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Exceptional nasal-stop inventories*

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Abstract

This article explores the topic of exceptionality in phonology focusing on nasal-stop inventories. A meticulous survey shows that it is normal for such systems to include at least two anterior units: /m/ and /n/. The finding that the introduction of /ŋ/, the first posterior unit to appear, normally follows that of both anterior units suggests that anteriority is somehow more compatible with this consonant class; however, this hypothesis is challenged by exceptions: /n/ is occasionally superseded by /ŋ/. The proposed analysis overturns the view that there is a single universal place hierarchy. It demonstrates that languages assess the cost of place features on multiple dimensions and that nasal-stop inventories are shaped by the conflict between three evaluation measures: one for articulatory cost, one for perceptual cost, and one for dispersion. A theory of far greater explanatory power emerges when each evaluation measure is empirically substantiated and their universality is strictly respected.

Keywords: sound inventories; nasal stops; place features; exceptions; place hierarchies; universal rankings; articulatory cost; perceptual cost; dispersion

Resum. *Inventaris excepcionals d'oclusives nasals*

Aquest article explora el concepte d'excepcionalitat en fonologia en relació amb els inventaris de les oclusives nasals. Un repàs meticulós d'aquests inventaris demostra que és normal de trobar-hi com a mínim les dues nasals anteriors /m/ i /n/. El fet que la introducció de la nasal velar /ŋ/, la primera unitat posterior a aparèixer, vagi precedida normalment per la introducció de les dues unitats anteriors suggereix que l'anterioritat és d'alguna manera més compatible que la posterioritat pel que fa a la classe de les consonants nasals. Tot i això, aquesta hipòtesi es veu compromesa per algunes excepcions: /n/ és substituïda de manera ocasional per /ŋ/. L'anàlisi proposada en aquest article invalida la idea que hi ha una sola jerarquia pel que fa al punt d'articulació. S'hi demostra que les llengües avaluen el cost pel que fa als trets de punt d'articulació en diverses dimensions i que la forma dels inventaris de les consonants nasals ve determinada pel conflicte entre tres mesures d'avaluació: cost articulatori, cost perceptual i dispersió. S'assoleix una teoria amb molt més poder explicatiu quan cada mesura d'avaluació troba suport empíric i la seva universalitat es respecta estrictament.

Paraules clau: inventari de sons; oclusives nasals; trets de punt d'articulació; excepcions; jerarquia de punts d'articulació; rànquings universals; cost articulatori; cost perceptiu; dispersió

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> "Isn't it possible that there is something that we might call *normal* in the sense that if we look at the thousands of languages that now exist or have been recorded from the past, the overwhelming majority of them work in a certain way? (Ferguson 1974: 5)

1. Introduction

It makes sense to begin a study on exceptions by establishing what the norm is. As concerns nasality, there are two main tendencies in its phonological use. Languages tend to have distinctive nasality in consonants, rather than in vowels, and in anterior, rather than in posterior articulations. These are the properties underpinning the notion of 'normal nasality' defended by Ferguson (1974, 1975).[1]

The proclivity of nasality to appear in anterior consonants is manifested by the crosslinguistic prevalence of /m/ and /n/, the labial and coronal nasal stops. Ferguson's claim that languages normally have at least this pair of nasal phonemes is substantiated by the Auckland Nasal-Stop Inventory Database (ANSID).[2] The results in Table 1 provide a sense of the extent to which this generalization is true. Here we see that 419 of the languages in the sample do indeed employ both /m/ and /n/. Since this figure amounts to 92.70%, it is sensible to regard this pattern as a language universal; however, it would not be absolute as in (1), but probabilistic as in (2).

(1) *All languages* have at least two nasal-stop phonemes, both of which are anterior.

1. It is assumed that consonants articulated in front of the protuberance of the alveolar ridge are anterior, while those articulated behind it are posterior.
2. ANSID is essentially a revision of the nasal-stop systems catalogued in UPSID-451 (Maddieson and Precoda 1990). The discovery of numerous coding and analytical errors in the existing phonological segment inventory databases led to the conclusion that an accurate typology of nasal-stop inventories cannot be developed based on them. The nature of the problems is such that the recommendation not to use such tools for typological phonological research has repeatedly been made in the literature (Basbøll 1985, Pagliuca and Perkins 1986, Simpson 1999, Vaux 2009).

   The decision to emulate UPSID was motivated by its effort to ensure a reasonable level of genetic diversity: only one language from each small family grouping (Maddieson 1984: 5). Exact replication of the sample was not possible, however, because there were a few languages for which reliable primary sources could not be obtained, in which case a related language was used as substitute. The substitutions made were Afitti for Nyimang, Gbaya Kara for Gbaya Bossangoa, Ipai for Kumeyaay (Diegueño), !Xoon for Jul'hoan (!Xu), and Urdu for Hindi-Urdu. The only other alteration was the addition of Palauan, a language exemplifying a pattern that would have been missed otherwise. This raised the total to 452 languages.

Table 1. Quantification of the norm in ANSID

	Language type	Number	Percentage
a.	with both /m/ and /n/	419	92.70%
b.	without both /m/ and /n/	33	7.30%
	TOTAL	452	100.00%

Table 2. Quantification of the exceptions in ANSID

	Language type	Number	Percentage
a.	without phonemic nasal stops	26	5.75%
b.	with /n/ only	4	0.89%
c.	with /m/ only	2	0.44%
d.	with /m ŋ/ only	1	0.22%
	TOTAL	33	7.30%

(2) *Most languages* have at least two nasal-stop phonemes, both of which are anterior.

The present study focuses on the exceptions to normal nasality; that is, the 33 ANSID languages with fewer than two anterior nasal stops. As seen in Table 2, only four types of exception were found. In first place comes the absence of nasal stop phonemes, which evinces that this consonant class falls short of being universal. The next two types reveal that languages may also opt for a single nasal-stop phoneme: either /n/ or /m/. The final type is the most unexpected. Dorsal /ŋ/, the most common of the posterior units, manages to oust /n/ in one language. Were it not for this particular pattern, the preference for anterior articulations would be absolute.

There are several challenges that these findings pose to Phonological Theory. To begin with, the theory must provide a mechanism whereby phonologies can opt out of nasality, so that those that function without it can be accommodated. Secondly, it must ensure that the selection of nasal-stop phonemes prioritizes anterior units over their posterior congeners. This is imperative to account for two facts: the absence of nasal solos consisting of a posterior unit (e.g. */ŋ/, */ɲ/, */ɳ/, etc.) and the absence of nasal duos consisting of two posterior units (e.g. */ŋ ɲ/, */ŋ ɳ/, */ɲ ɳ/, etc.). Thirdly, while both anterior units must be granted special status, there must also be a way to assess their properties separately, so that it can be explained why some languages compose their nasal solos with /n/, while others do so with /m/. Lastly, the theory must find a principled way to justify the fact that, occasionally, an anterior unit may be excluded for the sake of a posterior one. This is essential to account for the duo /m ŋ/ without invalidating the hypothesis which facilitates the analysis of all other languages; that is, that anterior nasal-stops make better phonemes than their posterior congeners.

One gathers from the above that a satisfactory account of normal and exceptional nasality must strike a balance between restrictiveness and flexibility. It needs

to be highly restrictive to prevent the creation of random nasal-stop inventories, yet flexible enough to allow a modicum of variation.

2. Questionable explanations

The challenges identified above are hardly trivial. This section reviews three lines of analysis in order to demonstrate that the dichotomy between norms and exceptions escapes historical, structural, and hierarchical explanations.

2.1. Historical approach

One way to explain why nasal-stop inventories do not come in an endless variety of forms is to refer to previous evolutionary stages. The argument is that normal and exceptional patterns follow from diachrony. To provide a concrete example, one could argue that it is for historical reasons that the nasal-stop inventory of Onge—one of the languages spoken in the Adaman Islands—is /m n ɲ ŋ/. Diachronic analyses have concluded that this nasal quartet was already present in Proto-Ongan, which passed it on to its descendants: Onge and Jarawa (Blevins 2007). From this optic, it would seem that ancestry is the key to understanding why nasal-stop inventories are the way they are. Onge has two anterior and two posterior units because it inherited them from its ancestor.

Unfortunately, this type of explanation does not get very far. It soon runs into trouble because there are numerous languages which have modified the nasal-stop inventories of their ancestors. It is well known that language evolution may involve the introduction of phonemes that were missing from the ancestor as well as the elimination of phonemes that the ancestor did have. An example of the former case is Spanish, one of the Romance languages which developed a palatal nasal-stop phoneme that Latin did not know. Thus, while the modern language has the trio /m n ɲ/, the classical language had the duo /m n/ (Penny 2002). A language whose evolution involved reduction of the nasal-stop inventory is Palauan. Foley (1975) demonstrates that a sound shift turned Proto-Austronesian /n/ into Palauan /l/, as a result of which the trio /m n ŋ/ of the parent language became the duo /m ŋ/ in the descendant. The latter example is of special significance. It tells us that, because language evolution may involve the loss of anterior nasal stops, ancestry cannot be the reason why languages are prone to having them.

Another obstacle to upholding explanations based on ancestry is that they keep sending us back to previous grammatical stages without ever addressing the matter. They tells us that language A has such and such sound inventory because it inherited it from language B, which inherited it in turn from language C, and so on; however, it is evident that this only serves to evade the question. At some point in this constant referral to the past, the analyst seeking to gain a deeper understanding of the facts realizes that he must face the inevitable question: how did languages come to have the nasal-stop inventories that they have?

Evolutionary Phonology (Blevins 2004) resolves some of these objections by recognizing that diachrony may lead to maintenance, enrichment, or impov-

erishment of sound inventories. The latter two are logical consequences of sound change. But the explanation that this theory offers for the consolidation of some patterns as norms and of others as exceptions remains unsatisfactory. It is claimed that sound patterns may be frequent or rare because the sound changes which create them are frequent or rare themselves (Blevins 2004: 83). The problem with this view is that, because the ultimate cause remains unidentified, the mind is led to recast the question. Why are certain sound changes frequent whereas others are rare?

