Vowel space as shape: Applying geometric morphometrics to sociophonetic variation

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Sociophonetic investigations of vowels have traditionally focused on individual or selected subsets of vowels, but recent work shows that variation can be systematically coordinated across the whole vowel system (Brand et al. 2021). In this paper, we propose an approach for analysing vowel systems based on geometric morphometric techniques (Adams et al. 2013) for the analysis of shape. With this approach, the position of each vowel in formant space is treated as a landmark, and each set of landmarks is considered a shape and analysed as a single entity. This means that the relationship between each landmark (i.e. each vowel) is preserved, while permitting direct comparison between shapes (i.e. vowel spaces). The appeal of such an approach to sociophonetic analysis is twofold: (1) geometric morphometrics seeks to decouple shape from size through a step known as Generalised Procrustes Analysis (GPA), which involves shifting, scaling (by centroid size) and iteratively rotating each speaker's vowel space to minimise the Procrustes distance between shapes, and thus integrates speaker normalisation; (2) each speaker's vowel system then exists as a single point in a 'shape space', which allows orthogonal dimensions of variation in shape to be identified and quantified using principal component (PC) analysis.

We illustrate this approach using a corpus of 32 speakers of Derby English (Milroy et al. 1997) to analyse how the vowel system varies in relationship with gender, age and class. F1 and F2 measurements from stressed tokens of 11 monophthongs were automatically extracted from word-list speech using LaBB-CAT (Fromont & Hay 2012). GPA was performed on per-speaker formant means, using the *geomorph* package in R (Adams et al. 2021), to align the speakers' vowel spaces, followed by PC analysis in the shape space.

The first two principal components were shown to account for 47.2% and 14.0% of variance respectively. PC1 relates primarily to the movement of GOOSE and FLEECE along the front-back dimension, while PC2 relates to movement of NURSE and FOOT. While we found little evidence of gender- or class-based variation of vowel space shape, there is clear separation between older and younger speakers along PC1 and, to a lesser extent, PC2. In line with existing descriptions of Derby English (Docherty & Foulkes 1999; Jansen & Braber 2020), these results indicate the use of much more fronted GOOSE and backed FLEECE by younger speakers as the primary source of variation in vowel space, accompanied by independent NURSE-backing and FOOT-fronting. We will further discuss current limitations of this technique and explore how GMM can provide further insight into sociophonetic variation.

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