Modeling the nasal vowel inventories predicted by phonetic biases and learning

Cross-linguistically, nasal contrasts are more common for low vowels than high vowels [1]; Amuzgo contrasts [a] and [ã] but has no nasal counterpart to [i] [2]. Analogously, low vowels across languages are produced with a lower velum (more nasal) than high vowels, perhaps from lowering biomechanics, which researchers have hypothesized as causing the different nasal contrast frequencies [3].

However, mechanisms linking exactly *how* low vowels' greater nasality would lead to more low nasal contrasts remain to be specified and evaluated. As a proof of concept, I demonstrate that, when assuming one often-discussed (e.g. [4]) model of category learning and sound change, low vowels' greater nasality does *not* predict they are more likely to split into nasal/oral contrasts.

A Mixture of Gaussians (MOG, Figure 1) learner searches for the set of categories that maximizes the likelihood of its input data. Intuitively, the less overlap between vowel distributions, the more likely they'll be learned as separate categories (cf. [5]). When a learner's input is noisily sampled from parents' categories, it may learn slightly different ones. Differences can accumulate over generations of MOGs, with vowel categories splitting or merging (e.g. [4]).

Nasal contrasts arise when vowels neighboring nasal consonants split into a nasal category, followed by consonant deletion ({ba, ban} → {ba, bãn} → {ba,bã} , Figure 2) [6]. If greater nasality contributes to more nasal contrasts, then adding low vowels' greater nasality to the learning data (Figure 3) should make MOG more likely to split them into oral and nasal categories.

However, Figure 3 shows that even with greater nasality, oral/nasal splits for low vowels are *not* more likely given MOG; the overlap between {ba, ban} is still the same as {bi, bin}. This result challenges the hypothesis connecting low vowels' nasality and their nasal contrast frequency, but generates further questions: empirically, is low vowels' nasality *difference* (ba vs ban) also greater? Could a revised model, jointly inferring category and context, misattribute consonant nasality (cf. [7]) more to already-more-nasal low vowels? Broadly, this finding demonstrates that hypothesized relationships between phonetics and typology depend on assumptions about learning.

References [1]Kingston, J. (2007). The phonetics-phonology interface. *The Cambridge handbook of phonology*, 401-434. [2]Longacre, Robert E. 1966. On the Linguistic Affinities of Amuzgo. International Journal of American Linguistics 32. [3] Henderson, J. B. (1984). *VELOPHARYNGEAL FUNCTION IN ORAL AND NASAL VOWELS: A CROSS-LANGUAGE STUDY*. [4] Gubian, M et al. (2023). Phonetic and phonological sound changes in an agent-based model. *Speech Communication* [5] Feldman, N. H. et al. (2013). A role for the developing lexicon in phonetic category acquisition. *Psychological Review* [6] Hajek, J., & Maeda, S. (2000). Investigating universals of sound change: the effect of vowel height and duration [7] Ohala, J. J. (1994). Towards a universal, phonetically-based, theory of vowel harmony [8] Whalen, D. H., & Beddor, P. S. (1989). Connections between nasality and vowel duration and height: Elucidation of the Eastern Algonquian intrusive nasal. Language.

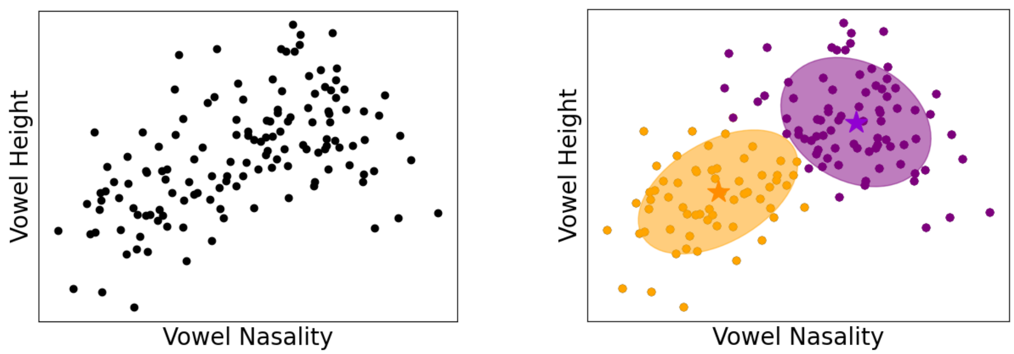

Figure 1. Example MOG uncategorized input (left) and categorized output (right). Categories are Gaussian distributions. Each point represents a vowel token. “Nasality” is abstracted here, but could be quantified by a perceptual scale ([8]) or velar port measurements as in (Henderson). The number of categories need not be prespecified, by using either a Dirichelet process ([5]) or model comparison ([4]).