A more explanatory answer is possible by drawing on phonetics. Sound changes which are phonetically motivated are natural, hence frequent, whereas those stemming from analogy, rule inversion, rule telescoping, or accidental convergence are unnatural, hence rare. The need to distinguish between natural and unnatural sound changes is recognized by most phonological theories, but Evolutionary Phonology sets itself apart by assuming that, even when they are natural, sound changes are non-teleological. That is to say that, rather than leading to the achievement of a goal, they are the outcome of random phonetic drift.

Little insight is gained when normal nasality is seen through this lens. Evolutionary Phonology would say that this phenomenon exists because there are natural sound changes which give rise to /m/ and /n/ for no practical purpose. It is the final part of this explanation that is questionable. If the development of anterior nasal stops afforded no practical benefits, why would most languages evolve in that direction? It does not stand to reason that a regularity that holds for over 90% of world's languages is haphazard.

2.2. Structural approach

Positing structural differentials is one of the tactics that one can use to tackle the problem synchronically. The pillar of this idea is the assumption that there are various degrees of complexity among nasal stops. This opens the door for the argument that the predilection for anterior units is driven by economy: simpler structures yield savings which enable grammars to operate at a lower cost.

Figure 1 illustrates an analysis along these lines proposed by Rice and Avery (1993: 143). It is hypothesized that coronal is the unmarked place of articulation and, since /n/ is a member of this category, it is held that its phonological representation includes no structure under the Place node. Other places of articulation are assumed to be more marked, from which it follows that their phonological representations should be more elaborate. Observe that the structure of /m/ includes one level under the Place node, while that of /ŋ/ includes two.

This analysis yields some positive results. First of all, the economy ensuing from the simple structure attributed to /n/ ensures that this unit will be the top choice for nasal solos. Secondly, since /m/ has only one additional level, it will be able to secure one of the positions available in nasal duos. Lastly, the first posterior unit to make the cut will be /ŋ/, which is expected to seize one of the positions available in nasal trios because it represents the next increase in structural complexity. The patterns /n/, /m n/, and /m n ŋ/, are thus accounted for.

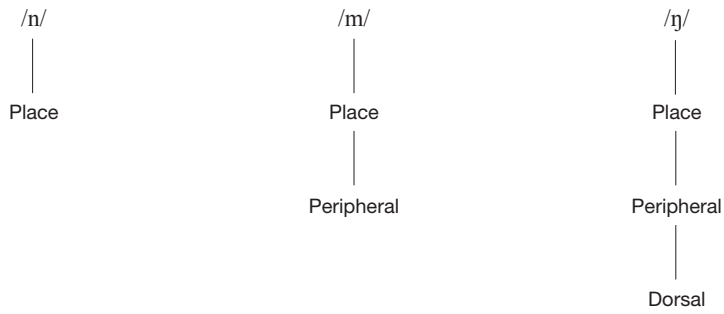


Figure 1. Increasing degrees of structural complexity among nasal stops.

But there are some negative results as well. The solo /m/ and the duo /m ŋ/ contravene this analysis because they favor the selection of an alleged complex unit over a simpler one (i.e. /m/ over /n/ in one case, /ŋ/ over /n/ in the other). Adjusting the representation of place categories according to the choices made by individual languages would remove these obstacles; however, that strategy does not translate into real progress because it merely trades one problem for another: the theory would go from undergenerating to overgenerating. Consider that, while it is possible to concoct representations conducive to the desired results (e.g. fewer structural levels for /m/ than for /n/, more structural levels for /n/ than for /ŋ/, and so on), these would empower grammars to generate all sorts of nasal-stop inventories, when the reality is that the exceptions to normal nasality are not so diverse (Table 2).

Doubts about the representations in Figure 1 are also raised by the fact that the articulators of /n/, /m/, and /ŋ/ perform essentially the same task: they occlude the oral cavity. This parallelism suggests that, rather than the amount of structure, it is the presence of a unique trait in each that makes these segments different. To be more precise, /n/ would not have the quality it has, if coronality were not part of its composition and, similarly, /m/ and /ŋ/ would not be the entities they are without the contribution of labiality to the former and of dorsality to the latter. A more sensible way to represent such distinctions is, therefore, to posit a privative feature for each place of articulation (Figure 2).

When one admits that the distinctions among /n/, /m/, and /ŋ/ hinge on the commutation of one place feature for another, the explanation based on structural economy collapses. These phonemes have exactly the same degree of structural complexity

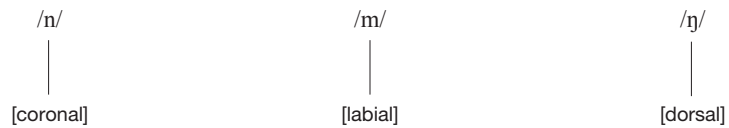


Figure 2. Equal structural complexity amongnasal stops.

and, therefore, it is unfounded to claim that simplicity is the source of the crosslinguistic preference for anterior nasal stops. In no way is /n/ structurally poorer than /m/ nor is /ŋ/ structurally richer than either one of its anterior congeners.

2.3. Hierarchical approach

Another scheme one can pursue is to order place features hierarchically so that they can be selected according to their rank. This is the foundation of the construct known as the Place Hierarchy. Optimality Theory offers the machinery needed to implement this vision (Prince and Smolensky 1993/2004).

A family of structural constraints banning place features—say *[place]—is pitted against a family of faithfulness constraints requiring the preservation of such entities—assume it to be IDENT(place). The outcome of this clash will depend on how individual grammars rank these principles with respect to one another. Ranking Ident(place) over *[place] will ensure that the segment bearing the feature in question is grammatically affordable but, because each grammar is free to decide which specific member of *[place] is to play that role, the results will vary. The most interesting part of this analysis is how the crosslinguistic preference for certain places of articulation is accounted for. It is assumed that the ranks among the members of *[place] are universal. To appreciate the merits of this approach, consider the ranking in (3). This version of the Place Hierarchy states that the features [labial] and [coronal] are equally costly, but less so than [dorsal].[3]

(3) Place Hierarchy (Prince and Smolensky 1993/2004)
*[dorsal] >> *[labial], *[coronal]

It is easy to foresee that the asymmetry that exists between anterior and posterior nasal stops is amenable to this interpretation. In a grammar where the ranking of IDENT(place) with respect to the Place Hierarchy is set as in (4a), both anterior units will be able to emerge without their posterior congeners. This positive result is strengthened by the fact that the preference for anteriority persists, even if one makes an express effort to favor posteriority. Note, for instance, that /ŋ/ will emerge in a grammar where IDENT(place) rises to the position it occupies in (4b); yet, it will not be alone, but in the company of /m/ and /n/, whose co-selection is guaranteed by the fact that the constraints against their place features hold the lower ranks of the Place Hierarchy.

(4) a. *[dorsal] >> IDENT(place) >> *[labial], *[coronal]
b. IDENT(place) >> *[dorsal] >> *[labial], *[coronal]

3. The study of place-of-articulation phenomena has led to the proposal of multiple versions of the Place Hierarchy. The version in (3) has been chosen to illustrate this line of analysis because it is the most successful in accounting for nasal-stop inventories.

Nasal solos respond well to this treatment too. Since the Place Hierarchy under consideration leaves the ranking between *[labial] and *[coronal] unspecified, IDENT(place) will be able to subdue each one of these constraints separately. Some grammars may therefore adopt the order in (5a), while others may opt for (5b). In either case, the only affordable nasal stop will be anterior.

(5) a. *[dorsal] >> *[labial] >> IDENT(place) >> *[coronal]

b. *[dorsal] >> *[coronal] >> IDENT(place) >> *[labial]

Despite such positive results, the hierarchical approach is not without problems; it too suffers from undergeneration. The duo /m ŋ/ is its nemesis. On the assumption that *[dorsal] dominates *[coronal], this inventory is incomprehensible. Why should a language drop /n/ to make room for /ŋ/ if the latter segment bears a place feature which is universally more costly?

One way to circumvent this impasse would be to grant languages the freedom to modify the Place Hierarchy at their discretion. One could assume that most languages accept the ranking *[dorsal] >> *[coronal], while a few opt to reverse it. The problem with this solution is that any modification to the Place Hierarchy—even if it is for just one language—invalidates its universal status and, if this premise is given up, then the explanation for the proclivity towards anteriority vanishes too. Nothing would prevent posterior units from crowding nasal-stop inventories.

It is worth pointing out that, in order to cope with exceptions, the hierarchical and the structural accounts are pressured to abandon their ground assumptions. One gives in by reversing dominance relations among the members of the Place Hierarchy, while the other one does so by adjusting the representation of place categories. Such repairs are to no avail. They merely turn the inability to generate a few patterns (undergeneration) into the ability to generate any conceivable pattern (overgeneration).

To stay away from ranking reversals, the hierarchical approach could capitalize on the mechanism that Optimality Theory uses to model conflict: constraint interaction. This would require the postulation of an additional principle against the feature [coronal]. Let us call it ANTI-COR. If dominant, the new player could tone down the coercive power of the faithfulness constraint. This happens in (6), a grammar where /n/ cannot emerge alongside /m/ and /ŋ/, despite the fact that the rank of IDENT(place) is high enough to justify the cost of three place features. It goes without saying that this solution is ad hoc. ANTI-COR—an obvious duplicate of *[coronal]—is brought in expressly to block an otherwise felicitous unit.

