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A Phonetically-Driven, Optimality-Theoretic Account of Post-Nasal Voicing

PROLOGUE

1. The Dilemma of Phonetic Naturalness

The tongue (and the ear) have preferences, and these preferences seem to govern a great deal of segmental phonology. How are these preferences to be reflected in the formal phonological grammar?

2. Some Responses to the Dilemma

a. *Cutting Down the Research Program* (Ohala 1974, 1981, 1983a, 1983b, 1990)

Restrict the research program to functionalist study: show how phonetic naturalness strongly influences phonological patterning.

Avoid trying to describe phonological patterns with explicit formal models.

b. *Natural Phonology* (e.g. Stampe 1973, Donegan and Stampe 1979)

Phonetic naturalness is incorporated into the theory, but at a tremendous cost in generality: every phonetic tendency gives rise to numerous "processes", whose origin (innate?) remains obscure.

c. *Much of Mainstream Phonological Theory*

ignores the naturalness problem entirely:

i. Phonological representations are impoverished and schematic, encoding only a tiny part of the richness of articulatory and perceptual phenomena.

ii. Researchers attempt to develop a model in which all phonological behavior is deducible from a limited set of formal structures and postulates.

3. Why the Problem is Especially Acute in Optimality Theory

OT depends on typologically well-documented principles of well-/better-formedness (Prince and Smolensky 1993).

These are abundant for prosody: syllable structure, metrical structure, prosodic morphology, etc.

What are the constraints that govern segmental phonology?

Proposed answer*:* they are phonetic in character, and in many cases have already been discovered in phonetic work.

Access to such constraints requires representations that are non-schematic, being rich enough to encode the level of detail at which phonetic explanation functions.

4. **The Form of the Evidence**

grossly asymmetrical phonological patterns that have no plausible formal explanation, but directly reflect phonetic principles.

Crucial point: although one might expect the cognitive principles embodying phonological computation to be streamlined and elegant,

nothing requires an actual vocal tract to be so.

⇨ cf. the case of postnasal voicing discussed here, which has an utterly idiosyncratic phonetic explanation

I. POSTNASAL VOICING AND ITS TYPOLOGY

5. **Postnasal Voicing is Common**

A healthy supply of languages voice obstruents after nasals, but not after vowels, glides, or liquids.

6. **Wembawemba** (Hercus 1986)

has allophonic voicing:	/taka/	[ˈtakʌ]	'to hit'
	/milpa/	[ˈmɪlpʌ]	'to twist'
	/yantin/	[ˈyandɪn]	'me'
	/panpar/	[ˈpanbʌr]	'shovel'

7. **Scope**

Locke (1983) checked the 197 languages of the Stanford Universals Project and found 15 with specifically post-nasal voicing.

8. **A Likely Greenbergian Implicational Universal**

Post-{liquid, glide, vowel} voicing ⇨ Post-nasal voicing BUT
Post-nasal voicing - Post-{liquid, glide, vowel} voicing

9. **The Target: Not Postnasal Devoicing per se, but Avoidance of NC[-voice]** (Pater 1995)

E.g. you can also

delete the nasal
denasalize the nasal
delete the obstruent
guarantee the voicelessness of the obstruent by aspirating it

10. **The Effect is Not Symmetrical** (Pater 1995)

Neither Pater nor I have located cases of pre-nasal voicing, other than those subsumed under general intersonorant voicing.

II. PHONETICS OF THE NASALITY/VOICE CORRELATION

11. **Voicing in Obstruents** (see Westbury 1979, 1983; Westbury and Keating 1986)

requires airflow across the glottis
- ⇨ requires somewhere for the air to go
- ⇨ requires either leakage or oral expansion

An large number of factors determine whether an obstruent will be voiced (see refs. above).

12. **Nasal Leak**

A small velum opening creates real nasal airflow, but little or no acoustic nasality (Bell-Berti 1993; Westbury 1983; Ohala and Ohala 1991, 1993): [b::::::::::::::::::::::::]

13. **The Velum as a Piston**

Velum = a movable flap, mostly horizontal

separates the nasal and oral cavities over a considerable length
rises and falls

When the velum is high:

upper surface is "folded down" at the rear to a vertical orientation
vertically-oriented surface engages the rear pharyngeal wall
achieves closure of the velar port
closes off the nasal passage.

