What does cross-linguistic perception tell us about phonological categories?

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The internal representation of linguistic speech segments is not well understood. Yet, the encoding of the building blocks of speech segments is central to many phonological theories (for features, see e.g. Durand, 1990; for gestures, see e.g. Browman & Goldstein, 1992). However, the relationship between perception and phonological categories is not well explored. We hypothesize that phonological natural classes are a product of ingrained perceptual mechanisms. If we are correct, we should observe phonologically distinct subgroups of the natural classes clustering together within the perceptual space, but if we are incorrect, we anticipate that there will be no subgrouping along phonological lines of the segments we examine.

We chose to use fricatives and rhotics for this experiment because they have definable phonological subgroupings (e.g. sibilant vs. non-sibilant fricatives). For our stimuli, we recorded L1 speakers of a language with target phonemes in intervocalic position between low vowels (i.e. aCa). For the sibilants, we recorded English, /f, h/, Polish, /s̪, ʂ, ɕ/, Hindi, /ʃ/, and Russian, /x/ speakers. For the rhotics, we recorded Hindi, /ɾ^{a}/, Malayalam, /ɾ^{c}, ɻ^{c}/, Mandarin, /ɻ^{b}/, Russian, /r/, English, /ɹ/, and Upper Sorbian, /ʁ/, speakers. We carried out two AX discrimination experiments using the recorded stimuli. Perceivers were 40 L1 English and 40 L1 Malayalam listeners. 20 participants from each group took part in either the Fricatives experiment or the Rhotics experiment. Participants heard 8 of each *different pair* for 176 tokens and an equal number of *same pairs*. d-prime scores (Macmillan & Creelman, 1991) were calculated for each of the comparisons and were used as the input dissimilarity matrix for a multidimensional scaling (MDS) solution. *k*-means clustering solutions were also performed on the fricative and rhotic space to determine if clustering in the perceptual space corresponds to the natural classes.

The results of the MDS solution for the Fricatives revealed grouping of sibilants, /s̪, ʂ, ʃ, ɕ/, and two distinct groups for labio-dental, /f/, and the posterior segments, /x, h/ (Figure 1, left). The *k*-means clustering analysis also indicated three clusters in the perceptual space and that each cluster matched the location of one of the phonological subgroups of fricatives (Figure 1, right). The results for the Rhotics revealed more central clustering in the perceptual space for English perceivers, but still some separation between the trills/taps and approximants. However, the Malayalam perceivers had greater separation between the trills/taps and the approximants (Figure 2, left). The *k*-means clustering reflects the subgroups of rhotics (Figure 2, right), one cluster for the trills/taps and one for the approximants.

For the fricatives, the intra-class clustering corresponded to the phonological subclasses within the natural class. However, the observed effects are not well captured by articulatory specifications. The sibilants group together despite the disparate articulatory strategies (apical: /s̪, ʂ/; tongue blade/body: /ʃ, ɕ/). It seems more likely that shared acoustic similarities between subgroups of fricatives produce clustering in the perceptual space. We hypothesize that the subgroup clustering contributes to shared phonological behaviour. For example, /x, h/ undergo morphophonemic alterations in many languages (Maddieson, 1984) and there are many different phonological processes that target the subgroup of sibilants.

The intra-class clustering of the rhotics does reflect an articulatory difference (contact or no contact), making it possible to explain the results in terms of articulatory specification. However, observed acoustic similarities between rhotics (e.g. Howson, 2018) better captures the more centralized clustering and the tendency for separation between trill/tap and approximant segments. The results also revealed the separation between trill/tap and approximant segments

was amplified for Malayalam listeners and it is precisely the segment (approximant) that behaves differently in Malayalam phonology, suggesting a connection between perception and phonology.

In summary, the findings contribute to existing research that ties (inter- and intra-) class membership to acoustic-perceptual qualities and connects phonology and perception.

References.