(6) ANTI-COR >> IDENT(place) >> *[dorsal] >> *[labial], *[coronal]

While blocking by a higher-ranking constraint safeguards the universality of the Place Hierarchy, it does not avoid overgeneration. This problem is palpable in (7), where the strategy used in (6) is reapplied to generate the solo */ŋ/. Observe that, when an additional constraint against [labial]—call it ANTI-LAB—is ranked above IDENT(place), both anterior units are ruled out while the posterior unit manages to

go through. This effectively reverses the dominance relations encoded in the Place Hierarchy; hence, it is no different from assuming that [dorsal] is less costly than both [labial] and [coronal] or, more straightforwardly, that there is no universal Place Hierarchy.

(7) ANTI-LAB, ANTI-COR >> IDENT(place) >> *[dorsal] >> *[labial], *[coronal]

The ineluctable conclusion is that the hierarchical approach does not measure up to the task either. This is unsurprising considering that the Place Hierarchy is simply a set of stipulations. To this date, no justification has been provided for the alleged parity between the anterior place categories or for the advantage they presumably have over their posterior congeners. Are there any actual properties behind such an appraisal? As long as this question remains unanswered, there will be no hope for the hierarchical approach.

3. An alternative based on functional hierarchies

The solution advanced here is both functional and hierarchical. I draw on articulatory and perceptual functions to validate the hypothesis that there are universal dominance relations among place features. This view is founded on the premise that different linguistic structures strain the human linguistic capacity to different extents. Accordingly, place features which are articulatorily taxing will rank high on a hierarchy guided by articulatory factors. A parallel thesis is defended for the perceptual dimension. Place features which are perceptually taxing will rank high on a hierarchy guided by perceptual factors. Also central to the proposal is the assumption that the difficulty in articulating or perceiving place features depends on the type of segment within which they appear. That is to say that the assessment of their cost is not absolute, but relative to each segmental class.

The split between articulation and perception and the diversity of segmental classes join forces to overturn the view that there is a single universal place hierarchy. Phonologies must refer to multiple place hierarchies because, due to their different nature, articulatory and perceptual demands need to be assessed separately, and also because place features occur in different segmental classes, some of which are more compatible with certain places of articulation than with others. Importantly, the recognition of this plurality does not preclude the postulation of universal rankings. The condition that a hierarchy must meet in order to qualify as universal is to hold true for all languages where the relevant variables are present. For instance, if an articulatory place hierarchy appraises that feature X is more difficult to articulate than feature Y in segmental class Z, then that must be the case for all languages where X and Y are present in Z. This condition notwithstanding, it is still possible that X be less difficult to perceive than Y in the same segmental class or that it be less difficult to articulate than Y in a different segmental class.

In this section I develop two universal place hierarchies which are crucial for the selection of nasal-stop phonemes. The first one is the *Articulatory Consonant Place Hierarchy*, which assesses the articulatory cost of place features within con-

sonantal segments. The second one is the *Perceptual Nasal-Stop Place Hierarchy*, which assesses the perceptual cost of place features within nasal stops.

3.1. The articulatory cost of place features in consonantal segments

It is defended here that certain sound structures are articulatorily more demanding and, therefore, more costly to the phonology than others. In assessing the articulatory cost of place features, it is essential to consider whether they are part of a consonant or a vowel. When included within a consonant, features such as [labial], [coronal], and [dorsal] are tied to the ability of the articulators to travel at high speed. This is because consonants are produced by constricting the vocal tract at a local point, an event which must be rapidly executed given that the duration of consonants is significantly shorter than that of vowels (Cooper et al. 1952, Klatt 1976, Borzone de Manrique and Signorini 1983). Such requirements suggest that reaching the constriction location (i.e. the place of articulation) is less taxing for articulators excelling at fast movement. Articulator velocity thus emerges as one of the criteria that can be used to guide the assessment of articulatory cost. On the basis of this substantive factor, I propose the constraints in (8) and the hierarchy in (9).

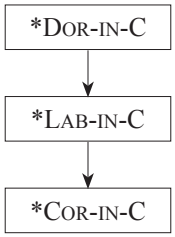
(8) A family of articulatory structural constraints

*DOR-IN-C = Do not use the dorsum to articulate a consonant.
*[dorsal] / [___, consonantal]

*LAB-IN-C = Do not use the lips to articulate a consonant.
*[labial] / [___, consonantal]

*COR-IN-C = Do not use the corona to articulate a consonant.
*[coronal] / [___, consonantal]

(9) Articulatory Consonant Place Hierarchy (fragment)[4]



4. Languages may, of course, distinguish more than three places of articulation, which means that the Articulatory Consonant Place Hierarchy must be more elaborate than in (9). In this article I focus on the fragment that is needed to explain the preference/dispreference for anterior/posterior articulations.

The findings of several experimental studies support the claim that, within a consonantal segment, [dorsal] is articulatorily more costly than [labial], which is in turn articulatorily more costly than [coronal].

Hudgins and Stetson (1937: 92) conducted a series of diadochokinetic experiments with a view to determining the maximum speed of certain speech movements. The nine speakers who participated in this study were asked to repeat rhythmic groups of repeated syllables as rapidly as they could. The results indicate that the corona is the fastest speech organ. It yielded a maximum-rate average of 8.2 syllables per second, while the corresponding figures for the dorsum and the lips were 7.1 and 6.7, respectively. The decision to concede the lowest rank of the Articulatory Consonant Place Hierarchy to *COR-IN-C is thereby justified. It captures the fact that drawing on the corona for the purpose of forming a consonantal constriction is most efficient; hence, least costly.

A subsequent experimental study employed lateral-view cineradiography to measure the velocity of the corona, the lower lip, and the dorsum relative to the maxillary and the mandibular systems (Kuehn and Moll 1976). The results for the maxillary system show that the corona moved the fastest (196mm/s), followed by the lower lip (166mm/s), which was in turn faster than the dorsum (129mm/s). The data for the mandibular system also show that the corona was the fastest articulator (142mm/s), but neither the lower lip (102mm/s) nor the dorsum (102mm/s) was faster than the other in this case. These findings corroborate the decision to place *COR-IN-C below the other members of its family and hint that *LAB-IN-C should be ranked below *DOR-IN-C.

Roon et al. (2007) examined the same set of articulators using a different technique. They employed electromagnetic articulography to calculate stiffness, a measurement of the velocity that an articulator can reach independently of the distance it travels (Byrd 1992, Roon et al. 2007). Given that an organ of high stiffness returns to its equilibrium position faster than one of lower stiffness, it can be inferred that the former has a superior ability for fast movement. Two speakers participated in this experiment. For one of them, the stiffness of the corona (mean=3.15, SD=2.00) was significantly higher than that of the lower lip (mean=2.61, SD=0.27), whose stiffness was in turn significantly higher than that of the dorsum (mean=1.85, SD=0.31). The same order followed from the results for the second speaker (corona: mean=2.21, SD=2.48, lower lip: mean=2.06, SD=0.39, dorsum: mean=1.44, SD= 0.47), although it should be noted that, in this case, the advantage of the corona over the lower lip did not prove to be statistically significant. These findings back up the decision to rank *LAB-IN-C below *DOR-IN-C.

To synthesize, there is recurrent evidence that the corona is the articulator of highest velocity, which clinches the argument that, when it comes to producing consonants, no other articulator is more efficient. Somewhat less forceful is the evidence available for the difference between the lips and the dorsum. While the earliest study placed the dorsum ahead of the lips (Hudgins and Stetson 1937), the more recent studies, which were able to use more advanced techniques, indicate that the lips outperform the dorsum (Kuehn and Moll 1976, Roon et al. 2007). The development of new experimental techniques will most certainly afford

more accurate measurements in the future; however, the evidence that is currently available is consistent enough to assert that the corona is the fastest articulator, the lips come next, and the dorsum falls behind them. The ranking *Dor-in-C >> *Lab-in-C >> *Cor-in-C is thereby substantiated.

It is important to point out that, although the same dominance relations were previously posited by some versions of the Place Hierarchy (e.g. de Lacy 2002, 2006), the present proposal breaks new ground in two ways. Firstly, the adoption of articulator velocity as the criterion that guides the ranking has the benefit of avoiding stipulation. The hierarchical organization of place features now has a justification. It stems from substantive factors; that is, from differences in the ability of the articulators to perform their functions. Secondly, the Articulatory Consonant Place Hierarchy acknowledges that the established order of precedence does not apply across the board. It is specific to consonantal segments and not from every angle, but specifically from an articulatory perspective. The lesson to learn from this is that the search for a place hierarchy that works for all place-of-articulation phenomena is futile. The fact that the cost of place features is conditioned by segmental classes as well as by articulatory and perceptual factors means that they can be organized in multiple hierarchies, which are nonetheless universal.

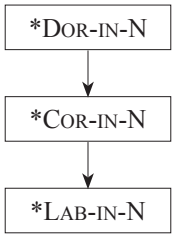
3.2. The perceptual cost of place features in nasal stops

A lack of symmetry among sound structures is also true of the perceptual dimension. Depending on the segment within which they appear, certain place features are more difficult to perceive and, consequently, more costly to the phonology than others. I argue next that, in the context of a nasal stop, the cost of perceiving place features increases proportionally to the distance that separates the constriction location from the lips. That is to say that the more posterior the articulation, the more challenging the perception of the nasal consonant. The application of this generalization to /m/, /n/, and /ŋ/ gives rise to the constraints in (10) and to the hierarchy in (11), where [coronal] has been bumped out of the bottom rank by [labial]. This new assessment does not change the status of [dorsal], which remains less affordable.

