In Defence of Structure: Phonotactics in Hindi

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Introduction

- Over the past two decades, a body of research has strived to reduce the role of hierarchical representations in phonology.
- Syllables have been abandoned by some scholars (e.g., Steriade 1999), in favour of an approach where segments are ordered to maximize their perceptibility (e.g., Wright 2004).
- We motivate a **structured approach** to the syllable, drawing on data from Hindi. We show that:
  - Phonetically similar strings respect different phonotactic constraints which, in turn, motivates different syllabifications;
  - The same surface string can be subject to alternative syllabifications.
- **Our focus:** Consonant + Approximant + Vowel (CAV) strings.

Phonotactics of CAV strings

- Phonotactic constraints regulate the shapes of syllable constituents (e.g., Selkirk 1982, Steriade 1988, Goldsmith 1990, Harris 1994).

- In languages that permit CAV strings, two (or more) analyses are observed, based on phonotactics – sonority and place constraints that hold between C and A or between A and V:

  - More constraints hold between C and A when CA forms a branching onset than when a constituent boundary interrupts C and A (i.e., when A forms a diphthong with V).

  - More constraints hold between A and V when AV forms a diphthong than when a constituent boundary interrupts A and V (i.e., when A forms a branching onset with C).

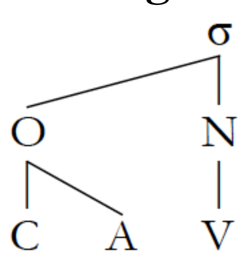
Phonotactics of CAV strings

Branching onset (1a):
- Liquid forms branching onset with preceding C (Germanic, Romance, etc.; Clements 1990);
- Glide forms branching onset with preceding C (English [w]; Davis & Hammond 1995).

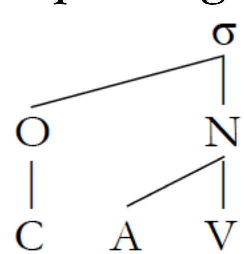
Diphthong (1b):
- Glide forms diphthong with following V (Spanish [w, j]; Harris 1983);
- Liquid forms diphthong with following V (Vata [l]; Kaye 1985).

Dual representation (1c):
- Proposed for English [j] (Anderson 1986, Giegerich 1992); French [j] (Klein 1991, 1993).

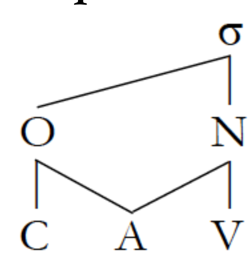
(1) a. **Branching onset:**



b. **Diphthong:**



c. **Dual representation:**



Proposal for CAV in Hindi

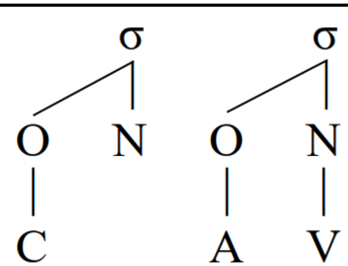
Initial and medial positions: Phonotactic constraints motivate all three representations in (1), depending on type of A:

Branching onset (1a)	Diphthong (1b)	Dual representation (1c)
[l]	[j]	[w]
[r]	$[r_i]$	

$[r_i]$ is rhotic in loanwords from Sanskrit (only occurs before [i])

Medial position: Additional representation required:

Empty nucleus between C and A:



What data count for Hindi?

- Hindi lexicon is categorized into native vocabulary and loanwords from three sources: Sanskrit, Perso-Arabic (Persian, Arabic, Turkish), and English (Ohala 1983);
- Loanwords are common and can include clusters not present in the native vocabulary;
- Clusters that are borrowed are generally not repaired via epenthesis (cf. Hyman 1970 on Hausa borrowings in Nupe) or deletion (cf. Yip 1993 on English borrowings in Cantonese),
  - although individual segments may be adapted (e.g. English ‘fuse’ → [p^hjuːz]);
- Loanwords are integrated into Hindi to different degrees (consistent with Haspelmath 2009).

What data count for Hindi?