The closure point is not all the way up:

You can raise the velum quite a bit more after closure is achieved (Bell-Berti 1993).

Nontransmissible art here: a velum that is all the way down;
a velum that is sufficiently up to achieve closure
a velum this is all the way up

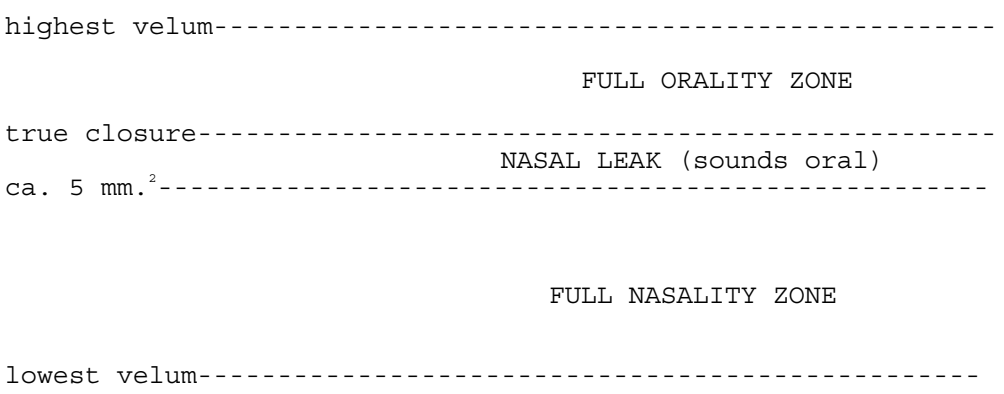
⇨ a closed but rising velum expands the oral cavity ⇨ a closed but falling velum contracts the oral cavity

14. **Behavior of the Velum**

Velar behavior is closely controlled at the segmental level (Boyce et al. 1991; Bell-Berti 1993)

highest: obstruents
oral vowels
nasal vowels
lowest: nasal consonants

15. **Acoustic Consequences of Various Velar Heights**



16. **Velar Coarticulation**

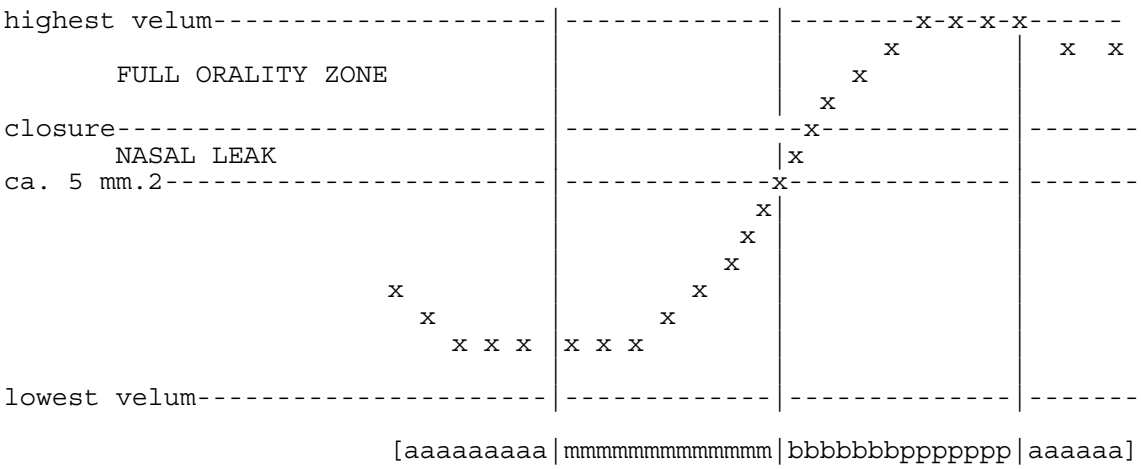
/NC/ sequences are hard, and require compromises during each of the segments:

Begin transition early; end it late.

