# Normalizing Nasality? Across-Speaker Variation in Acoustical Nasality Measures

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## Objectives and Research Questions

Acoustical methods for measuring vowel nasality are increasingly being used in the linguistic literature. Although these measures have been shown to be correlated with nasality, their variability across speakers has been largely ignored. Here, we ask three research questions:

1. Do A1-P0 and F1's Bandwidth vary across speakers?
2. What is the nature of this variability?
3. How can we best compare nasality across speakers?

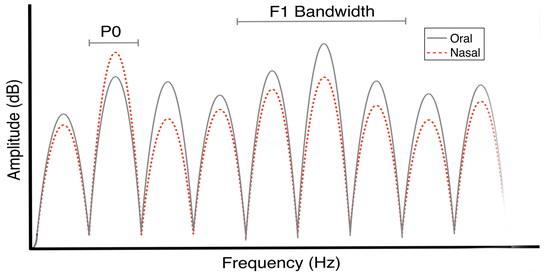
## Features Examined

**A1-P0** (Chen 1997)

- Very commonly used composite measure of vowel nasality in the literature
- Measures the amplitude of the nasal pole near 250Hz ("P0") relative to amplitude of F1 ("A1").
- A1-P0 *decreases* with increased nasality

**F1's Bandwidth** (e.g. Maeda 1993)

- Found to be primary cue for the perception of vowel nasality in English in Styler 2015
- Captures both nasal pole/zero complex and increased heat loss from nasal coupling.
- F1's Bandwidth *increases* with increased nasality




## Feature Measurement

All features were measured automatically by script using the Praat Phonetics Software Package.

1. Hand annotate vowel boundaries in each word
2. Automatically extract two measures per vowel (at $\frac{1}{3}$ and $\frac{2}{3}$) using Praat
   - The Nasality Automeasure Praat script (c.f. Styler 2015) was used to extract all measures
   - P0 is defined as the amplitude of H1 or H2, whichever is greater
   - A1 is the amplitude of the harmonic nearest to the center of the first formant in the LPC analysis
   - F1 Bandwidth extracted directly from LPC analysis
   - Two timepoints were used to capture both carryover and anticipatory coarticulation
3. Suspect measurements were flagged and removed.
4. Means were compared across speakers for each phonological structure in each corpus, averaged over the two timepoints

## About the Corpora

**Colorado Corpus**

3823 words in CVC, NVC, CVN and NVN quadruplets from 12 college-aged speakers at the University of Colorado. Collected in 2014 in preparation for Styler 2015.

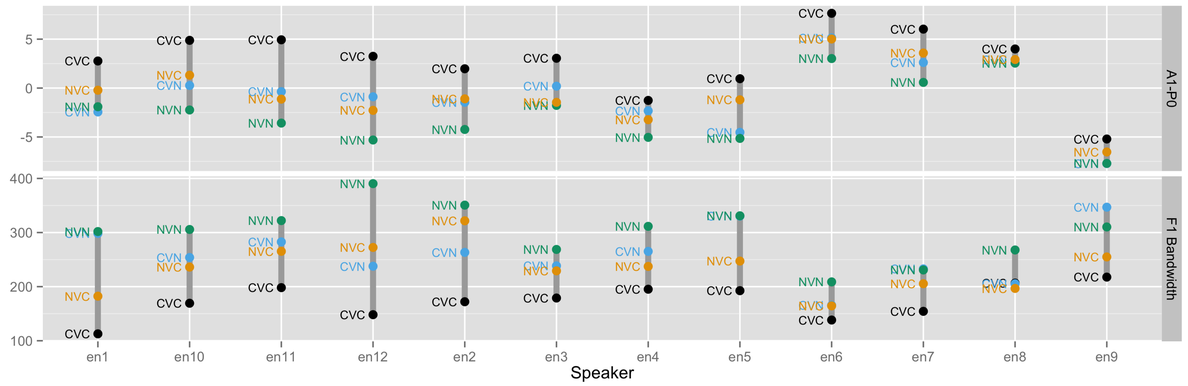
- Sets like "bad, mad, ban, man", with words including the vowels /i ɪ eɪ ɛ æ ɑ aɪ ʌ oʊ u/

