

# Directional asymmetry in contextual vowel nasalization: a perceptual account

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# 0. Preview

- Contextual vowel nasalization is a common process: a vowel takes on the nasality of a neighboring nasal consonant.
- Example) English: van[væ̃n]
- Two types of nasalization:
  - anticipatory: VN → ṼN
  - carryover: NV → ÑV

cf) nasal harmony: a subset of contextual nasalization that shall not be dealt with in this presentation; here we focus only on local cases of nasalization.

# 0. Preview

- There is an asymmetry in the direction of vowel nasalization.
  - Classic view (Ohala 1975, Ruhlen 1978, Kawasaki 1986): Anticipatory nasalization ( $VN \rightarrow \tilde{V}N$ ) is more extensive and typologically more common than carryover nasalization.
  - Competing view (Delvaux 2000): Carryover nasalization ( $NV \rightarrow N\tilde{V}$ ) is more extensive and more common than anticipatory nasalization.
- Two contradicting views concerning the directional asymmetry of nasalization.

# 0. Preview

- My review of the relevant literature: The two opposing lines of thought have focused on different parts of the picture.

*In phonetic coarticulation, carryover nasalization is more extensive. In contrast, in phonological assimilation, anticipatory nasalization is more common.*

# 0. Preview

- This observation can be seen as a challenge to the conventional assumption on the relationship between phonology and phonetics.
- There is a discrepancy between phonetic coarticulation tendency (in favor of carryover nasalization) and categorical phonological patterns (in favor of anticipatory nasalization).
- Proposal: This seemingly problematic phonetics-phonology discrepancy is due to an asymmetry in nasality perception.

# 0. Preview

- My hypothesis

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

→ An AXB perception test was conducted, and the result confirmed this hypothesis.

# 0. Outline of the talk

- Arguments supporting the primacy of anticipatory nasalization
- Arguments supporting the primacy of carryover nasalization
- My proposal: predicted typology and further implications
- Phonetics-phonology discrepancy: a perceptual hypothesis, AXB perception experiment

# 1. The primacy of anticipatory nasalization

- 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.



# 1. The primacy of anticipatory nasalization

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

< Typology table: expected patterns >

# 1. The primacy of anticipatory nasalization

- Underlying assumptions
  - This analysis and the predicted typology presuppose that anticipatory nasalization is common, whereas carryover nasalization is rare.
  - This assumption 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 range of evidence that seems to support the assumption.

# 1. The primacy of anticipatory nasalization

- Evidence
  - Many synchronic vowel nasalization processes have been observed to happen predominantly in VN sequences.
  - A study on language typology suggests that anticipatory nasalization is more common than carryover nasalization.

# 1. The primacy of anticipatory nasalization

In general, a syllable-final nasal nasalizes a vowel more than a syllable-initial nasal. Some languages with anticipatory nasalization are Azerbaijani, Cayapa, Chipewyan, Delaware, English, Hupa, Kashmiri, Malay, Nahuat, Nez Perce, Panamanian Spanish, Tagalog, Tewa, Tolowa, Tunica, and Wolof.

(Kawasaki 1986, p.83)

- In the above mentioned cases, anticipatory nasalization generally takes place as a relatively salient phonological process.

# 1. The primacy of anticipatory nasalization: unpredicted patterns

- Recall the standard constraint-based analysis of nasal vowel typology mentioned in the previous section.
- The presence of \*VN and the absence of \*NV → only the tendency of anticipatory nasalization exists as a phonological universal, and there is no comparable tendency of carryover nasalization.

# 1. The primacy of anticipatory nasalization: unpredicted patterns

- Therefore, in this analysis, no constraint ranking can capture the following attested pattern.

Contrast Patterns	Oral vs. Nasal V	Attested
(unexpected) allophonic	always oral but nasal after nasal	ba, nã

- languages with more extensive degree of carryover nasalization. e.g. French, Greek.

