Directional asymmetry in vowel nasalization: a perceptual account

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I. Problem

1. Contextual vowel nasalization: a vowel takes on the nasality of a neighboring nasal consonant.
   (cf. Processes of nasal harmony have been excluded from the discussion. Only local cases of vowel nasalization will be examined.)

2. There is an asymmetry in the direction of vowel nasalization.
   - Classic view (Ohala 1975, Ruhlen 1978, Kawasaki 1986): Anticipatory nasalization (VN → ṼN) is more extensive and typologically more common than carryover nasalization.
   - Competing view (Delvaux et al. 2008): Carryover nasalization (NV → NṼ) is more extensive and more common than anticipatory nasalization.

3. There exists two contradicting views in the literature concerning the directional asymmetry of nasalization.

II. The primacy of anticipatory nasalization

1. Standard OT analysis on contextual nasalization (for instance, Kager's OT analysis, 1999)
   - Assumes only *VN and not *NV as a universal constraint.
     (cf. *VN = No oral vowel is allowed before a nasal. *NV = No oral vowel is allowed after a nasal.)
     The ensuing typological predictions are restricted by this assumption.
   - Typology table: expected patterns

Contrast Patterns	Oral vs. Nasal V	Attested
no contrast	always oral	ba, ban
phonemic	always oral/nasal contrast	ba, bã, ban, bãn
allophonic	always oral nasal before nasal	ba, bãn
neutralization	oral/nasal contrast elsewhere but nasal before nasal	ba, bã, bãn

2. Underlying assumptions
   - This analysis and the predicted typology presuppose that anticipatory nasalization is common, whereas carryover nasalization is rare, an assumption which is supported directly or indirectly in many previous studies including Ohala (1975), Ruhlen (1978) and Kawasaki (1986).
   - Major reason behind this support: There is a wide array of evidence that seems to support the assumption.

3. Supporting evidence
   - Synchronic evidence: A study on language typology suggests that anticipatory nasalization is more common than carryover nasalization (e.g. Kawasaki 1986, Cohn 1993b).
     In general, a syllable-final nasal nasalizes a vowel more than a syllable-initial nasal. (Kawasaki 1986: 83)
   - Diachronic evidence (indirect): Phonemic nasal vowels are frequently developed from VN sequences and seldom from NV or other sequences (Beddor 2009).

4. Unpredicted patterns
   - In the standard constraint-based analysis mentioned above (only ID(nasal), *Ṽ and *VN posited as relevant constraints), no constraint ranking can capture the following attested patterns.

Constraint Ranking	Contrast Patterns	Oral (vs) Nasal V	Attested Patterns
none	neutralization	oral/nasal oral before nasal	ba, bã, ban
none	allophonic	oral elsewhere nasal after nasal	ba, nã

   - The analysis cannot predict (1) languages with more extensive degree of carryover nasalization compared to anticipatory nasalization (e.g. Greek) and (2) languages that normally allow phonemic nasal vowels but disallow them specifically in the pre-nasal context (e.g. French).

III. The primacy of carryover nasalization

1. Several phonetic production data seem to point to the fact that carryover nasalization is quite extensive in many languages; in most cases, more extensive than that of anticipatory nasalization (e.g. Italian (Farnetani 1986), Akan (Huffman 1989), Ikalanga (Beddor and Onsuwan 2003), Greek (Diakoumakou 2004) and French (Delvaux 2000)).

2. Based on the growing amount of phonetic data, some scholars have concluded that carryover nasalization is the more universal form of nasalization compared to anticipatory nasalization.
   (...) many studies that focused on the difference between carryover and anticipatory nasalization concluded on the preeminence of the first over the second (...) (Delvaux et al. 2008: 596)

3. This view is also problematic, because as can be seen in the previous section, there are many other languages that show a more extensive degree of anticipatory nasalization than carryover nasalization.

4. Is there no directional universality worth discussing after all? Are patterns of nasalization just random and language specific?
   → My answer: There *is* a certain directional asymmetry.

IV. My Argument: asymmetries in different levels

1. By undergoing a critical reanalysis of the two types of existing studies mentioned above, the following conclusion has been derived.

   Carryover nasalization is more extensive as phonetic coarticulation, but anticipatory nasalization is more common as phonological assimilation.

