

# Experimental and typological approaches to nasal vowel sonority

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Annual Meeting of the Canadian Linguistics Association

May 31, 2020

- Sonority is important in explaining and predicting phonological phenomena, but nasal vowels are noticeably absent from discussions of sonority and the generic sonority hierarchy.
- Intensity is often cited as a phonetic realization of sonority, but nasalization has particular consequences for intensity which may obscure or modify already observed relations.
- What could be the relation among nasal vowels and with respect to other sound categories, and what kind of evidence could argue for a given possibility?
- This talk considers possible types of evidence (phonological and phonetic) and takes first steps at filling these gaps.

- 1 Background:
  - What is sonority, and what evidence is used for establishing sonority relations?
  - What consequences does the intersection of height (or quality) and nasal coupling have on amplitude?
- 2 New experimental evidence (nasometric):
  - When we include split-channel (oral & nasal) data, how does amplitude differ among nasal vowels?
  - How do oral vowels stack up using the same methodology?
- 3 Typological evidence: How do nasal vowel inventories compare with oral vowel inventories?
- 4 Discussion & conclusion: What does this all mean, and where can we go from here?

- Notions of relative prominence among segment classes date back to origins of modern linguistics (e.g., Sievers, 1876; Whitney, 1865) and give us the basis for the concept of sonority.
- Despite the oft-cited vagueness of its definition (e.g., Clements, 1990) and controversy over its existence (e.g., Harris, 2006; Ohala and Kawasaki-Fukumori, 1997), the sonority hierarchy remains common in the analysis of multiple phonological phenomena.



**Fig. 1** General sonority hierarchy (e.g., De Lacy, 2006, after Kenstowicz, 1997; Walker, 1998)

- Further breakouts (e.g., laterals vs. rhotics, voiced vs. voiceless obstruents) are found in many scholars' hierarchies but may be subject to some language-specific phenomena.

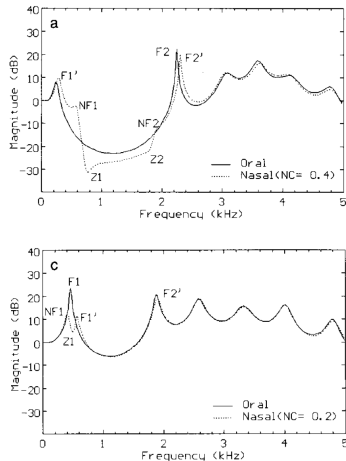
## Some uses for (or evidence of) vowel sonority

- Epenthetic vowels: Maga Rukai (Austronesian) copies preceding vowel unless of highest sonority (i.e., /a/), in which case [i] is epenthetic (De Lacy, 2006, citing Hsin, 2000).
- Quality-driven stress: Kobon (Trans-New Guinea) stress prefers more sonorous vowel of two candidates (Kenstowicz, 1997, citing Davies, 1981).
- Neutralization and unstressed vowel reduction: sonority reduction is blocked for vowels that are heads in every prosodic category (De Lacy, 2006, pp. 306-328).
- Syllabification: Tahitian (Austronesian) avoids creation of diphthongs unless V<sub>2</sub> is of lower sonority (Gordon, 2016, citing Bickmore, 1995).
- Deletion: Blackfoot (Algonquin) targets vowel of lower sonority for deletion (Elfner, 2005).
- Harmony systems: Higher sonority vowels are less likely to be transparent (Nevins, 2010).

- While a given phonological category is likely to have some degree of diversity, variation and language specificity in its phonetic correlates (e.g., Hamann, 2011), most definitions of sonority incorporate a phonetic dimension.
- Of the ~100 identified by Parker (2002, pp. 44-48) in the literature, he finds intensity (measured relative to a reference consonant) to correlate most significantly (**NB:** vowel results don't correspond as neatly).
- Parker (2008) gets a more expected low > mid > high > central continuum by comparing maximal intensity to that of a reference low vowel (this approach adopted here).
- Sonority is also quite frequently linked to aperture, impedance and susceptibility to spontaneous voicing in spoken languages, and visual salience in signed languages (Parker, 2002).