## 2. The primacy of carryover nasalization

- Several phonetic production data seems to point to the fact that carryover nasalization is quite extensive in many languages; in most cases, more extensive than that of anticipatory nasalization.
- These production data include Italian (Farnetani 1986), Akan (Huffman 1989), Ikalanga (Beddor, Onsuwan 2003), Greek (Diakoumakou 2005) and French (Delvaux 2000)

## 2. The primacy of carryover nasalization

- Based on these 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 2000)



## 2. The primacy of carryover nasalization

- But this view is also problematic, because we have seen in the previous section that there are many other languages that show a more extensive degree of anticipatory nasalization than carryover nasalization.
- Is there no directional universality worth discussing in the first place? Are patterns of nasalization just random and language specific?
- My answer: There is a certain directional asymmetry.

### 3. My proposal and predicted typology

- From the above, the following conclusion is derived.

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

→ Several types of observations led me to this conclusion. These observations are as follows:

### 3. My proposal and predicted typology

- 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.
- On the other hand, 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 (M. Ohala 1975, Solé 1992, etc.)

# 3. My proposal and predicted typology

- Also, anticipatory nasalization is typically related to other corollary phonological processes such as neutralization.
  - Neutralization of vowel oral-nasal distinction occurs more frequently in VN sequences than in NV sequences (Kawasaki, 1986).
  - An implicational relationship seems to hold; if a vowel is neutralized after N, then it is neutralized before N.
  - cf. Those that allow only NV neutralization are mostly languages with simple CV structure (no tautosyllabic VN).
- Finally, anticipatory nasalization is often involved in the diachronic development of phonemic nasal vowels.

### 3. My proposal and predicted typology

- In contrast, although carryover nasalization is generally quite extensive, it is usually gradient in nature (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.

### 3. My proposal and predicted typology

- The predicted typology following my proposal:  
a recapitulation of the relevant data
  - Type1: extensive carryover coarticulation,  
categorical anticipatory assimilation
  - Type2: extensive carryover coarticulation, less  
extensive anticipatory coarticulation

# 3. My proposal and predicted typology

type	language	carryover	anticipatory	
		NV	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)	(lim)	-

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)

### 3. My proposal and predicted typology

- 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%.



## 4. Phonetics-phonology discrepancy

- Carryover nasalization is more extensive than anticipatory nasalization as a phonetic coarticulation, but it is anticipatory nasalization which is more often observed as a phonological pattern.
- There is a discrepancy between phonetic coarticulation tendency and categorical phonological patterns.

## 4. a perceptual hypothesis

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

## 4. An AXB experiment

- Vowels with 4 distinct degrees of nasality  $\{a_0, a_1, a_2, a_3\}$  were synthesized with Hlsyn, a Klatt-type quasi-articulatory formant synthesizer, and 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.

## 4. An AXB experiment

- A, B: a single vowel with different degrees of nasality
- X: is either
  - (i) (b)**am** (a word with anticipatory context) or
  - (ii) (a)**ma** (a word with carryover context)
- In each AXB,  $A \neq B$
- The orderings were switched between AXB and BXA in a single stimulus type.