(10) A family of perceptual structural constraints

*Dor-in-N	=	Do not listen for cues to [dorsal] in a nasal stop. *[dorsal] / [___, nasal, occlusive]
*Cor-in-N	=	Do not listen for cues to [coronal] in a nasal stop. *[dorsal] / [___, nasal, occlusive]
*Lab-in-N	=	Do not listen for cues to [labial] in a nasal stop. *[labial] / [___, nasal, occlusive]

(11) Perceptual Nasal-Stop Place Hierarchy (fragment)[5]



The evidence for the ranking in (11) is to be found in the *nasal murmur*—the sound radiated through the nose while the oral cavity is occluded.[6] Acoustic studies have identified several spectral traits characteristic of nasal murmurs (House 1957, Delattre 1958, Fant 1960, Fujimura 1962a, b, Recasens 1983, 1992, among many others). The most conspicuous one is a series of increasingly higher nasal formants (N1, N2, N3, N4, N5, …), among which the first one is clearly dominant given its much higher intensity. It will be important to keep in mind that the intensity of nasal formants decreases as their frequency rises; for instance, N5 is less intense than N4, which is less intense than N3, and so on. Of special interest here is the concomitant presence of a nasal antiformant or zero (NZ), whose frequency correlates with place of articulation (House 1957, Fujimura 1962a, b, Recasens 1983).[7]

To appreciate how the place of articulation of a nasal stop relates to its antiformant, consider the diagrams in Figure 3, where the most anterior unit appears

5. From the existence of additional place features, it follows that this is not the full hierarchy. Only the fragment which is relevant to the account of normal and exceptional nasality is presented here.
6. Despite the fact that vowel transitions also carry place cues for nasal stops, the decision not to base the Perceptual Nasal-Stop Place Hierarchy on them was made for the following reason. Studies such as Cooper et al. (1952), Liberman et al. (1954), Malécot (1956), and Delattre (1958) have revealed that the F2 and F3 transition shapes which cue place of articulation in nasal stops are similar to those that serve the same purpose in their oral counterparts. That is to say that there is acoustic parallelism among the members of the sets /m b p/, /n d t/, and /ŋ g k/. It is possible to hypothesize from this that, if vowel transitions were responsible for the difficulty in perceiving posterior articulations, /ŋ/, /g/, and /k/ would pattern together, or, to put it another way, the presence of a gap in the nasal-stop series would be mirrored by the presence of a similar gap in the oral-stop series. The reality is, however, that there is a tendency for languages that have /m/ and /n/ to be deprived of /ŋ/, whereas languages that have /b/ and /p/, on the one hand, and /d/ and /t/, on the other hand, normally possess /g/ and /k/ as well (Maddieson 1984, Recasens 1992, Clements 2009). The fact that it is specifically the nasal-stop series which tends to lack a posterior member indicates that the factor responsible for the difficulty in perceiving posterior articulations resides in a property specific to nasal stops: the nasal murmur.

   The centrality granted to the place cues carried by the nasal murmur is what sets this proposal apart from that by Narayan (2006). This author attributes the difficulty in perceiving /ŋ/ to the shapes of the F2 and F3 vowel transitions. The problem with this approach is that it fails to establish a differential between /m/ and /n/.
7. Simply put, a nasal formant represents frequencies amplified by the pharyngeal and nasal cavities, whereas a nasal antiformant stands for frequencies attenuated by the occluded oral cavity.

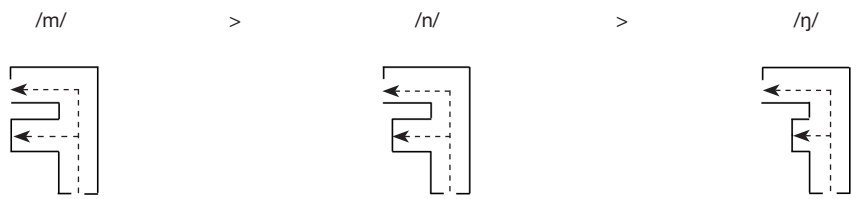


Figure 3. Place of articulation determines oral-cavity size[8].

to the left, while the most posterior one appears to the right. It is easy to see that the three diagrams are identical except in one respect: the size of the oral cavity. A quick comparison shows that this particular resonator becomes gradually smaller as the constriction retracts. This phenomenon is bound to have acoustic consequences because the frequency at which a resonator vibrates depends largely on its size. Given that a small resonator vibrates faster than a larger one, a natural consequence of reducing the size of the oral cavity is that there is a rise in NZ values.

Confirmation that a reduced oral cavity leads to higher NZ frequencies is abundant (see House 1957, Delattre 1958, Fant 1960, Fujimura 1962a, b, Dukiewicz 1967, Recasens 1983, Gubrynowicz et al. 1985, and Ladefoged and Maddieson 1996). These studies report that the large oral cavity of /m/ leads to a low NZ (around 800 Hz), whereas the small oral cavity of /ŋ/ results in a high NZ (around 3700 Hz). It has also been verified that occlusions formed at intermediate locations between the velum and the lips give rise to intermediate NZ values. The NZ of /n/, for instance, occurs at about 1780 Hz.

The presence of a formant cluster above N2 is another aspect of the nasal spectrum that bears on place of articulation (Fujimura 1962a, b, Recasens 1992). By plotting their movements through the murmur, Fujimura discovered that nasal formants are involved in clustering patterns induced by the antiformant. He observed that, while the formants which are out of the immediate vicinity of the antiformant remain relatively constant, those surrounding it come closer together. In particular, the N2 and N3 of /m/ form a cluster with its low NZ, while the N3 and N4 of /n/ do the same with the significantly higher NZ that characterizes this unit. The fact that the NZ of /ŋ/ is even higher entails that the clustering formants are higher as well: N5 and N6. On the basis of this discovery, Fujimura (1962a: 1871) describes the difference between the murmurs of the three units under discussion as follows: "/ŋ/ has four formants in the main frequency range (up to about 3000 cps), /n/ is obtained when the third of the formants is replaced by a cluster consisting of two formants and one antiformant, /m/ is obtained when the second formant is replaced by a similar cluster."

In summary, the findings of the aforementioned acoustic studies indicate that posterior nasal stops have higher NZ and N-cluster values than their anterior

8. In these diagrams, the resonators of the vocal tract (i.e. the pharyngeal, oral, and nasal cavities) are represented as ducts contoured by straight lines. The horizontal duct that is occluded at the left end is the one representing the oral cavity. Arrows indicate the direction of airflow.

congeners. This may give the impression that /ŋ/ is acoustically superior to its competitors, but the reality is that it performs poorly. It turns out that having high frequencies is counterproductive for nasal stops because energy concentrates less intensely in the higher than in the lower regions of the nasal spectrum. As a result, it is the lower frequencies that are advantageous because they are more salient (House 1957, Ohala 1975, Ohala and Ohala 1993). Combined with the uncontroversial assumption that acoustic salience makes speech sounds easier to perceive, this means that, from a perceptual point of view, /m/ is the most affordable member of its class. It can be further inferred that /n/ and /ŋ/ strain the human auditory system to gradually greater extents because their higher NZ and N-cluster are gradually less salient. The ranking *DOR-IN-N >> *COR-IN-N >> *LAB-IN-N reflects precisely that.

It is worth noting that the Articulatory Consonant Place Hierarchy and the Perceptual Nasal-Stop Place Hierarchy invalidate two common assumptions about the major place categories. In the face of the phonetic evidence assembled above, it can no longer be claimed that the features [coronal] and [labial] are on equal standing (contra Prince and Smolensky's Place Hierarchy) nor that [coronal] is invariably less costly than [labial] (contra de Lacy's Place Hierarchy). In actuality, the cost of place features varies across segmental classes and across speech facets (i.e. articulation vs. perception). The evidence indicates that, for consonantal segments in general, the feature [coronal] is articulatorily less costly than [labial]; but for nasal stops in particular, [labial] is perceptually less costly than [coronal].

4. A three-way conflict

The stage is now ready to present the formal analysis. A cogent explanation for the crosslinguistic preference for anterior nasal-stops will emerge from the resolution of a three-way conflict. The Articulatory Consonant Place Hierarchy is bound to clash with the Perceptual Nasal-Stop Place Hierarchy because, although both oppose the use of place features, they disagree as to which value is the least costly. Additionally, the structure-saving nature of the place hierarchies puts them in direct conflict with Faithfulness, the constraint family demanding structural preservation. I assume that the principle in (12) is the relevant faithfulness constraint.

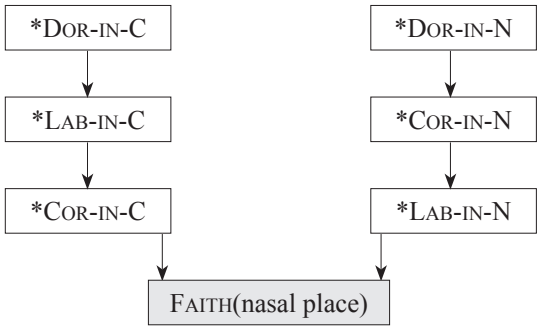
(12) FAITH(nasal place): Nasal segments standing in correspondence must be faithful to each other in terms of place features.

The size and structure of nasal-stop inventories will depend on the rank of Faith(nasal place) with respect to the place hierarchies. In general, the higher ranking the faithfulness constraint, the larger and more diverse the inventory will be. For expository ease, I will begin with the smallest inventory and advance towards the larger ones.

4.1. Absence of nasal stops

Although the prioritization of anterior nasal stops is a strong crosslinguistic tendency, there are a few languages where it is imperceptible. No signs of partiality can be found in languages deprived of phonemic nasal stops because all members of the class are left out. Such systems can be construed as the grammatical state in which both place hierarchies have absolute supremacy over FAITH(nasal place).