2. Observations that led me to this conclusion
   - In languages that are purported not to have any salient phonological process of contextual nasalization, anticipatory nasalization is less extensive in degree of phonetic coarticulation than carryover nasalization (e.g. Diakoumakou 2004).
   - However, in other languages where anticipatory nasalization *is* found to be extensive, it is usually categorical in nature, which means that the entire portion of the vowel is nasalized (Solé 1992, M. Ohala 1975, etc.)
   - Also, anticipatory nasalization is typically related to other corollary phonological processes such as neutralization. Neutralization of vowel oral-nasal distinction occurs much more frequently in VN sequences than in NV sequences (Kawasaki 1986).
   - Finally, anticipatory nasalization is often involved in the diachronic development of phonemic nasal vowels.
     → Roughly put, anticipatory nasalization is phonological in nature.
   - In contrast, although carryover nasalization is generally quite extensive, it is usually gradient in nature (usually around 70–90% of the vowel length is nasalized).
   - Additionally, carryover nasalization seldom triggers phonological processes such as neutralization and seldom results in diachronic development of nasal vowels.
     → Roughly put, carryover nasalization is phonetic in nature.

3. The predicted typology following my proposal

	nasalized portion of the vowel (%)
type1	anticipatory *assimilation* > carryover coarticulation (phonologization of ṽn)
type2	carryover coarticulation > anticipatory coarticulation (no phonologization of ṽn)

4. A recapitulation of the relevant data
   Data source: English (Flege 1988, Solé 1992), Greek (Diakoumakou 2004), French (Cohn 1990), Spanish (Solé 1992), Italian (Farnetani 1986), Japanese (Ushijima and Hirose 1974), Hindi (M. Ohala 1975), Swedish (Clumeck 1975), Brazilian Portuguese (Medeiros 2011), Ikalanga (Beddor 2003), Thai (Onsuwan 2003), Cairene Arabic (my pilot production experiment), Moroccan Arabic (Zellou 2012), Akan (Huffman 1988).

type	language	carryover NV	anticipatory VN]$_\sigma$	V]$_\sigma$N
type1	English	82%	100%	-
	Hindi	70%	100%	-
	Bengali	(ext)	100%	-
	B. Portuguese	(ext)	(imp)	100%
	Akan	85%	-	100%
type2	Italian	(ext)	43%	-
	French	73%	33%	17%
	Greek	71%	55%	29%
	Spanish	-	43%	-
	Thai	-	40%	-
	Swedish	(ext)	(lim)	-
	C. Arabic	72%	38%	-
	M. Arabic	(ext)	45%	-
	Ikalanga	76%	(imp)	33%
	Japanese	(ext)	(imp)	-

The nasalized portion of the vowel length in %

cf. (ext) = extensively but non-categorically nasalized, (lim) = limited nasalization (less than 50%), (imp) = unattested sequence in the language, (-) = no data available

5. Prediction quantified (tentative): Carryover nasalization typically falls between 70–80% nasalization range, whereas anticipatory nasalization falls either within (1) the non-extensive coarticulation range of 10–50%, or within (2) the categorical assimilation range of 90–100%.

6. Are there any other attested language types that may have been left out from the predicted typology?
   (e.g. co-existence of non-extensive carryover coarticulation and non-extensive anticipatory coarticulation)

7. Impossible pattern under my argument: the coexistence of non-extensive carryover coarticulation and extensive anticipatory coarticulation

V. Phonetic-phonology discrepancy

1. Carryover nasalization is more extensive than anticipatory nasalization as phonetic coarticulation, but it is anticipatory nasalization which is more often observed as phonological pattern.

2. **There is a discrepancy between phonetic coarticulation tendency and categorical phonological patterns.**
   → Is this common? No. Generally, phonetic/phonological patterns go hand in hand, and gradient phonetic tendencies become precursors to more categorical phonological phenomena.
   → *Then why does the mismatch between the two patterns arise in contextual vowel nasalization?*

VI. A perceptual hypothesis

1. Perceptual asymmetry in two directions of nasalization
   - Perceptual difficulty of progressive nasalization briefly mentioned in the previous literature: Cohn (1990), Medeiros (1995)

2. My proposal
   Anticipatory nasalization is more easily perceived, and hence more prone to phonologization even when produced with less degree of nasalization.

VII. An AXB perception test

1. The structure of the AXB test: Vowels with 4 distinct degrees of nasality $\{a_0, a_1, a_2, a_3\}$ were synthesized with Hlsyn (Stevens et al., Copyright 1990-2001, Sensimetrics Corporation, version 2.2), a Klatt-type quasi-articulatory formant synthesizer. They were used as A and B and the vowel part of X. A and B were single vowels and X was mono to disyllabic words containing either anticipatory environment (ma) or carryover environment (am). The subjects were asked to choose the one (A or B) that sounded more similar to the vowel contained in the middle word X.

2. e.g. sample stimuli: $[a_1 ..a_2\mathbf{m}\ a_2]$ (an anticipatory case), $[a_1 ..\mathbf{m}a_2\ a_2]$ (a carryover case)

3. The full set of vowels $\{a_0, a_1, a_2, a_3\}$ including oral vowel a_0 and full nasal vowel a_3 were used for A and B. As for the vowels of X, only a_1 (moderately nasalized vowel) and a_2 (extensively nasalized vowel) was used.

