NASAL PROCESSES AT THE INTERFACE BETWEEN PHONETICS AND PHONOLOGY

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ABSTRACT

This paper introduces to a special session on nasalization at the XVI[th] ICPhS. Nasal studies have a long history, at the interface between phonetics and phonology. The three invited papers of the session are presented and discussed in this framework.

Keywords: nasal, nasalization, fricatives, timing.

1. HISTORICAL OVERVIEW

From the first linguistic descriptions mentioning nasal sounds (as old as Panini's, 5[th] century BC) to the numerous phonetic and phonological studies in the 20[th] and 21[st] century, nasal processes have been the focus of a large amount of scientific articles and monographs that are briefly reviewed below.

The exploration of nasal sound patterns goes back to the work of comparative grammarians on indo-european languages (e.g. [16]). Early studies in experimental phonetics involved the investigation of nasal sounds using inventive instrumentation. (e.g. Rousselot [25]). Turning to the 20[th] century, the basic principles of the acoustics and perception of nasalization were determined in the 50's (e.g. Delattre [8], House & Stevens [18], Fant [12], Fujimura & Lindqvist [15]). Phonetic studies in the 60's and the 70's mainly concentrated on the production of nasal sounds using a variety of data and techniques such as (cine)radiography, electromyography, fiberoscopy, aerodynamic data (e.g. Björk [7], Bell-Berti [4], Benguerel et al. [5, 6]), and specific devices like the nasograph (Ohala [21]). Nasal studies much contributed to the elaboration of coarticulation theories and models (for a review, see Farnetani & Recasens [13]). Our understanding of the perception of nasalization has made much progress in the 80's and the 90's with the development of synthesized speech and modelisation (e.g. Krakow et al. [20], Beddor in [2], Kingston & MacMillan [19]).

Many issues need further exploration and the interest for nasalization remains considerable, as evidenced by the number of dissertations that have been defended in the last years, whether on languages that were poorly described regarding nasalization (e.g. Diakoumakou [10], Onsuwan [23]) or on more documented ones (e.g. on French: Rossato [24], Delvaux [9], Amelot [3]).

The scientific literature on nasal disorders developed somewhat apart from phonetic and phonological studies. Physicists started to investigate the specific (nasal) disabilities of cleft palate speakers in the mid-50's (e.g. Warren [29]). Weinberg and colleagues [30] showed that hypernasality in speech is the primary cue to diagnose velopharyngeal incompetence. Although there has been a growing body of literature on nasal disorders in the last decades, the cooperation between phoneticians and pathologists still needs to be reinforced.

2. PHONETIC CONSTRAINTS AND PHONOLOGICAL UNIVERSALS

Nasalization processes provide a case study to investigate the relationships between phonetic constraints and phonological patterns. In two influential papers, Ohala (in [1], & Ohala in [2]) reviewed a number of phonological processes in both synchrony and diachrony that occur more or less frequently in the world's languages, and related them to the phonetic constraints acting on the production and the perception of nasal vowels and consonants. Hajek [17] investigated the universals of sound change in nasalization and documented interesting convergences between these universals and general mechanisms of speech production and speech perception.

Phonological patterns that can shed light on nasalization are at least of three types: (i) inventories of phonemes and syllable structures, (ii) phonological processes in synchrony, (iii) sound change involving nasals and the corresponding fossilized morpho-phonological alternations. Our knowledge of these phonological patterns needs constant updating. First, new languages and dialects can be added to enlarge the available databases. Second, the phonetic descriptions of the phonological units involved in alternations may be refined. Third, so-called ‘universal tendencies’ need to be reassessed by investigating combinations of segments and lexical frequencies in addition to simple phonemic inventories. For example, Vallée et al. [28] studied the favoured syllabic patterns in 17 languages and found an exception to the sonority hierarchy in that [N+plosives] clusters are favoured over [plosives+N] clusters in coda and in onset position.