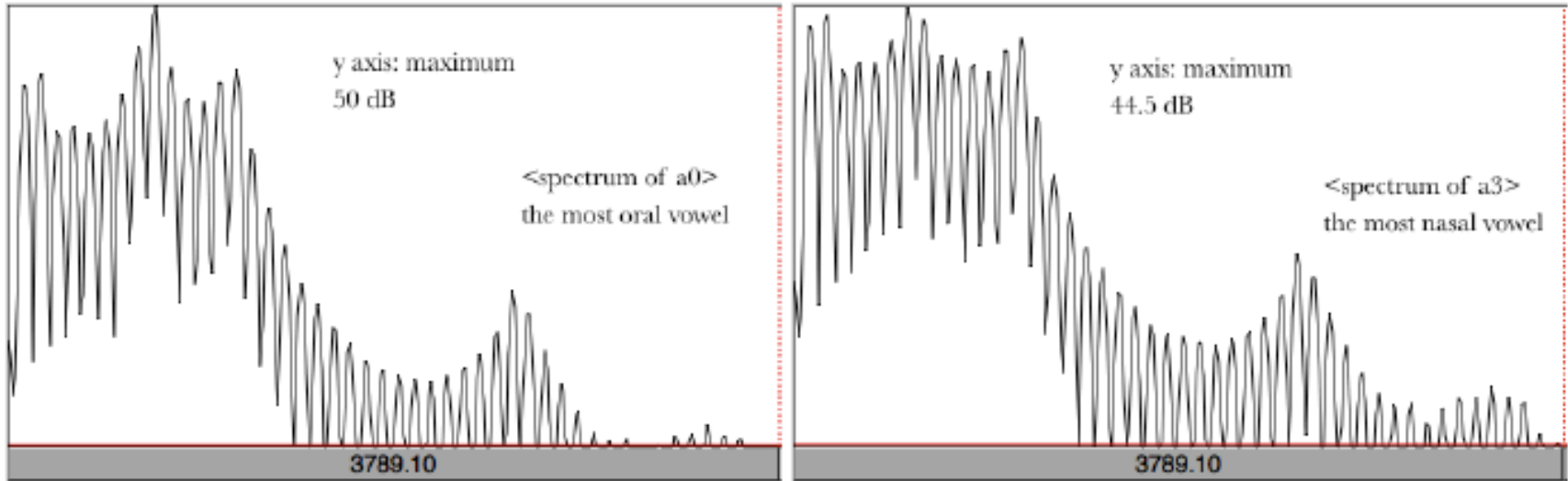
## 4. An AXB experiment

- e.g. a sample stimulus:  $[a_1 b a_2 m a_2]$  (an anticipatory case), where  $a_1$  is a moderately nasalized vowel and  $a_2$  is an extensively nasalized vowel.
- To create 4 distinctive strata of nasality, I adjusted the length of velopharyngeal port opening (one of the higher-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.

# 4. An AXB experiment

- 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. (Maeda 1993, Stevens 1998)
- Participants: 21 native speakers of Korean were recruited from the community at Seoul National University.
  - In Korean, there is no salient carryover/anticipatory nasalization.

# 4. An AXB experiment



Spectra of oral vowel  $a_0$  (left) and full nasal vowel  $a_3$  (right)

# 4. An AXB experiment

Sets of AXB tokens adopted in the experiment				
carr/ant	carryover		anticipatory	
order	AXB	(BXA)	AXB	(BXA)
X contains $a_1$	$a_1-ma_1-a_2$	$(a_2-ma_1-a_1)$	$a_1-a_1m-a_2$	$(a_2-a_1m-a_1)$
	$a_1-ma_1-a_3$	$(a_3-ma_1-a_1)$	$a_1-a_1m-a_3$	$(a_3-a_1m-a_1)$
	$a_0-ma_1-a_2$	$(a_2-ma_1-a_0)$	$a_0-a_1m-a_2$	$(a_2-a_1m-a_0)$
	$a_0-ma_1-a_3$	$(a_0-ma_1-a_3)$	$a_0-a_1m-a_3$	$(a_0-a_1m-a_3)$
	$a_0-ma_1-a_1$	$(a_1-ma_1-a_0)$	$a_0-a_1m-a_1$	$(a_1-a_1m-a_0)$
	$a_2-ma_1-a_3$	$(a_3-ma_1-a_2)$	$a_2-a_1m-a_3$	$(a_3-a_1m-a_2)$
X contains $a_2$	$a_1-ma_2-a_2$	$(a_2-ma_2-a_1)$	$a_1-a_2m-a_2$	$(a_2-a_2m-a_1)$
	$a_1-ma_2-a_3$	$(a_3-ma_2-a_1)$	$a_1-a_2m-a_3$	$(a_3-a_2m-a_1)$
	$a_2-ma_2-a_3$	$(a_2-ma_2-a_3)$	$a_2-a_2m-a_3$	$(a_2-a_2m-a_3)$
	$a_0-ma_2-a_2$	$(a_0-ma_2-a_2)$	$a_0-a_2m-a_2$	$(a_0-a_2m-a_2)$
	$a_0-ma_2-a_3$	$(a_0-ma_2-a_3)$	$a_0-a_2m-a_3$	$(a_0-a_2m-a_3)$
	$a_0-ma_2-a_1$	$(a_0-ma_2-a_1)$	$a_0-a_2m-a_1$	$(a_0-a_2m-a_1)$