(13) Grammar of languages deprived of nasal stops

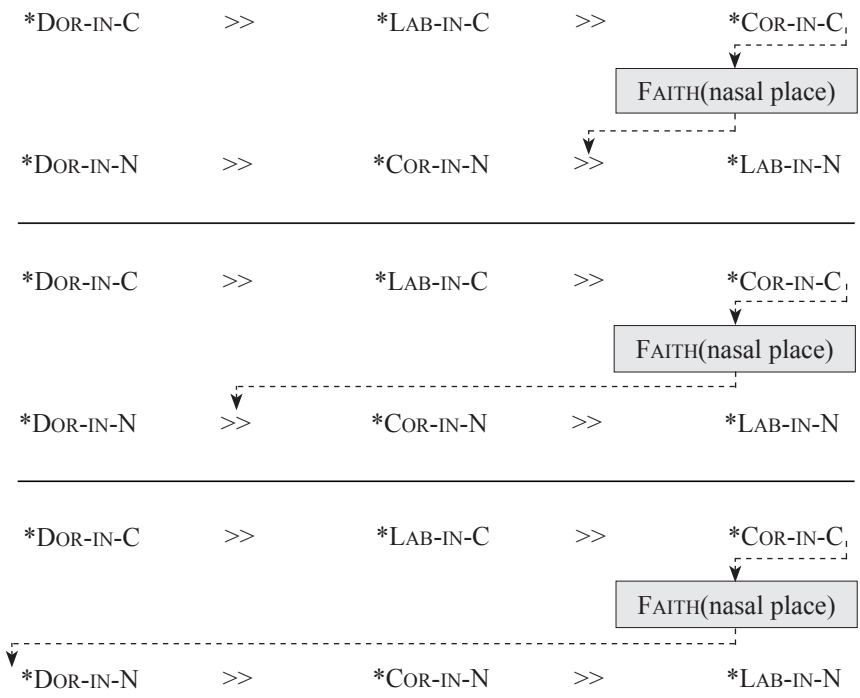


This arrangement has the effect of setting a cost threshold equal to nil, the upshot of which is that even the least costly units turn out to be unaffordable. Since nothing can be more restricted than an empty set, the extreme ranking in (13) seems appropriate for this language type. I take this to be the most primitive stage in the development of nasal-stop inventories and argue that growth from that point forth is brought about by the ascent of the faithfulness constraint with respect to the structural constraints.

Attached to this proposal comes a responsibility. It is imperative that every step in the ascent of FAITH(nasal place) be examined in order to verify that the theory does not overgenerate. This is not a small task. Given that the relevant fragment of each place hierarchy consists of three constraints, the number of positions that FAITH(nasal place) can occupy with respect to each one of them is four. It follows from this that the total number of rankings that need to be examined is sixteen (4 x 4).

A factor that makes it quicker to complete this task is that many of the positions that FAITH(nasal place) can occupy with respect to the place hierarchies yield the same result. That is the case with the absence of nasal stops. It turns out that, in addition to (13), there are seven other rankings whereby these constraints yield an empty set. Three of those rankings have been assembled in (14) on the basis of a common property: all members of the Articulatory Consonant Place Hierarchy retain their supremacy over FAITH(nasal place).

(14) Three additional rankings where the articulatory-cost threshold is nil[9]



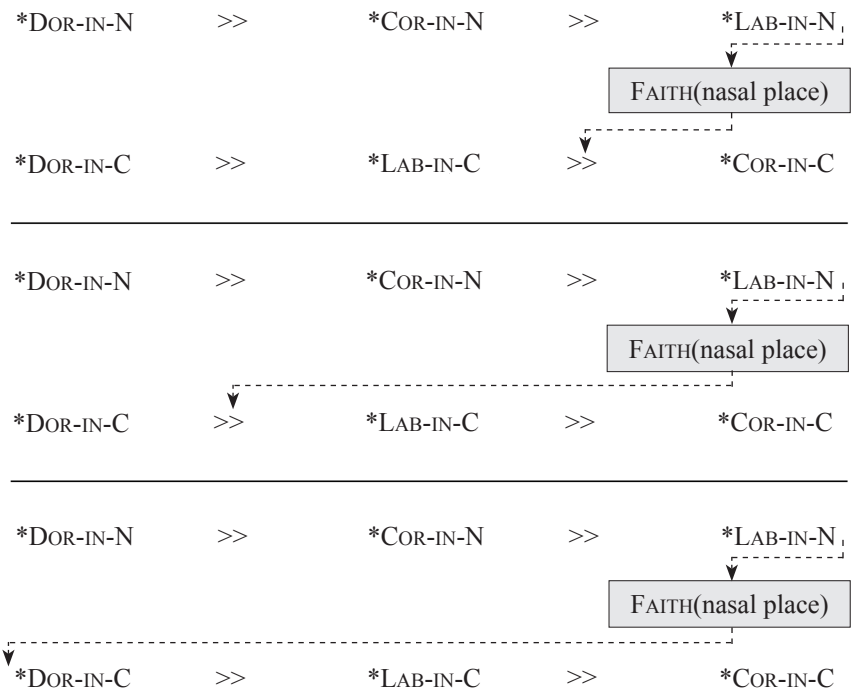
The differences among these rankings boil down to the number of members of the Perceptual Nasal-Stop Place Hierarchy that succumb to the faithfulness constraint. In an initial stage, only the lowest member of this place hierarchy gives in, but in subsequent stages two or three additional members yield as well. The development that is unfolding here is, therefore, a unilateral ascent, which is why there is no success. Given that all members of the Articulatory Consonant Place Hierarchy retain their influence over FAITH(nasal place), every unit that clears the perceptual dimension runs into a stone wall in the articulatory dimension.

Three other rankings can be assembled into another group because they also have a common property: all members of the Perceptual Nasal-Stop Place Hierarchy outrank the faithfulness constraint. This becomes apparent in (15),

9. To facilitate their comparison, related rankings are presented in this alternative format. Dominance relations among members of the place hierarchies are indicated through the symbol >> and the rank of FAITH(nasal place) with respect to both place hierarchies is signalled by the dashed arrows. A solid line separates different rankings.

where the structural constraints representing the perceptual dimension are now located on the top row, while those representing the articulatory dimension occupy the bottom row.

(15) Three additional rankings where the perceptual-cost threshold is nil



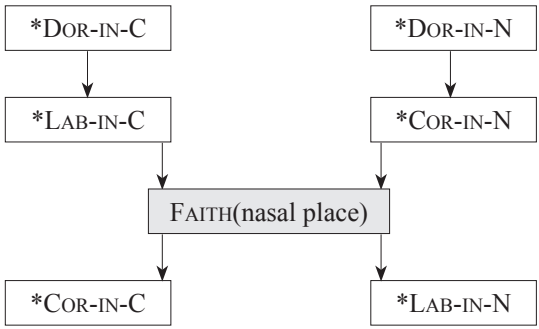
The number of members of the Articulatory Consonant Place Hierarchy overtaken by FAITH(nasal place) is what makes the difference in this case. In an initial stage, only the lowest member of that hierarchy falls below the faithfulness constraint, but in subsequent stages additional members lose their ground as well. Clearly, a unilateral ascent is unfolding here too but, unlike that in (14), it is at the expense of articulation. Because the perceptual dimension remains fully dominant, no unit can succeed.

The general point that the rankings in (14) and (15) demonstrate is that, as long as one of the place hierarchies retains full power, the advances made by the faithfulness constraint are inconsequential. This reflects the autonomy of the grammatical-cost dimensions. Each can reject any place category independently of the other.

The last of the rankings yielding an empty set is that in (16). It corresponds to the minimal ascent of FAITH(nasal place) with respect to its two rivals. What makes

this move unfruitful is that the place hierarchies cancel each other out because they disagree as to which place category is the least costly. Thus, although the ranking FAITH(nasal place) >> *COR-IN-C favors the selection of /n/, this unit cannot be recruited because *COR-IN-N disallows it. Similarly, although the ranking FAITH(nasal place) >> *LAB-IN-N is conducive to the selection of /m/, this unit remains unaffordable because *LAB-IN-C precludes it. Such interactions corroborate that this is a three-way conflict: two families of structural constraints compete with each other, despite their alliance against FAITHFULNESS.

(16) Minimal ascent of the faithfulness constraint with respect to both place hierarchies



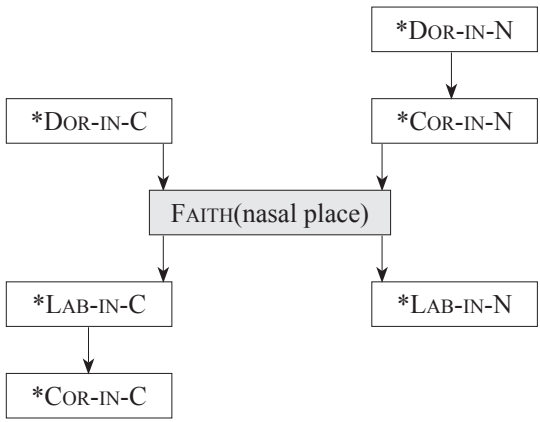
In conclusion, we now have a sensible understanding of why nasal stops are not universal phonemes. Some grammars deem that their articulatory cost, their perceptual cost, or both are too steep and choose not to invest in them.

4.2. Nasal solos

After conquering the lowest member of each place hierarchy, the next step in the ascent of FAITH(nasal place) is to overtake a second principle in either the articulatory or the perceptual dimension. The first of these scenarios is illustrated in (17), where FAITH(nasal place) has risen above the articulatory and the perceptual constraints against labial: *LAB-IN-C and *LAB-IN-N. A concomitant effect is that, since the place hierarchies are universal, *COR-IN-C is also surpassed. Given that this brings the articulatory and the perceptual cost of one place category below the critical point, the grammar is now able to make a minimal investment in nasal stops. That is how the solo /m/ is generated.