- We organize CA sequences into three categories: productive, marginal, illicit.

Productive:

- Hindi speakers can coin new words following the same patterns (e.g., Hyman 1970, Mohanan 1986, Haspelmath 2009), even patterns for non-native words;
- These words are judged by other native speakers to be well-formed.

Marginal vs. illicit:

- Native speakers may judge one cluster to be 'worse' than another along a gradient of well-formedness (Hayes & Wilson 2008);
- The marginality of a cluster may be affected by how frequently it appears in items in the lexicon (Davidson 2006);
- Ohala (1983) treat clusters in Hindi as not well-formed if they appear in only one or two words.
- Our analysis focuses on **productive** CAV strings only.

CAV in initial position
Sonority constraints between C and A

When A = [l, r, w] (2a):

- Onset head (C) must be obstruent, a constraint that holds of branching onsets in most languages (e.g., Kaye, Lowenstamm & Vergnaud 1990);
- If C is higher in sonority (e.g., nasal), cluster is ill-formed.

When A = [r_i, j] (2b):

- This constraint does not hold;
- C can be nasal, consistent with there being a constituent boundary between C and A (i.e., [r_i, j] are in the nucleus).

(2) a. **Consistent with branching onset analysis:**

A = [l]		A = [r]		A = [w]	
[pliːhaː]	'spleen'	[krodʰ]	'anger'	[twətʃaː]	'skin'
*mlV		*mrV		*nwV	

b. **Consistent with diphthong analysis:**

A = [r_i]		A = [j]	
[krijaː]	'act'	[kjũːki]	'because'
[mrig]	'deer'	[mjaːn]	'sheath'

CAV in initial position
Place constraints between C and A

When A = [l, w] (3a):

- Place agreement between C and A is not permitted;
- Consistent with CA forming a branching onset when A = [l, w].

When A = [j] (3b):

- This constraint does not hold;
- Consistent with there being a constituent boundary between C and A when A = [j].

[r, r_j] are set aside because rhotics seemingly never enter into place constraints in branching onsets, across languages.

(3) a. **Consistent with branching onset analysis:**

A = [l]	A = [w]
*tlV	*pwV
	*kwV

b. **Consistent with diphthong analysis:**

A = [j]

[tjohaːr]	'festival'
[ʧjəwənpraːʃ]	'ayurvedic jam'

CAV in initial position
Place constraints between A and V

When A = [l, r] (4a):

- No constraints hold between A and V;
- Consistent with branching onset analysis.

When A = [r_i, j] (4b):

- Constraints on front/back dimension hold between A and V;
- Consistent with AV forming a diphthong.

When A = [w] (4b):

- Surprisingly, [w] patterns with [j], not with [l, r].

(4) a. **Consistent with branching onset analysis:**

A = [l] can be followed by any V	A = [r] can be followed by any V

b. **Consistent with diphthong analysis:**

A = [r_i] followed by [i] only	A = [j] followed by back or central vowel only	A = [w] followed by front or central vowel only

CAV in initial position
Interim summary

- Phonotactic constraints motivate three representations for initial CAV in Hindi:

A	Sonority: CA	Place: CA	Place: AV	Analysis
[l]	✓	✓		branching onset
[r]	✓	NA		branching onset
[w]	✓	✓	✓	dual representation
[r_i]			✓	diphthong
[j]			✓	diphthong

CAV in medial position
Phonotactically expected patterns

- For CAV in medial position, phonotactic constraints seemingly parallel those seen for initial position.

(5) **CA constraints**:

a. **Consistent with branching onset analysis:**

	A = [l]	A = [r]	A = [w]
Sonority:	[kaːkliː] ‘melodious tune’	[wipriːt] ‘opposite’	[widwa:n] ‘oar’
	*VmlV	*VmrV	*VnwV
Place:	*VtlV	NA	*VpwV

b. **Consistent with diphthong analysis:**

	A = [r_i]		A = [j]	
Sonority:	[bhuːpriʃt]	‘surface of the earth’	[upjogiː]	‘useful’
	[amrit]	‘drink of the gods’	[kaːmjaːb]	‘successful’
Place:	NA		[udjamiː]	‘entrepreneur’

CAV in medial position
Phonotactically unexpected patterns

When A = [l, r, w]: Find unexpected patterns for branching onset analysis:

- Sonority: C can be nasal (6);
- Place: C and A can agree in place (7).