# 4. An AXB experiment

	$a_0-a_1-a_1$	$a_0-a_1-a_2$	$a_1-a_1-a_2$
carryover	48.81% 41/84	<b>72.62%</b> <b>61/84</b>	<b>80.95%</b> <b>68/84</b>
anticipatory	36.9% 31/84	<b>48.81%</b> <b>41/84</b>	<b>52.38%</b> <b>44/84</b>
	$a_1-a_1-a_3$	$a_0-a_1-a_3$	$a_2-a_1-a_3$
carryover	90.48% 76/84	96.43% 81/84	84.52% 71/84
anticipatory	82.14% 69/84	91.67% 77/84	82.14% 69/84
	$a_0-a_2-a_2$	$a_0-a_2-a_1$	$a_1-a_2-a_2$
carryover	41.67% 35/84	46.43% 39/84	<b>71.43%</b> <b>60/84</b>
anticipatory	34.52% 29/84	36.9% 31/84	<b>45.24%</b> <b>38/84</b>
	$a_2-a_2-a_3$	$a_1-a_2-a_3$	$a_0-a_2-a_3$
carryover	72.62% 61/84	91.67% 77/84	89.29% 75/84
anticipatory	70.24% 59/84	90.48% 76/84	90.48% 76/84

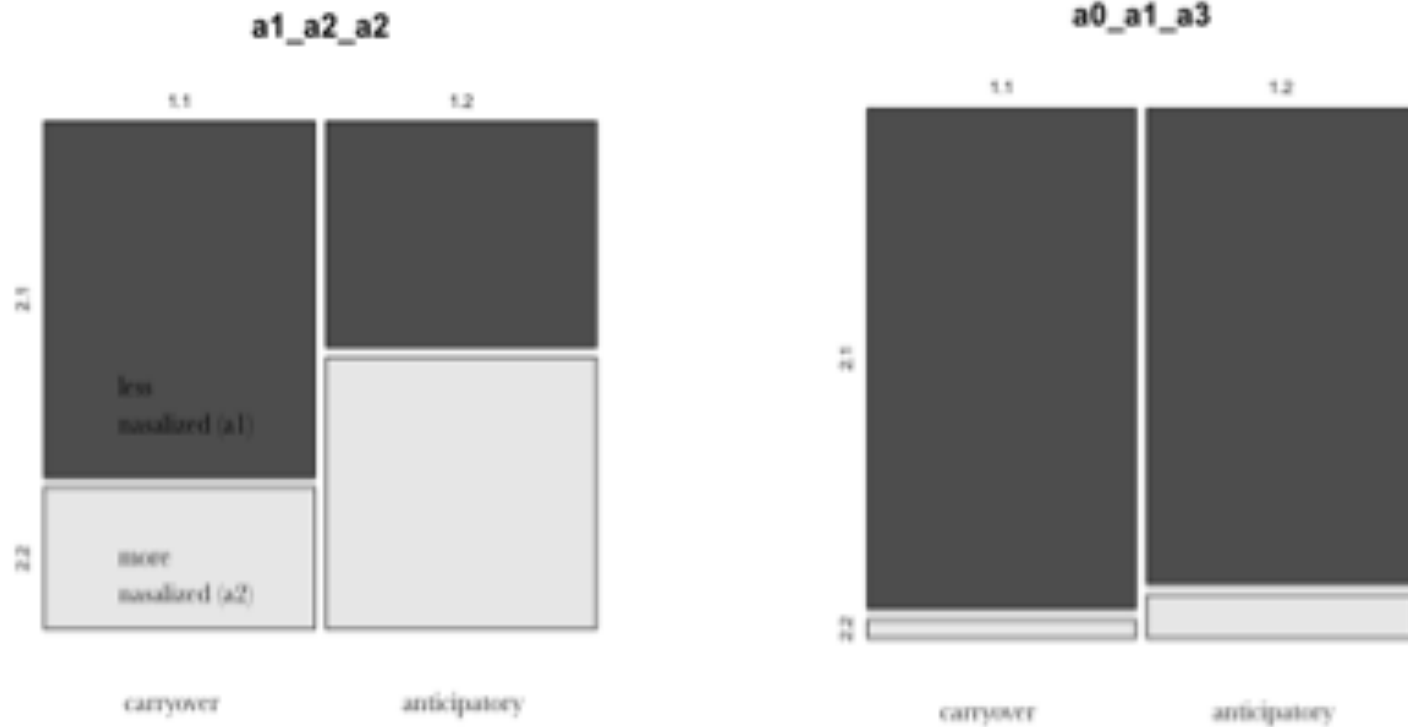
*Number of responses with the less nasalized vowel*

