change in the overall shape of the formant trajectories rather than a shift in formants at a particular point in time (Gubian et al, 2019).

We consider finally how such sound changes that emerge from speech dynamics can be incorporated into an exemplar model of speech (Pierrehumbert, 2003; Todd et al., 2019) in which the statistical association between phonological categories and speech signals is updated by remembered speech episodes. For this purpose, we make use of an analogous computational model of sound change (Harrington et al., 2018) in which the analysed Andalusian or New Zealand English speakers were each represented by computational agents that exchange such dynamic signals in communication. The aim was to determine whether older speakers' more conservative forms shifted towards those of the innovative forms of younger speakers, when agents representing older and younger speakers communicated with each other. The results were equivocal which suggests that the initial stages in the spread of sound change are conditioned by forces beyond those due to updating dynamic signals in speech communication.

In conclusion, dynamic techniques such as FPCA have been shown to be very useful in understanding the synchronic bases of at least two sound changes in progress. Further research is needed to understand the connections between sound change, speech dynamics and memory-rich models in which phonological categories are updated by perceived speech signals.

Key words: Speech dynamics. Sound change. New Zealand English. Andalusian Spanish. Agent-based modelling.

References

Beddor, P. (2009). A coarticulatory path to sound change. *Language*, 85, 785-821.

Gubian, M., Harrington, J., Stevens, M., Schiel, F., and Warren, P. (2019). Tracking the New Zealand English NEAR/SQUARE merger using functional principal components analysis. *Interspeech*, Graz.

Gubian, M., Torreira, F., and Boves, L. (2015). Using functional data analysis for investigating multidimensional dynamic phonetic contrasts. *Journal of Phonetics*, 49, 16–40.

Hay, J., Warren, P. and Drager, K. (2006). Factors influencing speech perception in the context of a merger-in-progress. *Journal of Phonetics*, 34, 458–484.

Harrington, J., Kleber, F., Reubold, U., Schiel, F., & Stevens, M. (2018) Linking cognitive and social aspects of sound change using agent-based modeling. *Topics in Cognitive Science*, 1-21.

Maclagan, M., and Gordon, E. (1996). Out of the AIR and into the EAR: another view of the New Zealand diphthong merger. *Language Variation and Change*, 8, 125-147.

Ohala, J. (1993). The phonetics of sound change. In C. Jones (Ed.) Historical Linguistics: Problems and Perspectives. Longman: London. (p. 237–278).

Pierrehumbert, J. (2003). Phonetic diversity, statistical learning, and acquisition of phonology. *Language and Speech*, 46, 115–154.

Rae, M. and Warren, P. (2002). Goldilocks and the three beers: sound merger and word recognition in NZE. *New Zealand English Journal*, 16, 33.

Ruch, H. & Harrington, J. (2014). Synchronic and diachronic factors in the change from pre-aspiration to post-aspiration in Andalusian Spanish. *Journal of Phonetics*, 45,12–25.

Ruch, H. & Peters, S. (2016). On the origin of post-aspirated stops: production and perception of /s/ + voiceless stop sequences in Andalusian Spanish. *Laboratory Phonology*, 7, 1–36.

Todd, S., Pierrehumbert, J., and Hay, J. (2019). Word frequency effects in sound change as a consequence of perceptual asymmetries: An exemplar-based model. *Cognition*, 185, 1–20.