- As the shape of the nasal cavity cannot be altered, the nasal signal, comprised of poles and zeroes in specific frequency ranges, is more or less constant. Its contribution to a nasal vowel thus depends on the acoustic structure of the oral cavity.
- The degree of nasal coupling can, however, be modulated up to a certain point by the size of the velopharyngeal port and the height of the velum (Maeda, 1993).
- Inherent velic height is relative to vowel aperture in the majority of studies (e.g., Henderson, 1984), which, in addition to acoustic and aerodynamic factors, render high vowels more susceptible to spontaneous nasalization with slight degrees of velic lowering (Hajek and Maeda, 2000).
- Low vowels, on the other hand, require greater effort to achieve sufficient nasal coupling (Feng and Castelli, 1996).

- Modification of formant frequencies aside, nasal coupling generally leads to an increase in formant bandwidth and a reduction in amplitude (House and Stevens, 1956).
- Where these effects occur depend on the frequency and proximity of oral formants, especially F1 and F2.



**Fig. 2** Transfer functions of [i] (top) and [ɛ] (bottom). NF = nasal formant, Z = nasal zero, F' = shifted oral formant. (Maeda, 1993)



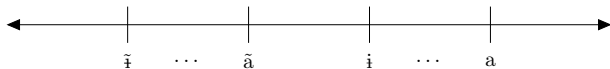
- It's entirely likely that nasal coupling muddles and/or transforms the intensity continuum observed for oral vowels.
- While height-specific effects do obtain, it's not a given that they fall along the same distinctions, in the same order.
- For instance, NF1 appears between a largely unaffected F1' and F2' in the case of nasal [i, u, o] but beneath a severely weakened F1' in the case of nasal [ɑ, ɛ] (Maeda, 1993).
- Going forward, we will have to be very clear and explicit about the link between sonority as a phonological category and its physical manifestation.
- That is, does amplitude reflect relations within nasal vowels and/or between nasal and oral vowels? Or does nasalization “overwrite” and supersede a typical but insufficient phonetic condition for a phonological primitive?

- For the sake of argument, let's make some potentially bold assumptions that:
  - The sonority hierarchy exists and is universal with respect to its categories (up to a certain degree of specificity),
  - Sonority has a primary phonetic correlate which delineates *and reflects* all major categories of that hierarchy,
  - Admissible phonological evidence converges with the phonetic evidence, and
  - Nasal vowels aren't, for some reason, exempt from this hierarchy.
- I then see three main potential scenarios for nasal vowel sonority.
- Let's consider the predictions made by each, assuming also intensity is indeed that phonetic correlate...



## Scenario 2

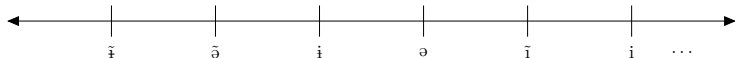
- Nasal vowels form a *distinct, cohesive class* in terms of sonority to be inserted somewhere in the existing hierarchy (e.g., interrupting glides and high central *oral* vowels).



- All nasal vowels' intensity values fall along a continuum (e.g., all are lower to those of oral vowels) and have some hierarchization among themselves (not necessarily that of oral vowels).
- The phonological predictions made by such a hierarchy are less clear, but for instance, with the hierarchy above, a language could allow all nasal vowels in unstressed position but only lower-sonority oral vowels.
- This scenario could at worst result in some bizarre predictions (e.g., unstressed nasalization, avoidance of stress on nasal vowels, etc.), but faithfulness to nasality is likely to prevent and/or obscure sonority-driven phenomena.

## Scenario 3

- Nasal vowels are *interleaved* with oral counterparts.