III. NASALITY-VOICING INTERACTIONS

17. **An Imperiled Voiceless Post-Nasal Stop: /ampa/**

Schematic for velum height against time:



a. The passage through the nasal leak region will facilitate voicing.
b. The passage through the "full orality zone" will facilitate voicing by oral cavity expansion--closed velum as rising piston.

This mechanism is felt even in English (Hayes and Stivers, in progress), where postnasal [p] shows between 15-70% voicing during closure.

18. **/apma/: Two Mutually Opposed Effects**

a. The passage of the velum downward through the full orality zone:
like a lowering piston, induces compression
⇨ a hindrance to voicing.

b. Next: nasal leak zone
--> encourages voicing

French pre-nasal stops with a brief "voicing restart" are shown in Rochette (1973).

19. **Summary**

a. *Postnasal position*

Both velar "pumping" (rarification) and nasal leak encourage voicing.

b. *Prenasal position*

Velar "pumping" (compression) and nasal leak are mutually cancelling.

c. *Oral environments*

Neither effect is present.

⇨ This matches the cross-linguistic typology perfectly

See Hayes and Stivers (in progress) for evidence that the magnitudes of these effects suffice to account for typology.

IV. ANALYSES

20. **Hypothesis**

Postnasal voicing takes two forms:

phonetic: gradient, sometimes optional, non-neutralizing, not directly grammatically conditioned

phonological: categorial, neutralizing, subject to lexical and grammatical conditioning

21. **The Phonetic Component**

consists, I suggest, of a vast array of optimality-theoretic constraints, in two groups:

a. Constraints maintaining perceptibility of distinctions

i.e. maintaining the saliency of the phonetic cues for the phonological features

b. Constraints enforcing ease of articulation

22. **Approximating Continua of Articulatory and Perceptual Difficulty**

here, done by breaking continua into sets of constraints, each constraint defining a cut-off point along its continuum

23. **Constraints Against The Effort Needed to Preserve Voicelessness**

Don't stiffen vocal tract walls x amount
Don't raise larynx x amount } Jointly: *x [-voice] Effort
Don't abduct vocal cords x amount

24. **Ranking Principle**

The greater the articulatory effort, the higher the ranking of the phonetic constraint that bans it.

25. **Perceptual Constraints**

Preserve at least x duration of non-vocal cord vibration in a [-voice] segment.

N.B. voicing is gradient at the phonetic level: what is crucial is how much of the closure is voiced.

26. **Ranking Principle**

Perceptual constraints that preserve less of a cue to a feature are ranked more strictly than perceptual constraints that preserve more of it.

27. **Ranking of Phonetic Constraints Across Families**

is fluid: casual speech ranks ease-of-articulation constraints high
careful speech ranks perceptibility constraints high

28. **The Post-Nasal Environment**

Recall: degree of voicing or devoicing effort must be ranked "sensibly"; i.e. the ban on more effort must always be ranked at least as high as a ban on less effort.

Then there will be constraint rankings that yield voicing after nasals, but voicelessness after other sonorants.

29. **English**

Postnasal [-voice] stops are considerably more voiced phonetically than other [-voice] stops.

Constraint hierarchy:

Preserve at least 15% voicelessness in a [-voice] obstruent.
>> Preserve at least 30% voicelessness in a [-voice] obstruent.
>> Preserve at least 50% voicelessness in a [-voice] obstruent.
>> Preserve at least 70% voicelessness in a [-voice] obstruent.
>> Preserve at least 85% voicelessness in a [-voice] obstruent.
>> Preserve at least 95% voicelessness in a [-voice] obstruent.
>> Preserve at least 100% voicelessness in a [-voice] obstruent.

*x_1 degree of [-voice] Effort (= avoid extraordinary exertion)
>> *x_2 degree of [-voice] Effort .
>> *x_3 degree of [-voice] Effort .
>> *x_4 degree of [-voice] Effort .
>> *x_5 degree of [-voice] Effort .
>> *x_6 degree of [-voice] Effort .
>> *x_7 degree of [-voice] Effort .
>> *x_8 degree of [-voice] Effort (= don't even lift a finger)

30. **Physics**

This chart is based roughly on Hayes and Stivers's (in progress) voicing simulations.

