# MOVING PHONOLOGICAL SCIENCE FROM PAPER TO THE LABORATORY: THE CASE OF NASALS AND NASALIZATION

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## ABSTRACT

The three papers in this session illustrate dramatically how far phonological science has evolved over the past few centuries. The behavior of speech sounds, in this instance, nasals, which previously could only be described or notated in a variety of ways, is now explained by reference to physical principles from anatomy, physiology, and acoustics, and perception.

**Keywords:** Phonology, nasals, fricatives, trills, coarticulation.

## 1. PHONOLOGICAL SCIENCE: BEGINNINGS

Phonological science, which seeks to understand the behavior or patterning of speech sounds in languages of the world, has a long history. It includes works spanning more than two millennia, e.g., those from the ancient grammatical traditions of the Indians, the Greeks, and the Arabs and Persians. With few exceptions the data informing this field were representations of speech either in written form with possibly a list of classificatory descriptors associated with them, e.g., occlusive, continuant, vowel, consonant, labial, velar, etc. Although there were notable achievements in certain areas, e.g., devising writing systems that were anatomically and physiologically insightful (e.g., the Korean script, Hangul, Wilkins' script [24]), speech pathology (e.g., Amman [1]), the physiology of speech, especially of phonation (Ferrein [6], Müller [11], etc.), the most important self-sustaining development (beginning around the end of the 18th c) was the establishment of the family relationship between languages largely on the basis of point-by-point systematic phonological alternations (Sajnovics [22], Rask [18] [19]; Grimm [7]).[1] Of necessity the basic data in this latter task was usually written: either orthographic citations from existing texts or phonetic transcriptions of heard speech. In both cases it is possible to generalize that the basic data informing the generalizations were on paper. From this beginning, attention was given to documenting and explaining sound changes. When going beyond description to explanation, the explanations were given in abstract terms with nebulous empirical foundation, e.g., markedness, strength and sonority hierarchies, or simply by names which were generally not further analyzed, such as assimilation, dissimilation, metathesis, etc. To be sure, outside this mainstream approach there were exceptions, where hypotheses were formulated and tested empirically or where accounts of sound patterns were given in terms of principles distinct from the data considered, e.g., Passy [17]).

## 2. PHONOLOGICAL SCIENCE TODAY

The 20th century saw a steady accumulation of experimental works ranging from phonetics to psycholinguistics (e.g., Rousselot [21], Sapir [23]). Collections focusing on experimental phonology were published (Ohala & Jaeger [14]); a regular series of meetings and their proceedings devoted to Laboratory Phonology was initiated and is still ongoing (Kingston & Beckman [9]). Sessions devoted to experimental phonology are now regular features of such national and international conferences as the Acoustical Society of America, the Linguistic Society of America, the International Congress of Phonetic Sciences, among others. Though still not "mainstream", experimental phonology now has carved out a self-sustaining niche within phonological science.

## 3. SOUND PATTERNS OF 'NASAL'

The phonological behavior of nasal sounds is a prime arena in which to demonstrate the advantages of experimental phonology Nasal sounds have unusual properties that constrain their combination with features of place and manner [12] [16].

[1] Not to neglect earlier discoveries of the same sort, e.g., ten Kate [8], des Brosses [4], Burnet [5]).

### 3.1. Aerodynamics

Aerodynamically a velic opening bleeds the oral pressure made by an oral constriction further downstream of the velic opening. Thus they impact on the production of buccal obstruents (those articulated further forward than the pharynx). Shosted and Solé both discuss this in the case of buccal fricatives and apical trills, respectively. One manifestation of this is that buccal obstruents block spreading nasalization in what has been called 'nasal harmony'. Thus in Sundanese, the occurrence of a nasal consonant in a word induces nasalization on all following segments unless the spread of nasalization is blocked by an oral buccal sound; e.g., as illustrated in the following words in Sundanese [20]: /nãĩãn/ 'to wet'; /ɲãh̃õkɤn/ 'to inform'.

Conversely, if a velic closure is made during a nasal consonant, say, due to assimilation to an adjacent oral obstruent, an emergent oral stop may appear that has the same place of articulation as the nasal. Familiar examples are Spanish *Alhambra* < Arabic *al hamra*, "the red (edifice)"; English *youngster* < original [ˈjʌŋstɚ] pronounced as [ˈjʌŋkstɚ].