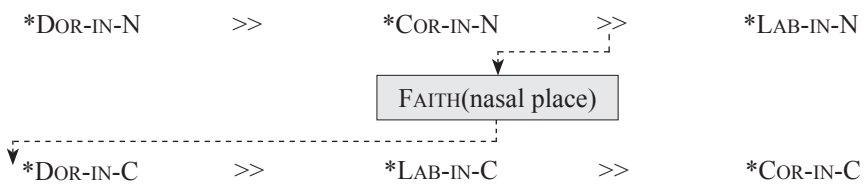
The configuration in (17) makes it clear that this grammar is characterized by a state of imbalance between articulation and perception. Because a greater number of articulatory than perceptual constraints have lost their ground to FAITH(nasal place), it is appropriate to say that this system sacrifices articulatory efficiency for the sake of perceptual ease.

(17) Grammar of languages with the solo /m/



There is another arrangement which produces the same result. The configuration in (18) helps to see that, although FAITH(nasal place) can make further progress by overtaking an additional member of the Articulatory Consonant Place Hierarchy, this is unavailing when no parallel progress is made on the perceptual dimension.

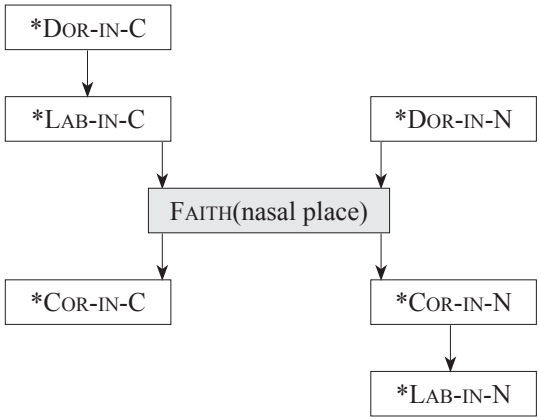
(18) Another ranking leading to the solo /m/



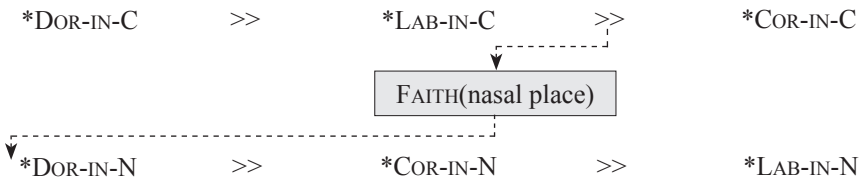
The other logical way to begin populating a nasal-stop inventory is to shift the pressure to the perceptual dimension. This development is portrayed in (19). The cost of [coronal] becomes fully affordable when FAITH(nasal place) surpasses *COR-IN-C and *COR-IN-N. It should be noted here again that, because the place hierarchies are universal, this entails that *LAB-IN-N is also surpassed. An interesting interpretation emerges from this arrangement. The solo /n/ is the product of prioritizing articulation over perception in a system which is willing to make only the minimal investment in nasal stops. This establishes a link between the attested nasal solos. The fact that (19) is the mirror image of (17) demonstrates that both stem from skewed grammars.

As expected, further advances of the faithfulness constraint in the perceptual dimension are unrewarding when no parallel progress is made in the articulatory dimension. That happens again in (20), a failed attempt to secure an additional unit. We have thus seen that four of the sixteen possible rankings lead to nasal solos.

(19) Grammar of languages with the solo /n/



(20) Another ranking leading to the solo /n/



A remarkable achievement of this constraint scheme is that it disallows the generation of nasal solos other than /m/ and /n/. This is proof that the crosslinguistic preference for anterior nasal stops has been successfully modeled. The position of *COR-IN-C at the bottom of the Articulatory Consonant Place Hierarchy entails that /n/ is the most affordable unit from an articulatory point of view and, similarly, the position of *LAB-IN-N at the bottom of the Perceptual Nasal-Stop Place Hierarchy guarantees that /m/ will be the most affordable unit from a perceptual point of view. Given that all posterior units are articulatorily and perceptually more costly, selecting an anterior unit is the most sensible way to begin the construction of any nasal-stop inventory. This explains why /m/ and /n/ are quasi-universal.

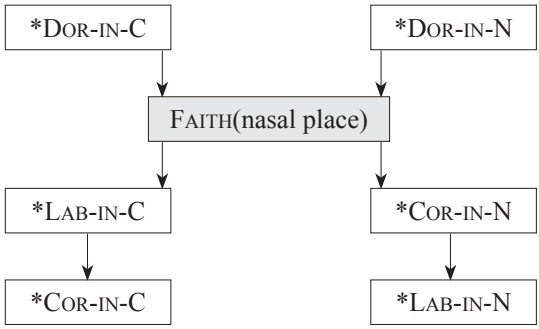
It is worth underscoring that the notion of grammatical cost is not one-dimensional. The proposed analysis demonstrates that both facets of speech have a say in the design of sound inventories. Thus, parallel to the articulatory dimension, there is a perceptual dimension, which can be equally influential. It is this duality that explains the variation exhibited by nasal solos. We have just seen that, when perception comes first, /m/ is the best choice; but when articulation takes the lead, /n/ is preferable.

4.3. The predominant nasal duo

The chances that the theory might overgenerate are substantially lower now. That is because twelve of the sixteen possible rankings have already been examined, yet only three inventory types —all of which have been attested— have emerged: the absence of nasal stops and the solos /m/ and /n/. This section adds to the positive results by showing that three of the remaining rankings converge on the duo /m n/.

The introduction of a second unit becomes possible when FAITH(nasal place) gains control over two members of each place hierarchy (21). This arrangement has the merit of resolving the disagreement between the grammatical-cost dimensions. In effect, while acting autonomously, the place hierarchies concur that [labial] and [coronal] are their top two choices; hence, the duo /m n/.

(21) Grammar of languages with the duo /m n/

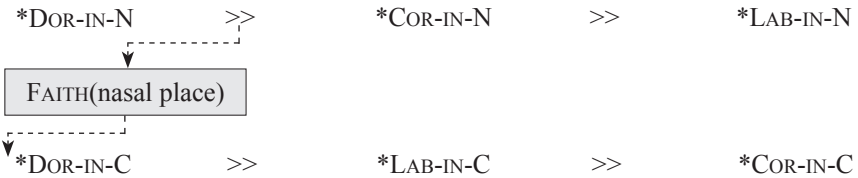


Harmony is the hallmark of this grammar. Note that the demands of both place hierarchies are being equally considered, while the faithfulness constraint has gained just enough power to ensure a reasonable investment in nasal stops. As a result, none of the conflicting forces is overwhelmed by the others. The stability ensuing from such a harmonic system suggests that it should be a common stage in language evolution, a hypothesis validated by the fact that the duo /m n/ is the most common nasal-stop inventory of all. In ANSID, it is represented by 109 languages (24.12%).

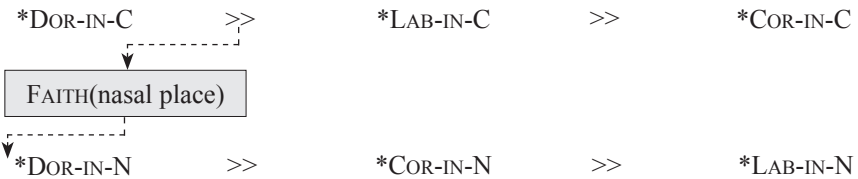
The fact that most languages have at least two nasal-stop phonemes can now be addressed. Why are there so few languages with nasal solos? A comparison among (17), (19) and (21) reveals the answer. Observe that, in the first two scenarios, obtaining a single unit requires paying half the cost of a second one. This is evinced by the fact that, in order to obtain either /m/ or /n/, at least two constraints need to be dominated on one of the place hierarchies, while the domination of a single constraint is enough on the other place hierarchy (see 17 and 19). Having already paid for one and a half units, the grammar might as well try to get two. Reaching that target requires making a further push, but the compensation is worth it. It ensures that no part of the investment goes to waste (21).

Two additional rankings lead to the duo /m n/. As the reader can verify in (22) and (23), attempts to recruit a third unit by making further advances in the articulatory or the perceptual dimension alone fail. This corroborates that the proposed model is a system of checks and balances which keeps the grammar from overgenerating.

(22) Attempt to enlarge of the duo /m n/ through a further trespass on articulation



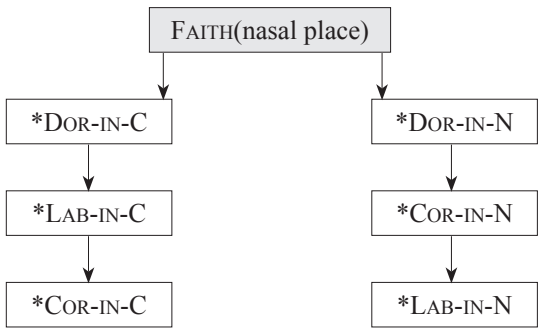
(23) Attempt to enlarge of the duo /m n/ through a further trespass on perception



4.4. The predominant nasal trio

The last of the sixteen rankings corresponds to the ascent of FAITH(nasal place) above the relevant fragments of both place hierarchies (24). This is the source of the trio /m n ŋ/, which, despite being more inclusive, perpetuates the bias towards anteriority.

(24) Grammar of languages with the trio /m n ŋ/



4.5. Ranking typology

Figure 4 provides a global view of the analysis. This is the ranking typology ensuing from the proposed constraint system. Each position that the faithfulness constraint can occupy with respect to the Articulatory Consonant Place Hierarchy has been identified with a letter, while the positions that the faithfulness constraint can occupy with respect to the Perceptual Nasal-Stop Place Hierarchy have been identified with a number. (The lowest and highest values have been assigned to the lowest and highest ranks, respectively.) This notation allows us to refer to each ranking as a function between a letter and a number: *f(Letter, Number)*.

The most restrictive ranking is (A, 1), the epitome of systems deprived of nasal stops. Six other rankings yield the same result, (B, 1), (C, 1), (D, 1), (A, 2), (A, 3), (A, 4), because each grammatical cost dimension is autonomous; hence, capable of counteracting the other one. Additionally, the ranking (B, 2) also precludes all nasal stops because the place hierarchies disagree as to which is the least costly place category.