Input: Degree of [-voice] effort	Output: Degree of voicelessness (% of closure) / N ___	Output: Degree of voicelessness / elsewhere
x_1	100	100
x_2	80	100
x_3	60	90
x_4	40	80
x_5	20	60
x_6	0	40
x_7	0	20
x_8	0	0

31. **The Constraints and Which Outputs Obey Them**

/mp:	[mp] 100	[mp] 80	[mp] 60	[mb] 40	[mb] 20	[mb] 0	= % of voiceless closure
Preserve 20%	✓	✓	✓	✓	✓	*	
Preserve 40%	✓	✓	✓	✓	*	*	
Preserve 60%	✓	✓	✓	*	*	*	
Preserve 80%	✓	✓	*	*	*	*	
Preserve 100%	✓	*	*	*	*	*	
*x_1 Effort	*	✓	✓	✓	✓	✓	
*x_2 Effort	*	*	✓	✓	✓	✓	
*x_3 Effort	*	*	*	✓	✓	✓	
*x_4 Effort	*	*	*	*	✓	✓	
*x_5 Effort	*	*	*	*	*	✓	
*x_6 Effort	*	*	*	*	*	*	
*x_7 Effort	*	*	*	*	*	*	
*x_8 Effort	*	*	*	*	*	*	
/rp/:	[rp]	[rp]	[rp]	[rb]	[rb]	[rb]	
Preserve 20%	✓	✓	✓	✓	✓	*	
Preserve 40%	✓	✓	✓	✓	*	*	
Preserve 60%	✓	✓	✓	*	*	*	
Preserve 80%	✓	✓	*	*	*	*	
Preserve 100%	✓	*	*	*	*	*	
*x_1 Effort	✓	✓	✓	✓	✓	✓	(Here, asterisks
*x_2 Effort	*	✓	✓	✓	✓	✓	reach lower, because
*x_3 Effort	*	✓	✓	✓	✓	✓	the "cost" of
*x_4 Effort	*	*	✓	✓	✓	✓	voicelessness is
*x_5 Effort	*	*	*	✓	✓	✓	lower.)
*x_6 Effort	*	*	*	*	✓	✓	
*x_7 Effort	*	*	*	*	*	✓	
*x_8 Effort	*	*	*	*	*	*	

32. **A Ranking Appropriate to Careful Speech**

/mp/:	[mp] 100	☞[mp] 80	[mp] 60	[mb] 40	[mb] 20	[mb] 0
Preserve 20%						*!
Preserve 40%					*!	*
Preserve 60%				*!	*	*
Preserve 80%			*!	*	*	*
*x_1 Effort	*!					*
Preserve 100%		*	*	*	*	*
*x_2 Effort	*	*				
*x_3 Effort	*	*	*			
*x_4 Effort	*	*	*	*		
*x_5 Effort	*	*	*	*	*	
*x_6 Effort	*	*	*	*	*	*
*x_7 Effort	*	*	*	*	*	*

*x_8 Effort	*	*	*	*	*	*

/rp/:	☞[rp] 100	[rp] 80	[rp] 60	[rb] 40	[rb] 20	[rb] 0
Preserve 20%						*!
Preserve 40%					*!	*
Preserve 60%				*!	*	*
Preserve 80%			*!	*	*	*
*x_1 Effort						
Preserve 100%		*!	*	*	*	*
*x_2 Effort	*					
*x_3 Effort	*					
*x_4 Effort	*	*				
*x_5 Effort	*	*	*			
*x_6 Effort	*	*	*	*		
*x_7 Effort	*	*	*	*	*	
*x_8 Effort	*	*	*	*	*	*

Crucial rankings: *x_1 Effort >> Preserve 100% >> *x_2 Effort

33. **A Ranking Appropriate to More Casual Speech**

/mp/	[mp] 100	[mp] 80	☞[mp] 60	[mb] 40	[mb] 20	[mb] 0
Preserve 20%						*!
*x_1 Effort	*!					
Preserve 40%					*!	*
*x_2 Effort	*	*!				
Preserve 60%				*!	*	*
*x_3 Effort	*	*	*			
Preserve 80%			*	*	*	*
*x_4 Effort	*	*	*	*		
Preserve 100%		*	*	*	*	*
*x_5 Effort	*	*	*	*	*	-
*x_6 Effort	*	*	*	*	*	*
*x_7 Effort	*	*	*	*	*	*
*x_8 Effort	*	*	*	*	*	*