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### 3.2 Acoustics

There are, of course, no 'articulators' in the nasal passage itself. Nevertheless its fixed resonances interact with the resonances of the oral tract in complex ways. In a branched resonator the resonators in one branch contribute anti-resonances to the resonances of the other branch. The consequence is that most resonances are considerably damped (i.e., they have broad bandwidths). A consequence of this is that there is more confusion of the nasal consonants among themselves than is the case with the purely oral consonants. Of course, contributing to this is the fact that nasal consonants do not have any burst or frication. (In oral obstruent consonants the sound resulting from such turbulence – stop burst or frication -- is shaped primarily by resonances of the cavity downstream of the place where the turbulence is generated thus providing crucial perceptual cues as to the consonant's place of articulation.)

There are rather severe physical constraints on the acoustic manifestation of voiceless nasals, given in the descriptive literature as /m̥ n̥ ŋ̊/. All would have frication generated at the outermost narrowing of the tract where the airflow vents to atmosphere. For these consonants that would be the nostrils which is the same for all of them. Then how can the different places of articulation be differentiated? The transitions in the formants upon release when voicing is re-initiated are part of the answer. But more important, in many cases what are called voiceless nasals are partially voiced, i.e., /m̥/ is phonetically [m̥͡m] [10]. The voiced portion would help to cue their place.

Besides the formant transitions from or to adjacent vowels, the physical factor which crucially differentiates one consonantal nasal from another is, of course, the length of the resonating cavity in the oral branch: this is longest for the labial nasal /m/ and shortest for the velar or uvular nasals /ŋ/ and /ɴ/. In the case of these rear-most articulated lingual closures there isn't much of an oral side branch at all. Consequently the output sound is more vowel-like – still having highly damped resonances given the highly sound-absorbent surfaces of the nasal cavity and, of course, the fact that the nasal cavity is divided by the septum giving rise effectively to two coupled resonance chambers. This may be the reason that the inventory of nasal consonants in languages of the world often consists of just 'anterior' nasals, i.e., /m/ and /n/, even though they may have posterior oral consonants.

### 3.3 Spontaneous Nasalization

It has been observed in a few languages that distinctive vowel nasalization arises on vowels adjacent to certain consonant types. Paradoxically, these consonants are those that require velic closure. E.g., Prakrit *akk$^h$i-* "eye" became Modern Hindi [ãk$^h$]; Prakrit *sappa* "snake" became Modern Hindi [sãp]; Spanish /si/ "yes" (< Latin *sic*) gives Mexican Spanish [sĩ]. Ohala and Amador [13] argue that the consonant types that apparently engender nasalization on adjacent vowels are those that require a glottal opening larger than normal for simple voiceless consonants and that this larger-than-normal glottal opening gives rise via assimilation to coupling between the supra-glottal cavity and the tracheal cavity that thus constitutes the kind of coupled resonators that mimic the effects of the coupled oral and nasal resonators that produce the kind of damped resonances that cue vowel nasalization. They give the results of a perception experiment that supports their claim.

## 4. A CASE STUDY: LABIAL-VELAR NASALS

To illustrate the advantages of integrating physical phonetic information into phonological analyses (as opposed to the 'paper' approach), I recapitulate briefly a case study treated in more detail in [15].

Anderson [2] observed that although labial-velar consonants such as /k͡p g͡b w/ were included in the segment inventories of many languages they patterned phonologically either as labials or as velars but not both. E.g., the labiovelar stops in Kpelle and Yoruba must be phonologically velars, he argued, since preceding nasals assimilating to their place of articulation show up as [ŋ] not [m]. Ohala and Lorentz [15] argued that this evidence was inconclusive since, given doubly-articulated stops such as [k͡p] or [g͡b], what determines the acoustic-perceptual character of a nasal assimilating to it is the rear-most articulation; the anterior constriction plays no role in shaping the spectrum of the nasal murmur. Moreover, they cited examples of languages where labial-velar sounds patterned as velars to assimilating nasals but as labials when becoming fricatives, e.g., In Tenango Otomi /h/ → [ɸ] / _ w, whereas /n/ → [ŋ] / __w [3]. (Unlike nasals, where it is the rear-most of multiple constrictions that determines the sound, in the case of oral fricatives it is the *front-most* constriction which predominantly determines the acoustic signal: the resonance chamber defined as bounded at one end by the point where turbulence is generated and at the other where the sound radiates, the lips. Any turbulence noise -- inherently high frequency – which might be generated at a second more back constriction is effectively low-pass filtered by any more foreward constriction. The alternation between [w] and a labial fricative, especially a voiceless labial fricative is common in many languages as either a regional or historical variant, e.g., *enow* ~ *enough* [iˈnʌf], *lieutenant* ~ [lɛfˈtɛnənt].)

## 5. THIS SESSION

The three papers in this session give dramatic evidence of the utility of addressing the causes of cross-language sound patterns by reference to empirical studies of the physical phonetic basis for speech sound production.