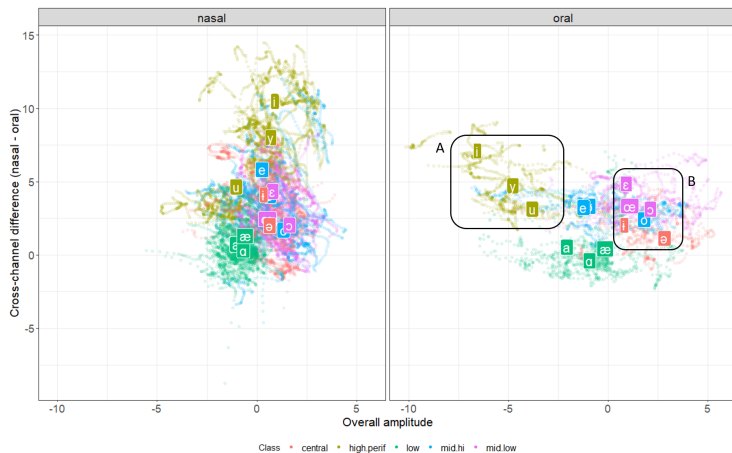
- The intensity of a given nasal vowel or natural class of nasal vowels falls between that of 2 contiguous oral vowel (classes), and so on.
- The order of nasal vowels relative to each other is again not necessarily the same as that of oral vowels.
- We can predict similar phonological behaviour as the first scenario, i.e., restrictions and alternations applying to one category may reference those of a contiguous category.
- Oral-nasal sets may not be necessarily complete, however. For instance, as per above, a language could allow [ã, ə, î] in unstressed positions but not [i].

# Intensity results



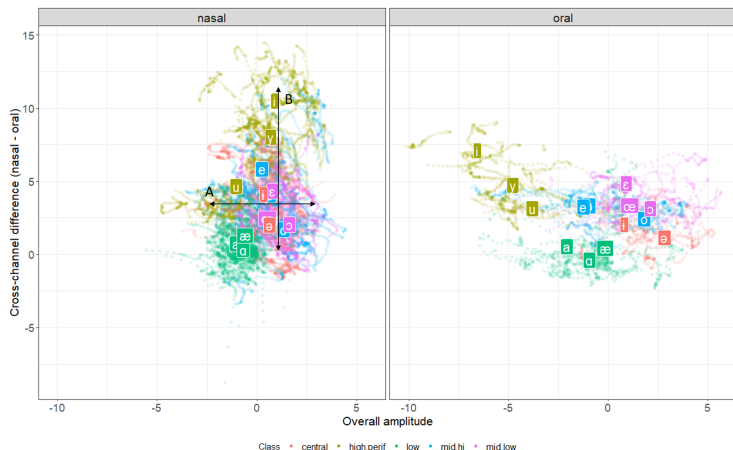
**Fig. 3** Combined signal vs. differential (nasal - oral) intensity (dB) relative to max intensity of /a/ or /ã/, by vowel quality and nasality. Labels indicate location of mean values.

# Oral vowels



- A. High oral vowels have lower overall intensity than low
- B. Some vowels (esp. mid-low and central) have slightly higher

# Nasal vowels



- A. No huge difference in overall intensity. Maybe a low (+ /u/?) – non-low split.
- B. Difference increases with height (larger = nasal channel has greater intensity)



- Oral vowel results not entirely incompatible with Parker (2002, 2008). Not a neat correlation, but no reversal.
- Combined-channel amplitude of nasal vowels is fairly equal between categories. Probably a useless predictor of sonority.
- The roughly constant overall amplitude of nasal vowels plus the cross-channel difference tells us:
  - The amplitude of one channel is either increasing or decreasing with respect to the other, and
  - The effect is larger for high vowels than for mid vowels.

- A closer look at the data (see Appendix) shows us nasal channel amplitude is fairly constant in non-low vowels, but that oral channel amplitude decreases from mid to high vowels.
- Mid and low nasal vowels are distinguished by the lower nasal channel amplitude of the latter.
- *Differences* in amplitude between channels may therefore be a better indicator of sonority specific to nasal vowels—but this is speculation from preliminary data.
- Parker (2002) found air pressure to have a strong negative correlation with sonority. This is a logical next step for approaching nasal vowel sonority from a phonetic perspective.