(6) **Sonority**:

A = [l]	A = [r]	A = [w]
[imliː] ‘tamarind’	[ʤʰumraː] ‘blacksmith’s tool’	[tənwiː] ‘slender girl’

(7) **Place**:

A = [l]	A = [r]	A = [w]
[mətləb] ‘meaning’	NA	[əpwaːd] ‘exception’

Previous analyses (Ohala 1983, 1999, Pierrehumbert & Nair 1996):

- CA strings in (6)-(7) are coda+onset.

Problem:

- This analysis does not respect cross-linguistic sonority constraints for coda+onset clusters (e.g., Vennemann 1988).

CAV in medial position
Phonotactically unexpected patterns

- Phonotactically unexpected strings can optionally have schwa between C and A (Ohala 1983);
- Schwa assumed to be in UR.

(8) **Schwa-Ø ‘alternations’:**

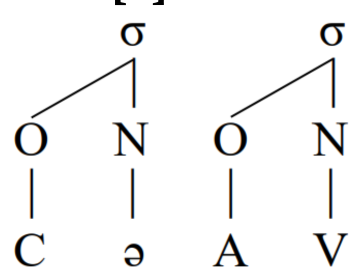
[iməliː] ~ [imliː]   [ʤ^{h}uməraː] ~ [ʤ^{h}umraː]   [tənəwiː] ~ [tənwiː]

[mətələb] ~ [mətləb]   [əpəwaːd] ~ [əpwaːd]

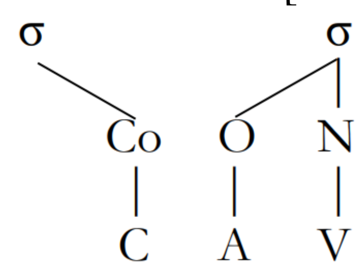
Consequence of Ohala’s analysis:

- Forms with [ə] and without [ə] have different syllabifications:

(9) a. **Onset+[ə]+onset:** [iməliː]



b. **Coda+onset**: [imliː]



CAV in medial position
Phonotactically unexpected patterns

Expanding the dataset:

- Some CA strings with the phonotactic profile of branching onsets can also have optional schwa:

(10) **More schwa-Ø alternations:**

A = [l]	A = [r]	A = [w]
[tak(ə)liːf] 'difficulty'	[gʰaːgʰ(ə)raː] 'long skirt'	[pət(ə)waːr] 'oar'

Ohala (1999):

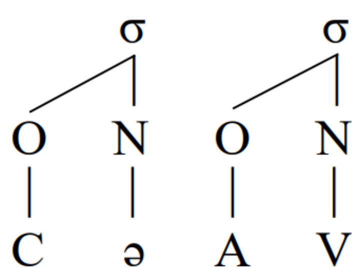
- In elicited production task, participants inserted a pause between C and A, not before CA, in strings with falling, flat or rising sonority;
- Ohala (1999) concludes that when /CəA/ strings surface without schwa, they are coda+onset, regardless of their phonotactic profile.

CAV in medial position
Motivating empty nuclei

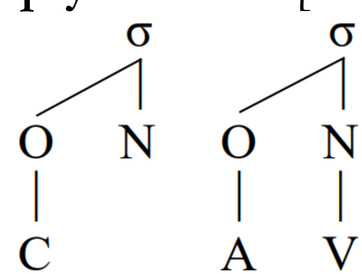
Our analysis:

- We argue that the coda+onset analysis cannot be motivated for CA strings with optional schwa.
- We propose instead that the forms where [ə] is present or absent have the same representation.