### 5.1 Beddor

Beddor gives a completely new account of the origin of distinctive nasalization on vowels adjacent to nasal consonants which in turn have their durations influenced by the contextual factors. There is evidence for a relatively constant velic opening gesture which can drift onto a preceding vowel if the nasal itself is short.

### 5.2. Shosted

Shosted presents evidence relevant to the issue of whether oral (buccal) fricatives can co-exist with concomitant nasalization. He presents instrumental evidence that some portion of oral fricatives can have some degree of nasalization. However the quantification of this nasalization and its consequences acoustically and perceptually, remain to explored.

### 5.3. Solé

Solé presents experimental and diachronic evidence that back-articulated consonants require more velic leakage during at least part of the stop closure in order to remain voiced. Her paper covers a wide range of phenomena, phonetic and phonological, that can be derived by considerations of how nasality interacts with other features.

## 6. SUMMARY

Together these three papers exemplify the increased power of explanation for sound patterns in languages when physical phonetic factors are taken into consideration.

## 7. REFERENCES


[1] Amman, Johan Conrad. 1700. *Dissertatio de loquela.* Amsterdam.

[2] Anderson, S.R. 1976. On the description of multiply-articulated consonants. *J Phonetics* 4.1.17-27.

[3] Blight, R.C. and E.V. Pike. 1976. The phonology of Tenango Otomi. *IJAL*. 42. 51-7

[4] des Brosses, Ch. 1765. *Traité de la formation méchanique des langues, et de principes physiques de l'étymologie.* Paris.

[5] Burnet, J. 1773-1792. *Of the origin and progress of language*. Edinburgh.

[6] Ferrein, A. 1741. De la formation de la voix de l'homme. *Memoires de l'academic royale.* 409-432

[7] Grimm, Jacob. 1822. *Deutsche Grammatik.* Vol. 1. 2nd ed. Göttingen.

[8] ten Kate Hermansz, L. 1723. *Aenleidning tot de Kennisse van het verhevene Deel der nederduitsche Sprake.* Amsterdam.
[9] Kingston, J., Beckman, M. E. (eds) 1990. *Papers in Laboratory Phonology. Bertween the Grammar and the Physics of Speech.* Cambridge: Cambridge University Press..
[10] Laefoged, P., Maddieson, I. 1996. *Sounds of the world's languages.* Oxford: Blackwell.
[11] Müller J. 1833-1840, *Handbuch der Physiologie des Menschen.* Coblenz.
[12] Ohala, J J 1975. Phonetic explanations for nasal sound patterns. In: *Nasálfest Papers from a Symposium om Nasals and Nasalization.* C.A. Ferguson, L.M. Hyman and J.J. Ohala.(eds.) Stanford: Language Universals Project. 289-316.
[13] Ohala, J. J. & Amador, M. 1981. Spontaneous nasalization. *J. Acoust. Soc. Am*. 69. S54-S55.
[14] Ohala, J. J. & Jaeger, J. J. (eds) 1986. *Experimental Phonology,* Orlando, FL: Academic Press.
[15] Ohala, J J & Lorentz, J 1977. The story of [w]: An exercise in the phonetic explanation for sound patterns. *Berkeley Ling. Soc., Proc., Ann. Meeting* 3.577 - 599.
[16] Ohala, J. J. & Ohala, M. 1993. The phonetics of nasal phonology: theorems and data. In *Nasals, nasalization, and the velum.* M. K. Huffman & R. A. Krakow (eds.), San Diego, CA: Academic Press. 225-249.
[17] Passy, P. 1890. *Étude sur les changements phonétiques et leurs caractères généraux.* Publisher Paris, Firmin-Didot, .
[18] Rask, R. K. 1811. *Bejledning til det Islandiske eller gamle Nordiske Sprog.* Kjo,/benhavn.
[19] Rask, R. K. 1818. *Undersøgelse om det gamle Nordiske eller Islandske Sprogs Oprindelse.* Kjo,/benhavn.
[20] Robins, R. H. 1957. Vowel nasality in Sundanese. In *Studies in Linguistic Analysis.* Oxford: Blackwell. 87-103.
[21] Rousselot, L'Abbé. 1897-1901. *Principes de phonétique expérimentale.* Paris : H. Welter.
[22] Sajnovícs, J. 1770. *Demonstratio. Idioma Ungarorum et Lapponum idem esse.*Tyrnavia.
[23] Sapir, E. 1929. A study in phonetic symbolism. *J. Experimental Psychol.* 12. 225-239.
[24] Wilkins, John. 1668. *An essay towards a real character and a philosophical language.* London. Sa: Gellibrand, John Martin.