The number of well-documented monographs on the production and perception of vowel and consonant nasalization has considerably grown in the last decades. The challenge now is to relate these data – usually collected on a single language and a laboratory corpus – to other language components involved in spontaneous speech (such as prosodic structure), or to the other aspects of phonetic implementation, relating production to perception data, and within production, relating aerodynamic to acoustic and articulatory properties. Moreover it is necessary to interrelate monographs on specific languages by carrying out large cross-linguistic studies using comparable methodological procedures. Demolin’s discussion of Beddor’s paper in this session illustrates how a paradigm suitable for the cross-linguistic study of the timing relationships between vowel and consonant nasalization (here, on English, Ikalanga and Thai) can be used by other researchers to scan data available on additional languages (here, Rwanda), in order to contribute to the verification of the originary hypothesis.

Another way of investigating the phonetic constraints acting on the production of nasalization consists in building models simulating the action of these constraints and compares their output with data collected on natural languages. Since Ohala’s initial proposals for the construction of an aerodynamic model of speech production [22], little progress had been made on the topics. A fully operational data-driven aerodynamic model of nasal production is still missing. Specifically, we have scarce information about the mathematical relation that would link aerodynamic variations with acoustico-perceptual variations. In a recent attempt, Shosted [26] constructed a model vocal tract in order to study the effects of nasalization on the acoustic properties of fricatives while controling the degree of velopharyngeal aperture. Results interestingly complemented measurements made on natural languages, even if the fricatives produced by the model were not totally naturalistic (Shosted, this session).

3. THREE STUDIES

In this special session, three invited papers and two discussing papers will be presented. All the papers forming the session adopt an integrated perspective in the study of nasalization: physical phonetic factors as well as phonological patterns are taken into consideration; the results of production and perception studies are presented and compared; all the papers adopt a cross-linguistic perspective. A wide range of the world’s language families is covered, namely Bantu languages from the Niger-Congo family (Umbundu, Ikalanga, Rwanda), Indo-european (including romance and germanic) languages, Tupi-guarani languages (Karitiana), and Tai-kadai languages (Thai).

Solé investigates the compatibility of nasalization with voicing and manner features, arguing that aerodynamic and acoustic interactions between [nasal] and other features determine their likelihood to combine within segments as well as through segment sequences. She discusses the literature on a variety of languages and phenomena. Based on the computation of transitional frequency of nasal and oral consonants following voiced and voiceless fricatives, she shows herself that there is a bias against fricatives followed by nasal segments in English, German and Dutch.

Shosted reports an experimental study on the aerodynamics of one of those rare features combination aims at in Solé’s paper, i.e. nasalized fricatives. Shosted measured oral and nasal airflow comparing the production of fricatives in oral and nasal context for Hindi, Brazilian Portuguese and French speakers. The aerodynamic parameters significantly differ across phonetic context.

Beddor presents data on English, Thai and Ikalanga suggesting that there is a relation between segmental and coarticulatory timing. In a production study, the temporal extent of vowel and consonant nasalization is assessed using acoustic measures in (C)ṼN(CV) sequences in Thai, American English and Ikalanga comparing different phonetic contexts. The total duration of acoustic nasalization (Ṽ plus N) is relatively constant across contexts in all three languages, and in two of them (C)ṼN(CV) sequences exhibit the predicted trade-off in the relative durations of vowel nasalization and N. A perceptual experiment shows that listeners are more sensitive to acoustic variation in total nasalization than to extent of nasalization on Ṽ or N. They experimentally respond to vocalic and consonantal nasality as though they were perceptually equivalent.

Demolin and Ohala discuss the three papers and contribute by providing additional data. Demolin presents complementary results from other languages, mainly Rwanda, but also Umbundu and Karitiana. Ohala uses labio-velar nasals as a case study to illustrate the advantage of integrating physical phonetic information into phonological analyses.

4. NASALIZATION IN FRICATIVES

The specific way in which nasalization in fricatives is dealt with in this session illustrates how nasalization processes can only be described and explained when taking into account both a diversity of phonological patterns and the multiple nature of phonetic implementation.

