#1aSC8

Surveying the nasal peak: A1 and P0 in nasal and nasalized vowels

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For more information:
http://savethevowels.org/asa2014

Research Goals

- Nasality is commonly measured using "A1-P0", a composite spectral measure which compares the first formant with a low frequency nasal peak
- We hope to better understand this measure, as well as its acoustic components
- We're laying the groundwork for deeper perceptual study of nasality
  - We want to know how to artificially manipulate nasalization
- We're searching for cross-linguistic differences in the realization of nasality
- Our Approach: **Measure various features in actual language data and examine their relationship to coarticulatory and contrastive nasality**

Data Collection

- Corpus of nasality in coarticulatory and contrastive contexts
- 160 English words in **oral** (CVC) vs. **nasal** (CVN/NVC/NVN) sets, 10 vowels
  - 12 college-aged speakers from the US = 3823 tokens
- 120 French words with phonemically **oral** vs. **nasal** vowels, /ɛ, ɑ, ɔ/ & /ɛ̃, ɑ̃, ɔ̃/
  - 8 speakers from Northern France = 995 tokens
- All tokens were machine-aligned with vowel boundaries hand-confirmed
- Features extracted automatically by Praat script at 1/3 and 2/3 of vowel dur.
- 35 features associated with nasality examined (7 reported here)

Acoustical Features

- P0 Amplitude (dB) - Amplitude of the higher of H1 vs. H2
- A1 Amplitude (dB) - Amplitude of the the first formant's highest harmonic
- A1-P0 (dB) - The difference of amplitude between A1 and P0
- A1-P0 Compensated (dB) - A1-P0 adjusted using Chen's Compensation formula, which minimizes the effect of formant variations (from Chen 1997)

$$T1(F_{P0}) = \frac{(0.5B1)^2 + F1^2}{[((0.5B1)^2 + (F1 - F_{P0})^2) \cdot ((0.5B1)^2 + (F1 + F_{P0})^2)]^{1/2}}$$

- P0 Prominence (dB) - The difference of P0's Amplitude from the average amplitude of the two surrounding harmonics

Statistical Analysis

- Linear Mixed-Effects Regressions (Feature ~ Nasality) using repetition, vowel and timepoint as factors, speaker and word as random factors
- Separate analyses for each feature in English and French data
- Analysis performed using the R Statistics Software Suite