/rp/:	[rp] 100	☞[rp] 80	[rp] 60	[rb] 40	[rb] 20	[rb] 0
Preserve 20%						*!
*x_1 Effort						
Preserve 40%					*!	*
*x_2 Effort	*!					
Preserve 60%				*!	*	*
*x_3 Effort	*					
Preserve 80%			*!	*	*	*
*x_4 Effort	*	*				
Preserve 100%		*	*	*	*	*
*x_5 Effort	*	*	*			
*x_6 Effort	*	*	*	*		
*x_7 Effort	*	*	*	*	*	
*x_8 Effort	*	*	*	*	*	*

Crucial rankings: *x_2 Effort >> Preserve 80%
Preserve 60% >> *x_3 Effort
Preserve 80% >> *x_4 Effort

34. **A Ranking Appropriate to Very Casual Speech**

/mp/:	[mp] 100	[mp] 80	[mp] 60	[mb] 40	[mp] 20	☞[mp] 0
*x_1 Effort	*!					
*x_2 Effort	*	*!				
*x_3 Effort	*	*	*!			
*x_4 Effort	*	*	*	*!		
*x_5 Effort	*	*	*		*!	
Preserve 20%					*	*
Preserve 40%					*	*
*x_6 Effort	*	*	*		*	*
Preserve 60%					*	*
*x_7 Effort	*	*	*		*	*
*x_8 Effort	*	*	*		*	*
Preserve 80%			*	*	*	*
Preserve 100%		*	*	*	*	*

/rp/:	[rp] 100	[rp] 80	[rp] 60	☞[rp] 40	[rp] 20	[rp] 0
*x_1 Effort						
*x_2 Effort	*!					
*x_3 Effort	*					
*x_4 Effort	*	*!				
*x_5 Effort	*	*	*!			
Preserve 20%						*!
Preserve 40%					*!	*
*x_6 Effort	*	*	*	*		
Preserve 60%				*	*	*
*x_7 Effort	*	*	*	*	*	
*x_8 Effort	*	*	*	*	*	*
Preserve 80%			*	*	*	*
Preserve 100%		*	*	*	*	*

Crucial rankings: Preserve 40% >> x_6 Effort

35. **General Pattern Here**

a. Degree of surface voicelessness depends on how low is the ranking for bans on articulatory effort.

b. Across the board, equivalent effort yields more voicelessness in the postoral environment than the postnasal environment.

c. Payoff: if the constraints are established blindly, without reference to environment THEN there will be a strong tendency toward postnasal voicing

36. **Further Possibilities if the Phonetics is Smart**

Cheaply rank a maneuver that will ensure voicelessness postnasally.

- vocal cord abduction (3/5 speakers in Hayes and Stivers, in progress)
- longer stop closure (all speakers in Hayes and Stivers, in progress)

37. **The Link to Typology**

There is no sensible arrangement of the phonetic constraints that would produce voicing after oral sonorants but not after nasals.

⇨ a partial account of the Greenbergian implication: if voicing after oral sonorants, then voicing after nasals

38. **A Note on Representation**

The phonetic computations described here must presumably manipulate extremely rich and detailed phonetic representations.

39. **But Is This Phonology?**

Numerous grammars report postnasal voicing.
Virtually none contain evidence concerning whether it is a categorial, fully-phonological phenomenon or a gradient, phonetic one.

Current track record, e.g.:

English "n → [m/ŋ] / ___ p/k" (phonetic: residual alveolar closure; Berry 1985 etc.)

English "sj → ʃ" (phonetic: output not the same as underlying /ʃ/; Zsiga 1993)

German etc.
"[-son] → [-vce] / ___ #" (phonetic: output not the same as underlying voiceless sonorants, Dinnsen 1985)

suggests that most postnasal voicing rules will indeed be phonetic in character.