# What about phonological evidence?

- Apart from inventory typology, it seems to be scarce (work in progress).
- Ruhlen's (1975) survey suggests only that low *phonemic* nasal vowels are implied by other types of nasal vowels.
- Tying this in with theories of markedness implications, this could mean that low nasal vowels are the most sonorous (and least marked).
- Vowel nasalization is contrastive only in stressed position in certain languages like Zuberoan Basque (Egurtzegi, 2015) and Guaraní (Tupian) (Kaiser, 2008).
- Ultimately, a negative result (i.e., nasal vowels simply don't participate in the same kinds of phenomena as oral vowels) would be very telling and could have implications for sonority and for the representation of nasal vowels.

- Data are from a metalinguistic task and a single person (though a graduate student with extensive training in phonetics). More data from participants from different linguistic backgrounds (*à la* Carignan, 2018) need to be gathered.
- Reference vowel was for unique combination of conditions (syllable structure, length, etc.) and not part of a carrier sentence. These intensity readings should thus be met with some healthy skepticism.
- Alternations in quality *subsequent to* nasalization (e.g., /V<sub>1</sub>N/ → [Ṽ<sub>2</sub>]) may be trickier to disentangle from diachrony and more universal phonetic factors.

- Intensity still may be a viable correlate of nasal vowel sonority but requires specialized equipment to separate channels.
- Oral-channel amplitude and/or the difference between channels' amplitudes may be indicative of nasal vowel sonority and so far appear to correspond to oral vowel results in the literature.
- Current typological evidence points to low nasal vowels as having higher sonority than non-low nasal vowels, again comparable to oral vowels.
- The exclusion of nasal vowels in unstressed position in certain languages, though, may complicate this picture.

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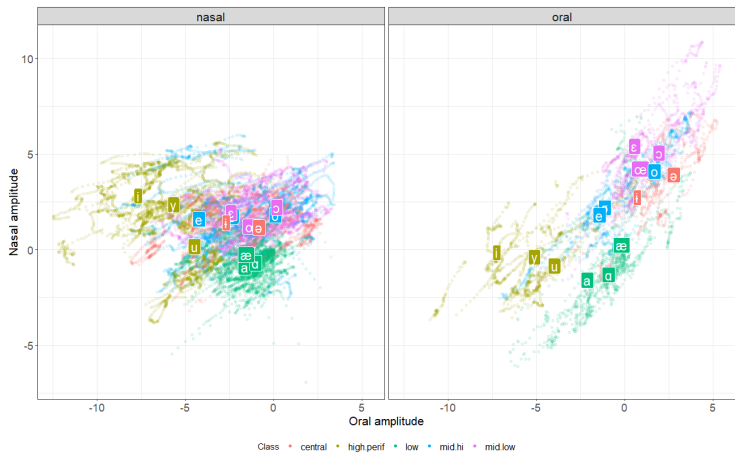
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Thanks to Félix Desmeules-Trudel, Jeffrey Lamontagne and Myriam Lapierre for their thoughts on the phonological evidence. Thanks to my participant for providing the data.



- Performed by bilingual French-English linguistics graduate student
- Recorded with a handheld nasometer (Glottal Enterprises NAS-1 SEP Clinic) in stereo, each microphone corresponding to a channel
- Stimuli:
  - Target oral and nasal vowels /i, ə, i, y, u, e, ø, o, ε, œ, ɔ, æ, a, ɑ/
  - Contexts: vowel-only, s\_, s\_s
  - Short & long variants for each combination
- Task repeated twice, order of vowel reversed for second recording  
→ 560 vowels

- Vowels isolated and tagged. First & final 50 ms excluded for each vowel
- Energy and intensity readings taken within combined signal and individual (nasal & oral) channels at 5 ms intervals
- Vowels classified into categories:
  - Central, high, mid-high, mid-low, low
  - Oral (oral target in isolated or oral contexts) and nasal (nasal target)
- Within conditions (e.g., length, context) *and nasality*, the max intensity of the low back vowel was used as reference.
- Comparisons of values between an oral vowel (class) and its nasal counterpart should therefore be avoided.



**Fig. 4** Nasal vs. oral amplitude (dB) relative to max amplitude of /a/ or /ā/ by vowel quality and nasality