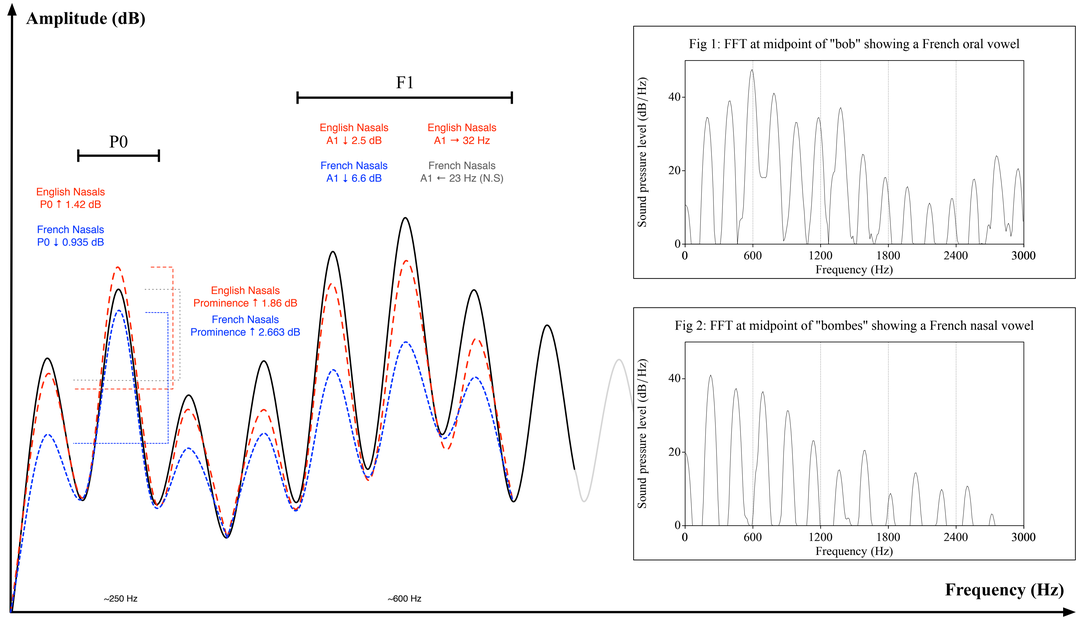

Table 1: Means, Coefficients and | t | stats showing the change in each feature in "oral" vs. "nasal" vowels

Feature	English Oral Mean	English Nasal Mean	English Coefficient	English | t | Value	French Oral Mean	French Nasal Mean	French Coefficient	French | t | Value	English-French Difference
P0 Amplitude	43.513	44.944	1.429	11.018	39.107	37.970	-0.935	-4.095	-2.425
A1 Amplitude	46.445	43.962	-2.503	-11.155	45.604	38.690	-6.676	-13.116	-4.173
A1-P0	2.932	-0.982	-3.939	-14.873	6.497	0.719	-5.733	-13.932	-1.794
A1-P0 Comp.	5.099	1.133	-3.989	-15.099	8.678	2.932	-5.703	-14.069	-1.714
P0 Prominence	10.290	12.083	1.876	7.724	2.995	5.645	2.663	7.890	+0.787
F1 Frequency	601.869	629.036	32.509	3.266	637.056	613.365	-23.612	-1.31 (N.S)	56.121
F2 Frequency	1770.088	1762.837	-24.777	-0.92 (N.S)	1587.827	1410.198	-177.572	-3.559	152.795

Results and Findings

- A1-P0 is strongly affected by the coupling with the nasal cavity
  - Lowering of A1 is the primary driver of this effect
  - P0 does not reliably gain amplitude in nasal vowels
  - ... but it very often gains prominence relative to the surrounding harmonics
- This "Prominence" of the nasal peak is another useful measure of nasality
- Chen's formant compensation formula enhances the nasal/oral difference
- Formant frequency changes from nasality are language-specific
  - These are unlikely to be direct consequences of the nasal coupling

Linguistic Significance

- Similar measures are predictive of nasality across both English (with coarticulatory nasality) and French (with contrastive nasality)
- There are differences with regard to the details of realization (especially in direction of change in P0 relative to oral vowels)
  - This may be under speaker control (e.g. Carignan et al. 2011, Carignan 2014)
- The best acoustical correlates of nasality - and the perceptual cues they represent - are relative
  - Nasal Peak vs. A1, Nasal Peak vs. Surrounding Spectrum, Nasal vs. Oral
- With better understanding of acoustical details, we can manipulate and test the perceptual consequences of these features and of types and patterns of nasality

Implications for Measurement and ASR

- A1-P0 remains the most reliable measure for nasality
  - Measurements are improved by using Chen's formant compensation formula
  - A1-P0 performs well across vowels, speakers and languages
  - The degree of expected change will vary by vowel, speaker, and language
- P0 prominence is an additional reliable feature for nasality
- Use of formant frequency for classification uses language-specific patterns

Ongoing work

- Evaluate relationship between nasality and the additional 28 features measured
- Investigate which of these features are used in human perception of nasality
- Use this understanding to reliably model (and modify) nasality in speech
- Continue exploring cross-linguistic differences in the realization of nasality

References

Chen, Marilyn Y. (1997) Acoustic correlates of English and French nasalized vowels, J. Acoust. Soc. Am. 102, 2360 ‖ C. Carignan, R. Shosted, C. Shih, and P. Rong. (2011) Compensatory articulation in American English nasalized vowels. Journal of Phonetics, 39(4):668 – 682 ‖ C. Carignan (2014) An acoustic and articulatory examination of the oral in nasal: The oral articulations of French nasal vowels are not arbitrary. Journal of Phonetics, 46(0):22-33