V. CASES OF POSTNASAL VOICING AS PHONOLOGY

40. **Postnasal Voicing Probably Does Exist as a Phonological Pattern**

cf. Japanese, where it is lexically and grammatically constrained

stem-structure constraint on native vocabulary stratum only
post-nasal voiced stops trigger Lyman's Law (Ito, Mester, and Padgett, forthcoming)

41. **Ecological Validity**

Steriade (1995): many constraints of the categorial phonology are phonetically based, too.

They represent the "typical" case (generalized across tokens), rather than the particular conditions that prevail during an individual token.

"The ... constraints are general grammatical statements that must be isolated from token-to-token variability."

I.e. They are "ecologically valid" in the phonetic domain.

42. **An Ecologized Constraint for Post-Nasal Voicing**

*[+nasal] [-voice] (after Pater 1995)

See Pater for multiple uses of this phonological constraint.

This is ecologized, because postnasal voicing is not a inevitable outcome;

Phonetically, it is only a partial skewing of outcomes toward more milliseconds of closure voicing in the postnasal position.

There are many conditions under which N[-voice] is actually favored.

43. **The Ecologization Problem**

How are categorial phonological constraints related to patterns of phonetic difficulty? (I.e. how are they "grounded" (Archangeli and Pulleyblank 1994)?)

b. *Strategy I:* suppose that phonological categories in some way illusory, treating them as emergent properties of an amplified, smarter phonetics (Steriade 1995; Flemming 1995; Kirchner, in progress)

a. *Strategy II:* define a procedure projecting phonological constraints from the speaker's tacit knowledge of phonetics

= characterize the human ability to "crystallize" true phonological constraints out of phonetic experience

44. **A Possible Strategy For Ecologization**

Phonological constraints represent a compromise between phonetic difficulty and formal symmetry.

Possible phonological constraints will not be "natural" across the board, but will be more natural than any formally simpler alternative.

45. **Ecologization Conjecture**

A phonological constraint is stable if any generalization of it would ban configurations of lesser phonetic difficulty.

46. **Postnasal Voicing as Ecologized**

a. *[+nasal][-voice]

is permissible, because any generalization would ban configurations of lesser phonetic difficulty--e.g.

[+sonorant][-voice] is more general but bans, e.g., the easier [rk]

b. *[+sonorant][-voice] is permissible on the same grounds.

c. *+sonorant [-voice] is illegal, because a generalization of it
-nasal ((b) above) bans only configurations that are just as hard or harder.

47. **A Possible Advantage of a Phonology/Phonetics Distinction**

It offers part of a possible cure for a major problem faced by Optimality Theory, namely dealing with opaque phonology.

Suppose (following Pierrehumbert 1980) that phonetic rules/constraints interpret but do not modify the output of the phonology.

Than many apparent cases of opacity will result from phonetic constraints interpreting the phonological representation.

VI. CONCLUSION

48. **Review**

a. Postnasal voicing is a result of very accidental circumstances:
- the velar port can leak during the production of an oral sound.
- the closed velum rarifies and compresses as it rises and falls.

b. An optimality-theoretic phonetics can get the tendency toward postnasal voicing "for free," by ranking constraints of articulatory effort against constraints of perceptual clarity.

c. Phonological postnasal voicing can be attributed to a constraint that is formally arbitrary, but justifiable as "ecologized" from the domain of phonetic experience.

49. **Postnasal voicing is not atypical**

It is exceptional only for the peculiarity of the phonetic explanation.

But it is reasonable to suppose, I think, that virtually all of segmental phonology (and even some non-segmental phonology) is driven by considerations of articulatory ease and perceptual distinctness.

See Steriade (1995) on feature licensing, Jun (1995) on place assimilation, Flemming (1995) on vowel-consonant interactions, Kaun (1995) on harmony

In all of these cases, the phonetics involved is beyond the capacity of ordinary, schematic phonological representations to depict.

50. **Moral of the Story**

Phonology is played on a bumpy playing field.

A grammar that directly reflects this will be more effective.

Further suggestion: when we understand better the factors in phonology that result from the bumpy playing field, then the purely formal, computational elements of the system will come into sharper focus.

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