**Michigan Corpus**

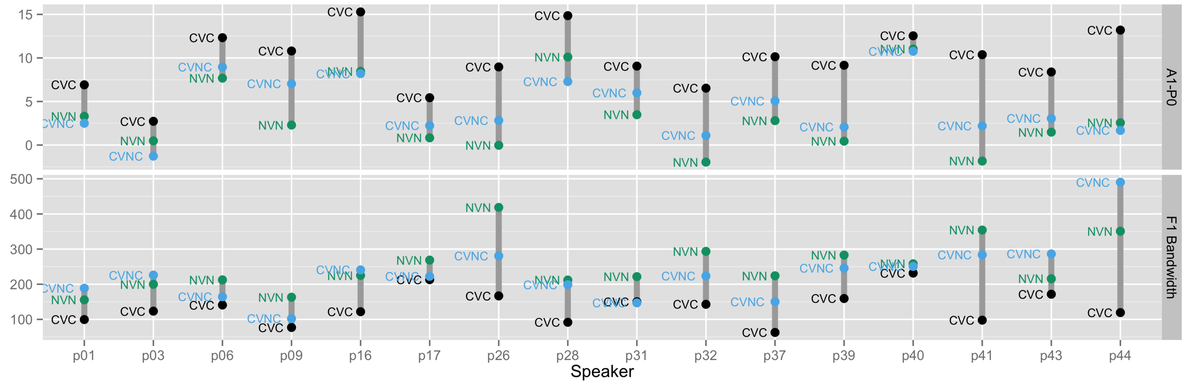
5820 words in CVt, CVd, CVNt, CVNd quadruplets with similar NVNs from 17 college-aged speakers at the University of Michigan. Collected in 2015 for ongoing NSF grant work.

- Sets like "bet, bed, bent, bend" with separate NVNs, with words including the vowels /i ɪ ɛ ɑ/

## Colorado Corpus Results




## Michigan Corpus Results




## Speaker Variability in Nasality Measures

**These measures vary considerably across speakers**

- There are differences in *baseline* for CVC and NVN
- There are differences in *range* from CVC to NVN
- Including speaker in analyses improved LMER model fit

**Some of this variability is due to nasality**

- Speakers may show actual differences in degree of coarticulation (e.g. greater nasalization in CVN or NVC)
- Speakers may show earlier/later onset of nasalization
- Speakers may differ in oral articulations of nasal vowels

**Some of this variation likely stems from non-nasal factors**

- Speaker vowel formant patterns interact with both measures
  - F1's positioning will interfere more for some speakers
- Differences in CVC baselines likely don't come from different degrees of nasality
  - P17 is likely *not* more nasal in CVC than P16 in NVN.
- No evidence that a given ΔA1-P0 or ΔF1_Width represents the same ΔNasality across speakers
  - P37's CVC to CVNC differences are P01's *entire range*

## Normalizing Nasality?

These Acoustical Nasality measures seem to act much like Vowel Formant measures in analysis:

- Within-speaker, across-condition levels and differences are safe and easily interpreted
- Values in isolation do not map onto categories across speakers (e.g. "oral" vs. "nasalized")
- Changes usually indicate changes in nasality, but the degree of change is not interpretable

*Can we "normalize" nasality using similar techniques as we use for vowel formants?*

- Variation in baseline and range can be controlled *within speakers* by centering or Z-Scoring measurements
- "Maximally oral" and "maximally nasal" means for each speaker can be used to create a more uniform scale
  - This allows comparison of ΔNasality as a fraction of possible change (e.g. "nasality went up by 25%")
- More precise algorithmic normalization of nasality measures may be possible and permit safer comparisons
  - The full Michigan corpus will include acoustic and airflow data from 42 speakers, allowing the author to develop and test such an algorithm.

## Conclusions

1. **Both A1-P0 and F1's Bandwidth vary considerably across speakers**
   - This variation stems from both nasality-related and measure-related sources.
2. **There is variability both in terms of baseline *and* range**
   - Speakers have *different raw values* for 'oral' and 'nasal'
   - Speakers show different *amounts of change* between oral vowels and maximally nasal vowels
3. **Across-speaker comparison of nasality is difficult**
   - These differences confound direct comparisons of both raw values and changes across speakers
   - The problem isn't eliminated by using mixed-effects models with random slopes by speaker
   - Scaling data to percentage of overall range can help to compare ΔNasality
   - Normalization may be possible (but imperfect)
   - Within-speaker comparisons are still the best approach

## References and Acknowledgements

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