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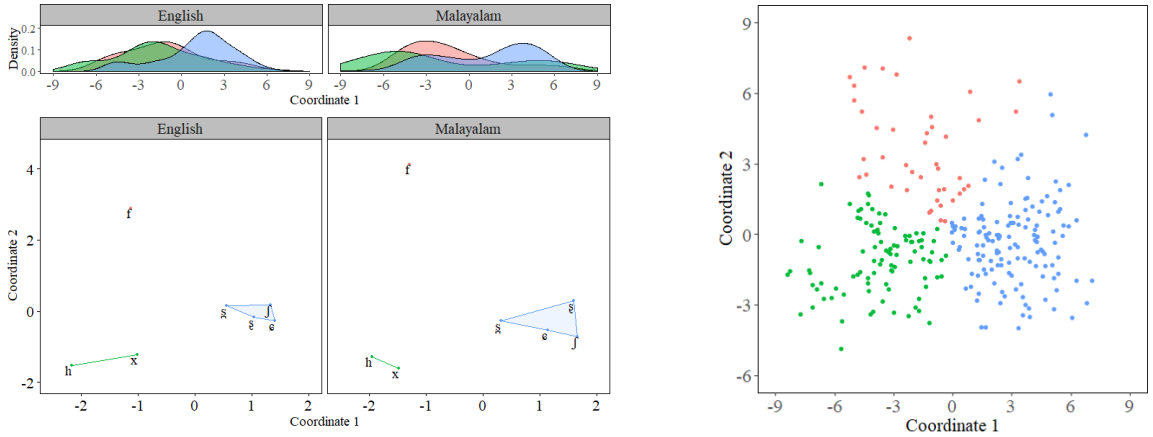

Figure 1. MDS of the perceptual space for fricatives by English and Malayalam listeners. Density of the x-axis is at the top of the image (left panel). Visualization of the *k*-means solution for the perceptual space with each cluster correlating with each of the phonological categories (right panel). Colors correspond to groups: red = /f/, green = /x, h/, blue = /s̪, ʂ, ʃ, ɕ/.

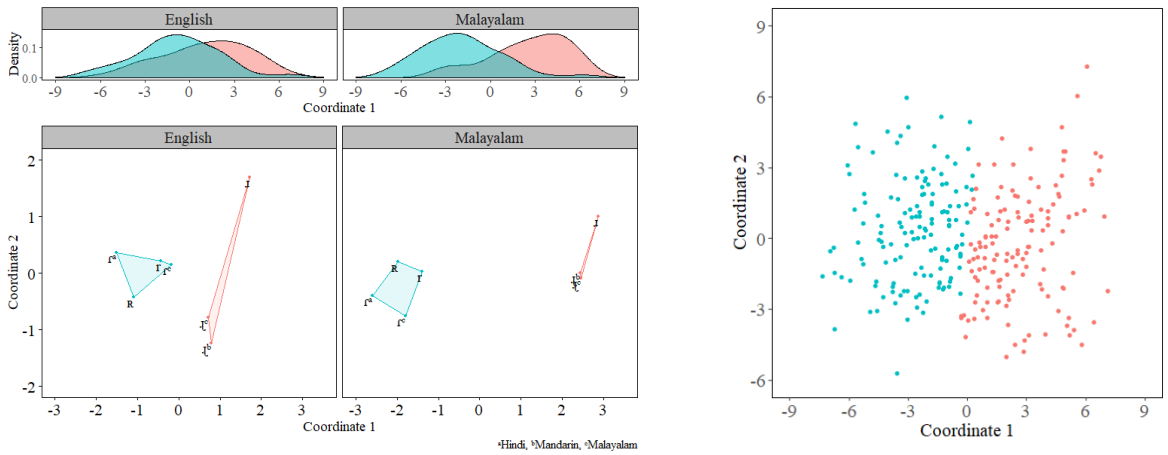

Figure 2. MDS of the perceptual space for rhotics by English and Malayalam listeners. Density of the x-axis is at the top of the image (left panel). Visualization of the *k*-means solution for the perceptual space with each cluster correlating with each of the phonological categories (right panel). Colors correspond to groups: blue = /r, ɾ, ʁ/, red = /ɹ, ɻ/.