The first nasal-stop phoneme is invariably an anterior unit. Its recruitment becomes possible when the lowest member of one place hierarchy and at least two members of the other one succumb. Two rankings, (C, 2) and (D, 2), generate the solo /m/, while another two, (B, 3) and (B, 4), produce the solo /n/.

Three rankings converge on the predominant nasal duo: /m n/. The epitome of such systems is (C, 3), a harmonic grammatical state given that none of the conflicting forces is oppressed by the others. Two other rankings yield the same result, (D, 3) and (C, 4), because all unilateral ascents are unavailing due to the autonomy of the place hierarchies.

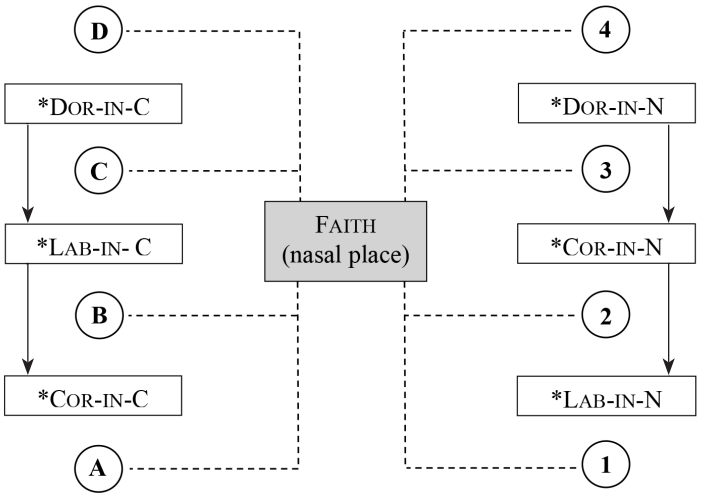


Figure 4. Ranking typology.

The last possibility gives rise to the predominant nasal trio: /m n ŋ/. At this stage, both fragments of the place hierarchies are conquered; hence, unable to prevent the introduction of posterior units.

5. Assessing the quality of phonological contrasts

While perception has been recognized as one of the forces shaping nasal-stop inventories, it needs to be added that shouldering one of the grammatical cost dimensions is not the only way in which it intervenes. Ensuring that the quality of phonological contrasts maintains a certain standard is another area where perceptual factors take center stage. In this section, I draw on this additional function to account for the most challenging of the exceptions to normal nasality: the duo /m ŋ/ (see Table 2). The goal is to demonstrate that the unexpected structure of this inventory is justified by the need to meet the heightened demands of a third evaluation metric: a perceptual-distance hierarchy.

That phonological contrasts differ in quality is one of the premises of Dispersion Theory (Flemming 1995, 1996, 2002, 2004a, b, 2006). This model holds that it is advantageous for languages to contrast sounds which are dispersed in the acoustic space because their separation makes them less confusable. It is then expected that languages seeking to reduce confusability will avert poorly dispersed contrasts. Signs of dispersion are rare in nasal-stop inventories, but they do exist. It will be shown that, despite being articulatorily and perceptually affordable, a nasal stop may still be rejected if its presence in the inventory is an obstacle to obtaining a more dispersed contrast.

The method used to calculate dispersion involves the construction of a perceptual scale where the relevant units are located according to the values of their acoustic properties. Recall from Section 3.2 that the properties serving to distinguish one nasal murmur from another are the NZ and N-cluster. The scale in Figure 5 draws on these cues to estimate the perceptual distance between /m/, /n/ and /ŋ/. (Every integer indicates a span of 1000 Hz.) Because the NZ and N-cluster of /m/ are around 800 Hz, this unit has been placed low. By contrast, /n/ and /ŋ/ have been granted increasingly higher positions because their values for the same cues are around 1780 Hz and 3700 Hz, respectively.

The acoustic proximity that exists between /m/ and /n/ yields a low dispersion value when these units are contrasted: 1. On the other hand, a contrast between a posterior unit such as /ŋ/ and an anterior one such as /m/ translates into a higher dispersion value: 3. One can then foresee that a language aiming to obtain the best possible contrast will have to abstain from using the acoustically intermediate unit: /n/.

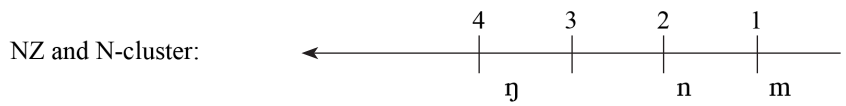


Figure 5. Nasal perceptual space.

A family of perceptual-distance constraints is introduced to formalize this proposal. Its general definition is given in (25). Its members, which are organized into the universal hierarchy in (26), require phonemic nasal stops to keep a certain distance between them. Note that members referring to low values are ranked higher than those referring to higher values. This is to promote dispersion. The further apart two phonemes stand, the less costly their contrast will be because fewer P-DISTANCE constraints will object to it.

(25) P-DISTANCE(N:x):[10] A perceptual distance equal or greater than x is required between contrasting nasal stops.

(26) Universal ranking within the P-DISTANCE family
P-DIST(N:1) >> P-DIST(N:2) >> P-DIST(N:3)

A feud between P-DISTANCE and FAITH(nasal place) is inevitable. These principles clash because, while discarding intermediate units is a logical way to improve the quality of contrasts, any simplification is detrimental to faithfulness. As with any other constraint conflict, the resolution will depend on which principle is in power. To begin with the most common scenario, let us assume that P-DIST(N:1) is the only member of its family that dominates FAITH(nasal place). A perceptual-distance requirement of 1 is thereby established, and since that happens to be the distance between /m/ and /n/, which are quasi-universal, it is possible to construe this ranking as a default setting, which few languages bother to reset.

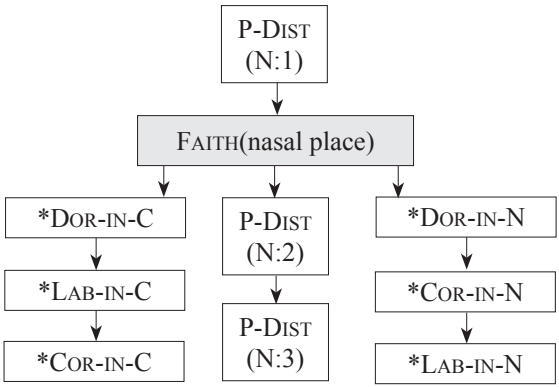
The fact that dispersion is a relational concept entails that it becomes relevant when several members of the same segmental class are affordable. A case in point is the trio /m n ŋ/. Returning for a moment to (24), it is easy to understand why it was possible to derive that inventory without considering that two of its units are acoustically adjacent. Since a perceptual-distance requirement of 1 sanctions adjacency, P-DISTANCE is powerless in languages embracing the default dispersion setting. It has no choice but to accept the selections agreed on by FAITH(nasal place) and the place hierarchies. This can be verified in (27) where the default dispersion setting has been added.

A special situation arises when FAITH(nasal place) falls below additional members of the P-DISTANCE family. In (28), for instance, it has lost its ground to P-DIST(N:2), which now has the power to influence the selections. The new perceptual-distance requirement that is established thereby compromises the integrity of the nasal trio because, while the contrast between /m/ and /ŋ/ manages to meet it, the contrast between /m/ and /n/ falls short. As the only escape from this impasse is to discard one of the anterior units, the grammar must weigh the consequences to make the best choice. If /m/ is forsaken, the contrast between /n/ and /ŋ/ will be sanctioned by P-DIST(N:1) and P-DIST(N:2), but it will be censured by P-DIST(N:3).

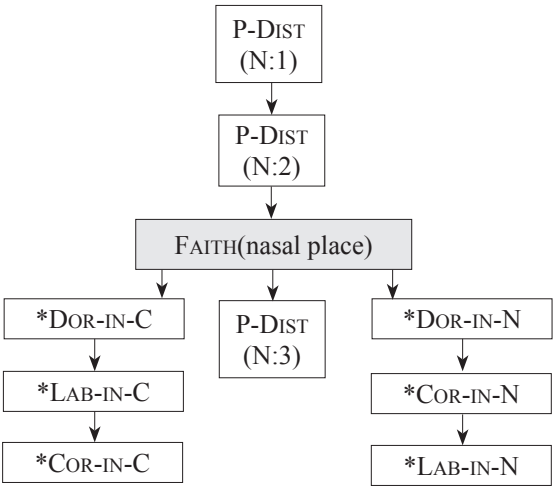
10. To keep the name of perceptual-distance constraints short, the pertinent acoustic cues—the NZ and N cluster—are abbreviated as N.

On the other hand, if /n/ is forsaken, the contrast between /m/ and /ŋ/ will be sanctioned by all three principles. The crux of the matter is that, because the violation of FAITH(nasal place) is inevitable, the decision falls on P-DISTANCE, whose members collude to favor of the most dispersed contrast.

(27) Grammar of languages with the trio /m n ŋ/



(28) Grammar of languages with the duo /m ŋ/



The picture emerging from the above is that the trio /m n ŋ/ and duo /m ŋ/ are akin. The latter is the product of contracting the former so that the best possible contrast can be obtained. Both diachrony and synchrony support this view as there are at least two languages where the transition from the larger to the smaller inventory occurred in the past (i.e. Palauan and Mekeo) and one where it is currently

active (i.e. Samoan).[11] In its evolution from Proto-Austronesian, Palauan simplified the trio /m n ŋ/ by changing the manner of articulation of the intermediate unit; it rendered it lateral (Foley 1975). Mekeo arrived at the same result by shifting the place of articulation of the intermediate unit backwards; it converted it into velar (Blevins 2009). The latter development also occurs in modern Samoan, where /n/ takes over the space of /ŋ/ when speakers switch from *tautala lelei* 'good speech' to *tautala leanga* 'bad speech' (Duranti 1994, Hyman 2008).