- 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  $a_1-a_2-a_2$

## 4. An AXB experiment

- a chi-square test between carryover and anticipatory responses (less nasalized vs. more nasalized), of the stimulus type  $a_1$ - $a_1$ - $a_2$ :
  - X-squared = 10.8, df = 1, p-value = 0.001015
  - The difference between the two cases is significant ( $p < 0.01$ ).
- a chi-square test between carryover and anticipatory responses (less nasalized vs. more nasalized), of the stimulus type  $a_0$ - $a_1$ - $a_3$ :
  - X-squared = 0.957, df = 1, p-value = 0.328
  - The difference between the two cases is not significant ( $p > 0.01$ ).

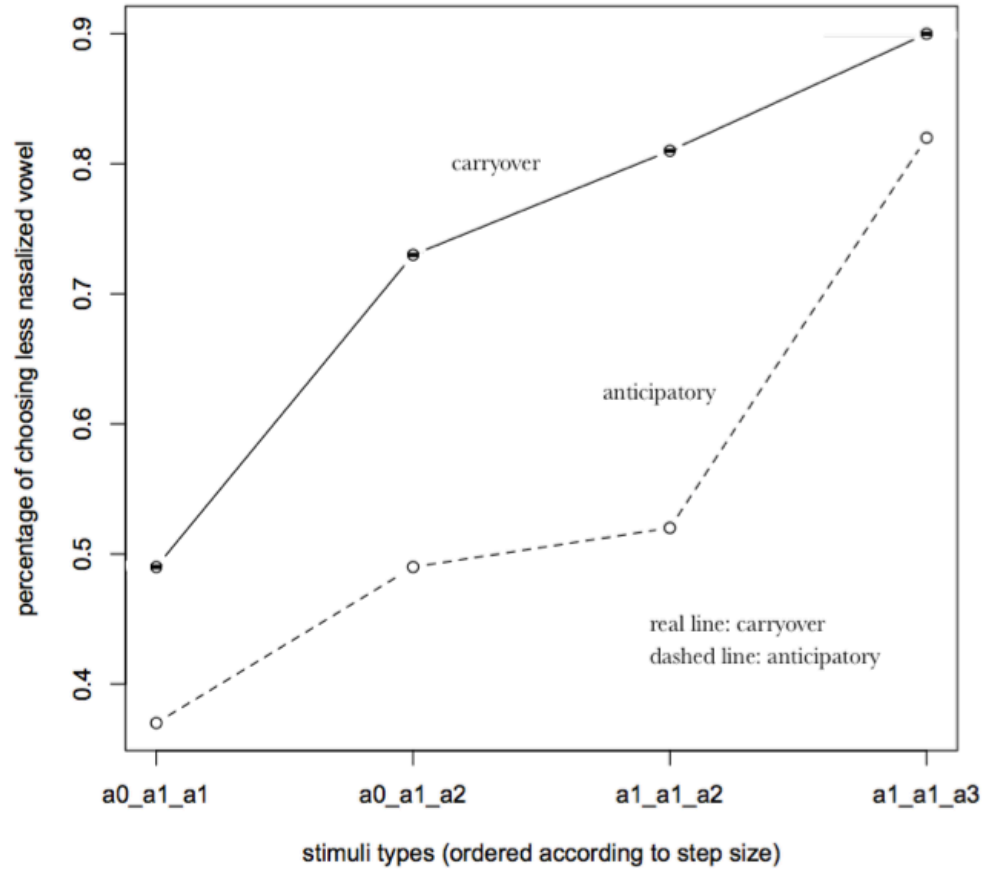
# 4. An AXB experiment



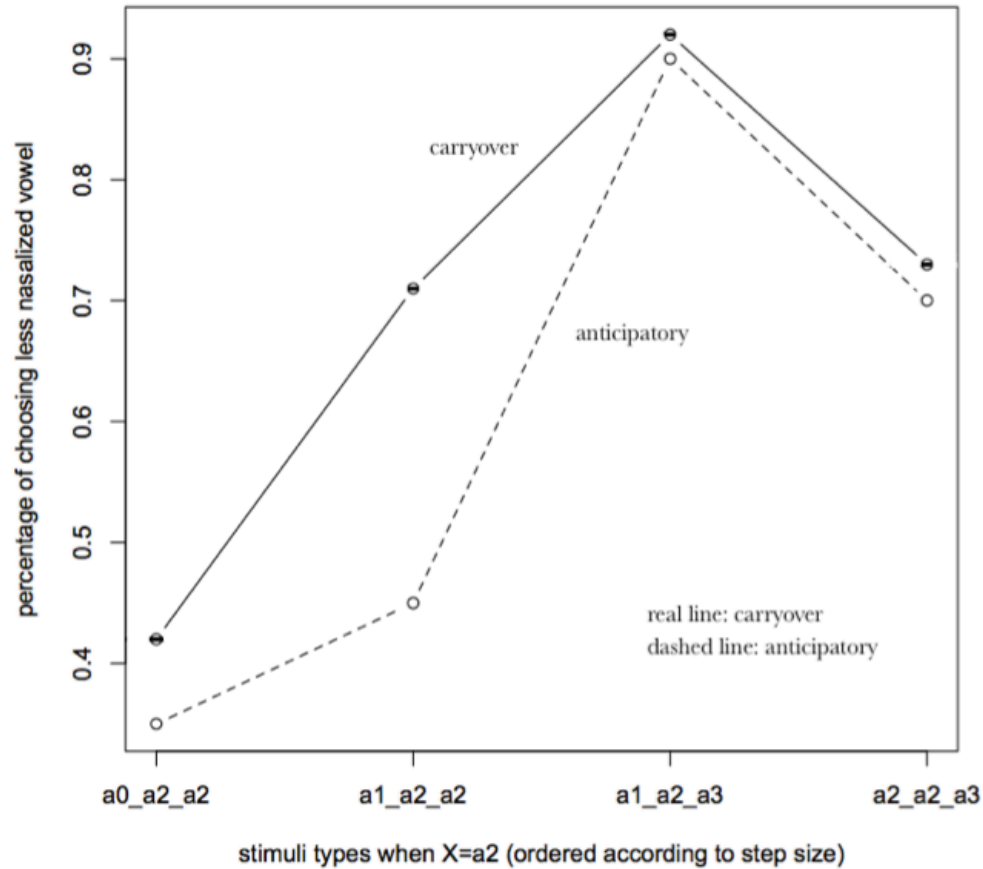
## 4. An AXB experiment

- 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 (The results converged to more than 80% of the time).
- 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.

# 4. An AXB experiment



# 4. An AXB experiment



# 4. An AXB experiment

- A logistic regression with
  - carryover vs. anticipatory, as well as the identity of A, B, X and step size as independent variables and
  - the number of choosing the less nasalized vowel token as the dependent variablewas conducted.
- The result showed that carryover/anticipatory distinction was a highly significant factor ( $p < 0.001$ ), as well as the identity of A, B, X and 0-2 step size.

## 4. Conclusion

- Carryover nasalization seems to be the default and extensive form of coarticulation in many languages, paradoxically because it is so seldom noticed.
- Anticipatory nasalization is initially more language-specific, usually happening from chance occurrence, but it is nonetheless more easily developed into categorical, phonological patterns because it is perceptually more salient.



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