At the margins of vowel-space change: Leaders and laggers in the evolution of vocalic subsystems

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The study of how vowels change over time has traditionally examined individual vowels or collections of structurally related vowels (e.g. mergers, splits, shifts). When examining change in any particular vowel, research tends to find socially meaningful distributions of speakers, with speakers on the margins of the distribution - representing 'leaders' or 'laggers' in that particular change. But it has proven challenging to move beyond individual or small groups of variables, towards an understanding of sound *systems*. Are there speakers at the 'margins', not just of any individual sound change, but of sound change in general? This is a challenging question, requiring us to control many factors that could lead to spurious covariation. These include (a) ***formant tracking errors*****:** while automated analyses of *individual* vowels can tolerate 'noise' in the form of tracking or alignment errors, errors occur disproportionately within some speakers. Analysis of *vowel systems* reveals errorful covariation more clearly and outlier removal processes that consider entire vowel systems are needed when working with automatically aligned corpora; (b) ***normalization:*** normalization algorithms developed for well-balanced data-sets collapse when subject to large unbalanced samples. An algorithm needs to be developed that is robust in the absence of balanced samples; (c) ***year of birth****:* vowel spaces of young speakers look different from speakers born much earlier. We need to control for this to ask - at any given time - are there speakers who are 'leaders' in all sound changes - or in a significant cluster of changes? We present a novel methodology to address this question, leading to important evidence revealing different ways multiple vowels pattern together, irrespective of known sociolinguistic predictors of change.

We extracted F1 & F2 for lexically stressed tokens of 10 vowels in a corpus of New Zealanders born between 1863-1983 [1]. After developing solutions for (a) & (b), our data contained 414,679 normalized tokens from 481 speakers. We ran generalised additive mixed-models (GAMMs) predicting each vowel's normalised F1 and F2, with smooth terms comprising an interaction between year of birth and gender, as well as speech rate. We extracted the speaker random intercepts, representing estimates of how innovative a speaker is in each vowel-formant, controlling for the model's fixed-effects (see [2]). We ran Principal Components Analysis (PCA) on the set of intercepts in order to assess whether structural patterns exist, which revealed 3 subsystems of vowels that meaningfully covary (Fig 1). There is no relationship between PCA score on any PC with the fixed-effects included in the GAMMs (Fig 2).

PC1 is driven by significant covariation between back vowels which have rearranged from a tight triangular shape to a more expanded configuration. PC1 suggests that there is a consistent overall drive toward expanding this tight triangle of vowels, but for some speakers this is carried by innovation in the higher vowels, and for others it is carried by innovation in the lower vowels (Fig 1b). PC2 reveals a cluster of covarying vowels all aligned in the direction of sound change - including, but not restricted to, vowels in the 'short front vowel shift' (see [3]; Fig 1a & 1c). PC3 reveals some opposing patterns in front vowels and back vowels, with speakers more advanced in one subsystem tending to be less advanced in the other (Fig 1d). Individuals, then, are on the margins not only of individual vowel changes, but of changes in major vowel subsystems.

Our results overcome long-standing methodological challenges to the understanding of covariation, and provide novel insights into the structure of sound systems, demonstrating the existence of structured patterns in the realisations of specific vocalic variables across large groups of speakers.

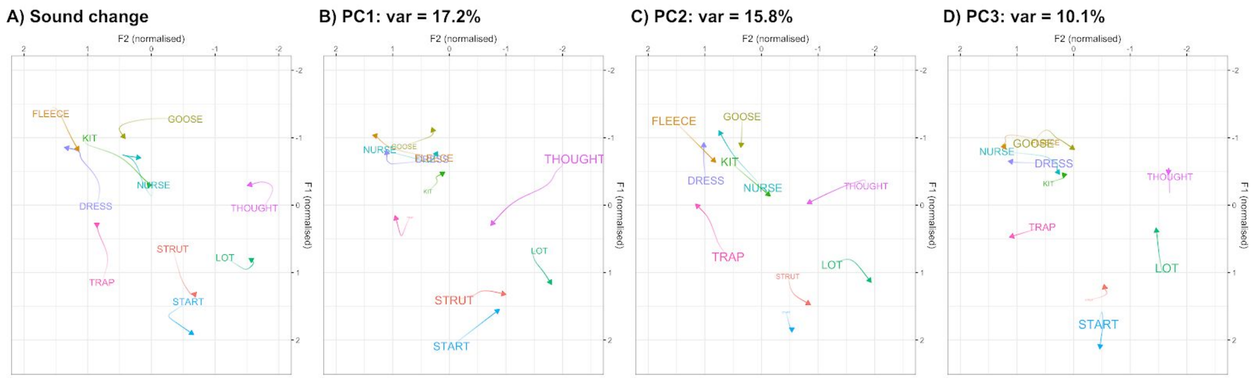

Fig 1. (A) Change over time as represented by GAMMs fit separately through F1 & F2 for each vowel-formant. Arrows represent trajectories as year of birth increases. (B) model fits by predicting F1/F2 for each vowel by the PCA scores in PC1, with arrows indicating trajectories as the scores increase. Larger font represents high PC1-loading (= stronger covariation). PC1 represents positive covariation between START and STRUT, with both in a repelling relationship with NURSE and THOUGHT. Speakers with a low PC1 show conservative START and STRUT and innovative THOUGHT/NURSE. Speakers with high PC1 have innovative START and STRUT, and conservative THOUGHT/NURSE (C) Notation as for B. PC2 is dominated by covariation in the front vowels, encapsulating the short front vowel shift (TRAP, DRESS and KIT), together with other vowels, including LOT. The vowels in the short front vowel shift, together with a number of other vowels, covary meaningfully within individual speakers in the direction of change. (D) PC3 captures F1 variation in the back vowels and F2 variation in the front vowels. Speakers who are innovative at the front are conservative at the back, and vice-versa.

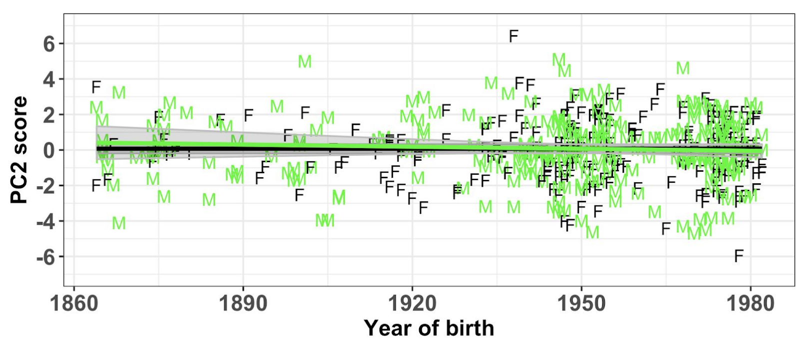

Fig 2. GAMM predictions fit through year of birth (x-axis) and PC2 score (y-axis), with speakers plotted separately (F = Female speakers, M = Male speakers). The lack of relationship shows that we successfully controlled for year of birth and gender, and that, at any given time, there are speakers on the 'margins' of different constellations of changes - 'leaders' and 'laggers'. The same pattern is observed for PC1 and PC3.

References

[1] Gordon, E., et al. 2007. The ONZE corpus. In *Creating and digitizing language corpora* (pp. 82-104). Palgrave Macmillan.
[2] Drager, K., Hay, J., 2012. Exploiting random intercepts: Two case studies in sociophonetics. *Language Variation and Change*, *24*(1), pp.59-78.
[3] Hay, J.B., et al.., 2015. Tracking word frequency effects through 130 years of sound change. *Cognition*, *139*, pp.83-91.