4. To create 4 distinctive strata of nasality, I adjusted the length of velopharyngeal port opening (one of the higer-level articulatory parameters) in Hlsyn. This made Hlsyn automatically introduce additional pole-zero pairs to the system, and adjust related lower-level Klatt (formant-based) parameters.

<Spectra of oral vowel a₀(left) and full nasal vowel a₃(right)>
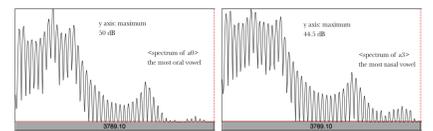
5. The spectrograms of the synthesized sounds confirmed that the bandwidth of the lower formants were correctly widened (flattened).
   cf. The general widening of the spectrum in the lower formant area is the most well known perceptual cue of nasality in vowels. (Stevens 2000)

6. Participants: 21 native speakers of Korean were recruited from the community at Seoul National University. (In Korean, there is no salient process of carryover or anticipatory nasalization.)

7. Hypothesis: I hypothesized that depending on whether X contains [am] or [ma], the percentage of selecting the less nasalized vowel (between A and B) would differ. For example, for the stimulus type $[a_1 (m)a_2(m) a_2]$, I expected that the subjects would choose a_1 (the less nasalized vowel) to a smaller extent when the stimulus is $[a_1 ..a_2m\ a_2]$ (X has anticipatory context) and to a greater extent when the stimulus type is $[a_1 ..ma_2\ a_2]$ (X has carryover context).

8. Results
   - Number of responses for each stimulus type = 84 (21 subjects x 4 repetitions (2 repetitions each for AXB and BXA))

	a_0-a_1-a_1	a_0-a_1-a_2	a_1-a_1-a_2	a_2-a_2-a_3
carryover (ma)	48.81% (41/84)	**72.62%** (61/84)	**80.95%** (68/84)	72.62% (61/84)
anticipatory (am)	36.9% (31/84)	**48.81%** (41/84)	**52.38%** (44/84)	70.24% (59/84)

	a_1-a_1-a_3	a_0-a_1-a_3	a_2-a_1-a_3	a_1-a_2-a_3
carryover (ma)	90.48% (76/84)	96.43% (81/84)	84.52% (71/84)	91.67% (77/84)
anticipatory (am)	82.14% (69/84)	91.67% (77/84)	82.14% (69/84)	90.48% (76/84)

	a_0-a_2-a_2	a_0-a_2-a_3	a_2-a_1-a_2	a_1-a_2-a_2
carryover (ma)	41.67% (35/84)	46.43% (39/84)	**71.43%** (60/84)	89.29% (75/84)
anticipatory (am)	34.52% (29/84)	36.9% (31/84)	**45.24%** (38/84)	90.48% (76/84)

Number of responses where the less nasalized vowel was selected

   - A higher number of responses with less nasalized vowel was obtained for carryover context compared to the corresponding anticipatory context in almost all types of stimuli (11 out of 12).
   - The difference between carryover and anticipatory nasalization was most striking in three types of stimuli: a_0-a_1-a_2, a_1-a_1-a_2 and a_1-a_2-a_2.
   - A logistic regression with carryover vs. anticipatory, as well as the identity of A, B, X and step sizes as independent variables and the number of responses with the less nasalized vowel token as the dependent variable was conducted. The result showed that **carryover/anticipatory distinction was a highly significant factor**, as well as the identity of A, B, X and 0-2 step size (for each variable, p < 0.001).
   - When the more nasalized vowel of A and B was a_3 (a full nasal vowel), both carryover cases and anticipatory cases preferred to choose the less nasalized vowel (more than 80% of the time). In other words, for stimuli with a_3, the percentage of choosing less nasalized vowel in carryover and anticipatory nasalization cases converged to a very high percentage (sticky ceiling effect).
   - When neither of A or B was a_3, carryover cases had significantly more tokens of choosing less nasalized vowels. Hence, people do seem to perceive vowels in carryover cases to be less nasalized.
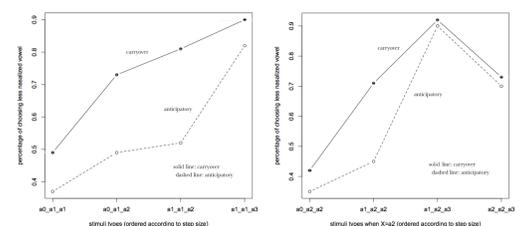
VIII. Conclusion

1. Carryover nasalization seems to be the default and extensive form of phonetic coarticulation in many languages.

2. Anticipatory nasalization seems to occur frequently as phonological assimilation process.

3. This mismatch between phonetic and phonological tendencies arises due to an asymmetry in perception: anticipatory nasalization is more easily perceived than carryover nasalization.

4. The above hypothesis has been confirmed by a perception experiment.

* References provided in the handout.