Nasalization in fricatives is the primary focus of Shosted's paper. The paper unambiguously shows that oral and nasal airflow pattern differently in fricatives depending on (oral vs. nasal) phonetic context. In particular, the integrated nasal airflow is significantly higher for fricatives in nasal context. However, as acknowledged by the author, the implications of this finding remain unclear since aerodynamic measurements are non monotonically related either to velopharyngeal aperture or to the acoustics of nasalized sounds. Based on pathological and modelization data from the literature, Solé notes that there may be a threshold under which a small velum opening is not sufficient to disturb the build up in oral pressure necessary for friction because of the high impedance remaining at the velopharyngeal port when compared to that of the oral tract. Alternately, when velopharyngeal opening exceeds 20 mm^2, the aerodynamic requirements for obstruency are not met any more, and friction is lost. Indeed, both Shosted and Solé insist on the strong aerodynamic constraint against nasalization in fricatives, a constraint that is evidenced by some well-documented phonological patterns among which the high position of fricatives in nasal harmony scales, the absence of contrastive nasalized fricatives in the world's languages, and the diachronic change from phonetically nasalized voiced fricatives to nasalized continuants (e.g. in Guarani). Solé notes that the latter change interacts with voicing, and she provides an aerodynamic and an acoustico-perceptual constraint that could account for this interaction. In voiced fricatives, nasal leakage may support the sustaining of voicing, and then add perceptible acoustic properties of nasal coupling to the weak frication noise. This favours the loss of frication and the preservation of nasalization. Alternately, nasalization is unlikely to be retained in voiceless fricatives since at most it does not support their production and its acoustic consequences are hardly detectable until fatal to the manner feature.

Beddor's paper sheds an interesting light on the interaction between nasalization, voicing and obstruency. Her data are best accounted for when considering that vowel and subsequent consonant nasalization are part of a single nasal gesture. This gesture is of fairly similar duration but starts earlier relatively to the oral closure in (C)VNC$_{[voiceless]}$ than in (C)VNC$_{[voiced]}$ sequences, explaining differences in vowel nasalization, N duration and C duration. Listeners also tend to treat vowel and subsequent consonant nasalization as perceptually equivalent. These results suggest that the temporal extent of the nasal gesture is a defining feature of nasalization. Beddor reviews a number of phonological findings that are convergent with her hypothesis, among which the evolution of nasal vowel phonemes from phonetically nasalized vowel followed by a homosyllabic nasal consonant. This broadly attested historical change may be considered as the phonologization of one end of the covariation continuum in which the temporal extent of vowel nasalization is maximal and that of consonant nasalization is minimal.

5. REMAINING QUESTIONS

There is no linguistically distinctive use of nasal consonants which differ in manner of articulation of the velum (Ladefoged & Maddieson, [20]:106). Similarly, no language has a three-way phonological contrast between oral, ligthly nasalized and heavily nasalized vowels. But the binarity of the [nasal] feature does not prevent nasalization processes from high complexity.

Phonetically speaking, a wide range of variation is observed in velopharyngeal aperture across segment type (consonant manner of articulation, vowel height, etc.), prosodic position (Fougeron

[14]), speaking rate, and even individual strategies (Vaissière [27]; Engvall, Delvaux & Metens [11]). Moreover, how exactly the spatial extent of the nasal gesture is related with the percept of nasalization remains unclear. Little progress has been made to enlarge the work of Maeda on articulatory modeling (in [2]). In fact, we still need a fully operational data-driven model of nasal production including the non linearities between the articulatory, aerodynamic and acoustic phase.

Moreover, the temporal extent of the nasal gesture is a defining property of nasalization. The trade-off in production and perception that is evidenced between Ṽ and N by Beddor's measurements (and corroborated by Demolin's data on Rwanda stops) seems to have no equivalent among other phonetic properties and as such deserves further work. The modalities of the perceptual equivalence will have to be specified, as well as the mechanisms of compensation for speaking rate. And the perceptual robustness of nasalization should be compared between vowels of different quality and consonants, since it could account for some aspects of the emergence of nasal vowel phonemes in the world's languages.

In conclusion, the session papers take into account both the phonetic constraints acting on the production and perception of nasal sounds, and the nasal phonological patterns in the world's languages. Alternately, these nasal studies improve our general understanding of phonetic and phonological processes, among which the central role of gestural timing.

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