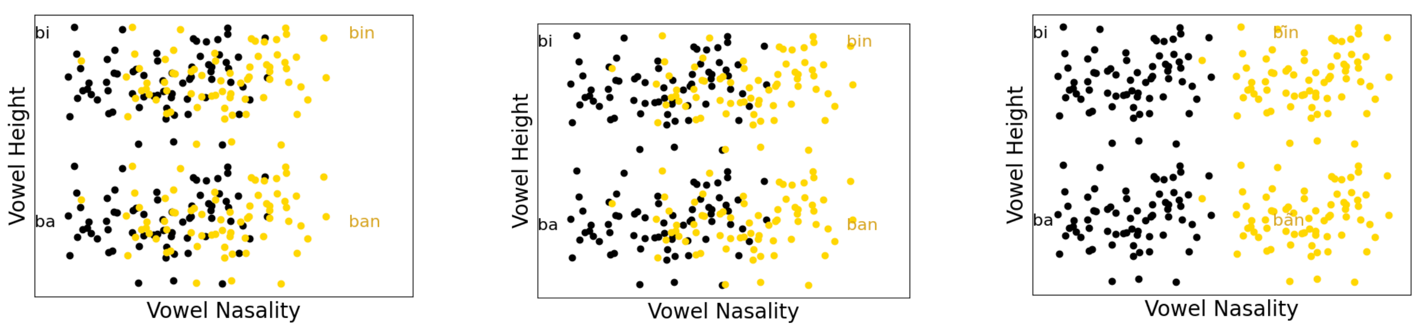

Figure 2. Example progression of nasal coarticulation (slightly more nasality in [ban] than [ba]) leading to separate nasal/oral allophone categories (e.g. ba vs bãn), with consonant deletion assumed to happen afterward.

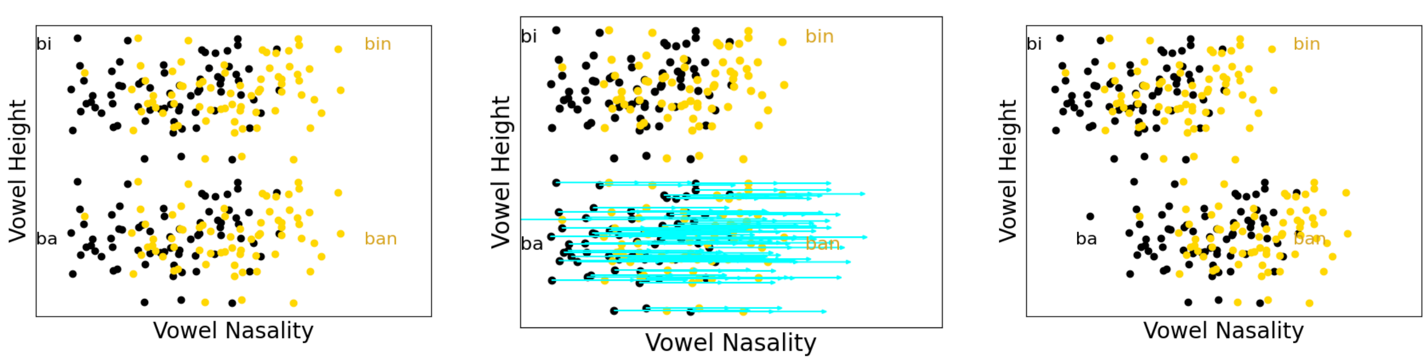

Figure 3. Speakers’ intended low vowels (left) are shifted (center) toward greater nasality (right), qualitatively reflecting [2]’s measurements of phonetic bias. Even when the low vowel distribution is biased to greater nasality, the amount of overlap between oral and nasal context vowels is the same for high {bi,bin} as low {ba, ban}.