To summarize this section, the conundrum posed by the duo /m ŋ/ has been solved. The ousting of an anterior unit by a posterior one is induced by dispersion. One of the merits of this account is that it corrects a theoretical blunder. Reversing the dominance relations on which the place hierarchies are based has been avoided. We have learned that what appears to be a change in grammatical-cost values is a mirage created by another contending force: the drive to enhance phonological contrasts. It is in response to this pressure that /n/ has to be left out of the exceptional nasal duo. The retention of /m/ is absolutely necessary because it plays a key role in achieving maximal dispersion within this consonant class. Another revelation this analysis makes is that, although posteriority is normally detrimental to the perception of nasal stops, it has the potential to become an advantage. That is because its combination with anteriority affords a better contrast than the combination of two anterior units.

As a final remark, it should be noted that the introduction of a third evaluation measure does not make the theory excessively permissive. That is thanks to the condition that universal rankings must be strictly observed. If we go back to (28), for instance, there is only one alternative arrangement the system allows. Assume that, instead of 2, the perceptual-distance requirement is increased to 3; that is to say that FAITH(nasal place) falls below P-DIST(N:3). It is easy to see that the outcome will still be the duo /m ŋ/ because no other pair can meet such a high standard.

6. Integration

The analysis presented above differs from previous functional approaches in several important ways. Unlike Functional Phonology (Boersma 1997, 1998), the roles of speaker and listener have not been segregated; in other words, there is not a production and a perception grammar working independently of each other. The strategy I have adopted has been to integrate the structural constraints grounded on articulatory factors with those grounded on perceptual factors into a single grammar, where they are free to interact with one another as well as with the relevant faithfulness constraint. This integration has been the key to explaining the modicum of variation that exists in nasal-stop inventories.

A notable difference with respect to Dispersion Theory (Flemming 1995, 1996, 2002, 2004a, b, 2006) is that, instead of introducing a constraint family dedicated to the promotion of contrasts (i.e. MAINTAIN CONTRASTS or MAXIMIZE CONTRASTS),

11. The fact that these are all Austronesian languages suggests that the tendency to heighten the perceptual-distance requirement is a rare areal trait.

an independently needed constraint family has been charged with that task (i.e. FAITHFULNESS). This has two positive effects. On the one hand, it avoids constraint duplication, and, on the other hand, it makes it possible to integrate sound inventories with the rest of the grammar because the principles that govern their structure turn out to be the same ones that govern phonological patterns: *STRUCTURE, FAITHFULNESS, and P-DISTANCE.[12] With regard to the latter principle, it should be added that it is superior to Flemming's MINDIST because, as shown above, the required minimal distance is not a primitive notion. It can be derived via interaction with FAITHFULNESS.

An additional difference with respect to both Functional Phonology and Dispersion Theory is that the present proposal recognizes that, parallel to the articulatory effort dimension, there is a perceptual effort dimension. Accordingly, every nasal stop has two different grammatical costs: one articulatory and one perceptual. This understanding is missing from previous functional proposals, which, despite arguing that perception plays a central role in the phonology, fail to recognize a perceptual effort dimension. The view defended here is that perception plays dual roles. In addition to being the driver of dispersion phenomena (26), it is the foundation of one of the grammatical cost dimensions (11).

In sum, full integration of articulation and perception into the phonology is the defining trait of the above analysis.

7. Conclusion

This article has explored the topic of exceptionality in phonology focusing on a subset of nasal-stop inventories: those falling below the normal use of nasality (Table 2). The typology shows that this consonant class has a proclivity towards anteriority, or seen from the opposite angle, an aversion towards posteriority. This is evinced by the absence of nasal solos consisting of a posterior unit and the attestation of only one and extremely infrequent nasal duo where a posterior unit is present (i.e. /m ŋ/). One cannot get past these findings without asking the following question: Why is there not a balanced mix of places of articulation in these inventories? A sensible hypothesis is that anterior nasal stops make better phonemes than their posterior congeners, but this is not easy to defend because the patterns are not consistent enough to postulate an invariable order of precedence.

The same difficulty arises in trying to rank the anterior units. Nasal solos, which should reveal which is the best member of the class, fail to do so because some of them pick /n/, while others opt for /m/. An easy way to deal with this variation is to grant the anterior place categories equal phonological status, but this is unsatisfactory because the structure of nasal solos becomes a matter of chance.

Another intriguing fact is that, when languages decide to use nasal-stop phonemes, they are not satisfied with only one. The vast majority recruits at least two

12. Enhancement phenomena (e.g. prenasalization of voiced stops, aspiration of voiceless stops, rounding of postalveolar fricatives, etc.) are proof that P-DISTANCE constraints are not confined to sound inventories. They are operative throughout the phonology.

(92.70%). Logic tells us that, if languages want to be economical, they should limit the number of such phonemes to one. Why should they insist on a minimum of two?

In order to cope with this range of facts, it is imperative that the theory be enriched. One of the conclusions emerging from this study is that grammars assess the cost of linguistic structures on multiple dimensions. The view that there is a single universal place hierarchy has therefore been rejected.

It has been demonstrated that both the articulatory and the perceptual facets of speech influence the design of nasal-stop inventories and that the cost of articulating or perceiving place features varies across segmental classes. Differences in articulator velocity underpin the Articulatory Consonant Place Hierarchy (9), the assessment that, when it comes to forming a consonantal constriction, the corona is most adept, the lips are less so, and the dorsum is even less. Likewise, differences in acoustic salience buttress the Perceptual Nasal-Stop Place Hierarchy (11), the assessment that, when enveloped in the nasal murmur, dorsality, coronality, and labiality are gradually less taxing to the human ear.

The point needs to be underscored that, despite being universal, these place hierarchies do not apply across the board. Their reference to co-occurring properties of the segment (e.g. [consonantal], [nasal], [occlusive]) makes them irrelevant to some segmental classes without compromising their universality. The application of different evaluation measures to the same segmental class has a sound justification as well. Although both hierarchies are concerned with the cost of nasal stops, there is no duplication of labor because one assesses them articulatorily while the other one does so perceptually. A third point to emphasize is that, since each place hierarchy is autonomous, variation is expected to arise. Languages will make different selections depending on whether they set articulatory or perceptual cost as their leading priority.

The grammar thus conceived is rich in interactions (Figure 4). The disagreement between the place hierarchies and their alliance against faithfulness gives rise to a three-way conflict, which individual languages arbitrate at their will. The one condition that applies is, of course, that universal rankings be respected. All possibilities that the constraint system allows have been checked in order to verify that the use of multiple evaluation metrics does not cause overgeneration. The results are highly positive. The proposed model is able to rule out unattested patterns, generate those that have been attested, and explain why, among the latter, there are some which are highly frequent and others which are extremely rare.

The existence of two different nasal solos is no longer a mystery. As [coronal] is the best place feature a nasal stop can have from an articulatory point of view, languages seeking articulatory savings will pick /n/ for their nasal solos. On the other hand, since [labial] is the best place feature a nasal stop can have from a perceptual point of view, languages seeking perceptual savings will choose /m/ instead. Additionally, because there are no evaluation measures according to which a posterior nasal stop is the least costly member of its class, nasal solos such as */ŋ/, */ɲ/, or */ɳ/ are impossible to generate.

The detriment to posterior units is perpetuated by nasal duos. It has been determined on empirical grounds that the next rank on each place hierarchy is

held by another anterior category. In the articulatory dimension, [labial] comes immediately after [coronal], while in the perceptual dimension, [coronal] comes immediately after [labial]. Since this means that the first two positions that become available will be seized by /m/ and /n/, there cannot be any nasal duos deprived of anterior units (e.g. */ŋ ɲ/, */ŋ ɳ/, and */ɲ ɳ/). There will be, by contrast, one nasal duo deprived of posterior units (i.e. /m n/).

The normal minimum of two units now makes sense. The fact that the category sitting at the bottom of one place hierarchy occupies the immediately higher rank on the other place hierarchy entails that, in order to recruit its first nasal stop, a language must pay half the cost of a second one (17 and 19). As paying the remaining half facilitates the recovery of the extra payment, the avoidance of nasal solos is to be expected. Languages will seek a minimum of two units so that they can get a full return for their investment (21). With this additional revelation, the reasons behind the probabilistic universal in (2) are fully understood.

Despite these gains, the analysis would not have been entirely satisfactory if a compelling explanation for the existence of the duo /m ŋ/ had not been found. This exception seems to contravene the universality of the place hierarchies because it escapes their prediction that the introduction of the first posterior unit should follow that of both anterior units. Fortunately, the problem is only ostensible. The duo /m ŋ/ is actually a contraction of the trio /m n ŋ/. This discovery was made by recognizing that there is a third evaluation measure at work: a perceptual-distance hierarchy (26). The drive to enhance phonological contrasts may cause languages to discard an acoustically intermediate unit while retaining the most peripheral ones. In this way, the fact that /n/, rather than /m/, is the anterior unit missing from the exceptional nasal duo has been explained and it has been further revealed that, although posteriority is normally disadvantageous for nasal stops, there are cases where it proves to be an advantage.

We now have sensible answers to some of the key questions about the design of nasal-stop inventories. Rather than grammatical malfunctions, the exceptions were found to be the product of an intricate network of interactions, which lead to variation because individual grammars may settle conflicts in different ways. The diversity promoted thereby is highly limited, nonetheless, because there are substantive factors which impose a universal order on certain linguistic principles. The balance between restrictiveness and freedom that was needed to cope with the facts has been achieved. Universal rankings make the theory highly restrictive, while multiple interactions afford a modicum of variation.

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