(11) a. **Filled nucleus:** [iməliː], [takəliːf]



b. **Empty nucleus:** [imliː], [takliːf]



Arguments for empty nucleus analysis:

1. Phonotactics (as discussed)
2. Stress
3. Duration

Experiment 1
Pilot study on stress

Stress in Hindi:

- Sensitive to three weight profiles (Kelkar 1968, Pandey 1989; Hussain 1997 for Urdu):
  CVXC > CVX > CV
- Stress falls on heaviest syllable that is rightmost in the word, excluding final syllable (unless it is CVXC) (Kelkar 1968, Pandey 1989, Hussain 1997).
- Window in which stress is assigned is four syllables (Hayes 1995, Kager 2012; cf. Pandey 1989 who proposes a three-syllable window).

(12) **When alternating schwa is overt, it is skipped for stress:**

['titliː] ~ ['titəliː] 'butterfly'

Questions:

In words shaped [CVX.CVC(ə).AVX] with optional schwa as penultimate vowel, if schwa is not produced:

- Will stress fall on **penult**? If CA is coda+onset, penult will be rightmost visible heaviest syllable: [CVX.'<u>CVC</u>.AVX]
- Will stress fall on **preantepenultimate**? If CA has empty nucleus between C and A, preantepenult will be rightmost visible heaviest syllable: ['<u>CVX</u>.CV.CØ.AVX]

Experiment 1
Pilot study on stress

Task:

- Production of 8 novel orthographically-presented schwa-Ø alternating words (schwa was orthographically expressed, as appropriate for Devanagari script).

Participants:

- Five native speakers of Western varieties of Hindi.

Sample stimuli:

कोन्देतली	[kondet(ə)liː]
किर्बुतवा	[kirbut(ə)waː]

Possible stress locations:

a. Coda+onset analysis: [kon.ˈdet.liː]
[kir.ˈbut.waː]

b. Empty nucleus analysis: [ˈkon.de.tØ.liː]
[ˈkir.bu.tØ.waː]

Our prediction:

- Stress will fall on preantepenult, as this will be the rightmost visible heaviest syllable.

Results:

- In fast speech, words were produced both with and without schwa.
- Productions without schwa had stress on preantepenult 92% of the time.
- This is consistent with the syllabification we assume.
- But maybe schwa deletion triggers resyllabification of CL as branching onset (e.g. [ˈkon.de.tliː]).

Experiment 2
Production study on medial CL strings

Questions:

- Are there duration differences in L, medial C and preceding V in branching onset (CV.CLV) strings vs. empty nucleus (CV.CØ.LV) strings?
- If the relative durations are different, are the latter strings truly represented with an empty nucleus (CV.CØ.LV) or could they instead be coda+onset (CVC.LV)?

Task:

- Participants see a word written in Devanagari script, along with a related image; they are asked to read the word to themselves.
- When they proceed to the next screen, the image is still present, but the written word is not; they are asked to say the word out loud.

Participants:

- Nine native speakers of Western varieties of Hindi.

Stimuli:

- 22 bisyllabic words with medial CL strings.
- Two conditions:
    - CL is branching onset: CV.CLV (e.g., [ʧəkriː] 'wheel')
    - CL has intervening empty nucleus: CV.CØ.LV (e.g., [bəkriː] 'goat')

Experiment 2
Production study on medial CL strings

Mixed-effects linear regression (Bates et al. 2015) in R (R Core Team 2024)

Dependent variables:

• Duration of liquid	L_dur
• Duration of preceding C	C_prec_L_dur
• Duration of V in preceding syllable	V_prec_C_dur

Predictors:

• Predicted type of syllabification: BO (branching onset) vs. NotBO (empty nucleus)	syl_c
• Identity of liquid	liq_c
• Phonemic length of pre-cluster vowel	longV_c

Random effects:

- Random intercept for participant
- Random intercept for liquid
- Random slope for predicted syllabification type by participant

Experiment 2
Predictions

Prediction 1:

- L in branching onsets should be shorter in duration than in strings with intervening empty nucleus since the two consonants are internal to the same constituent only in the former case:

  CV.CLV < CV.CØ.LV

Prediction 2:

- Medial C in branching onsets should be shorter in duration than in strings with intervening empty nucleus since the two consonants are internal to the same constituent only in the former case:

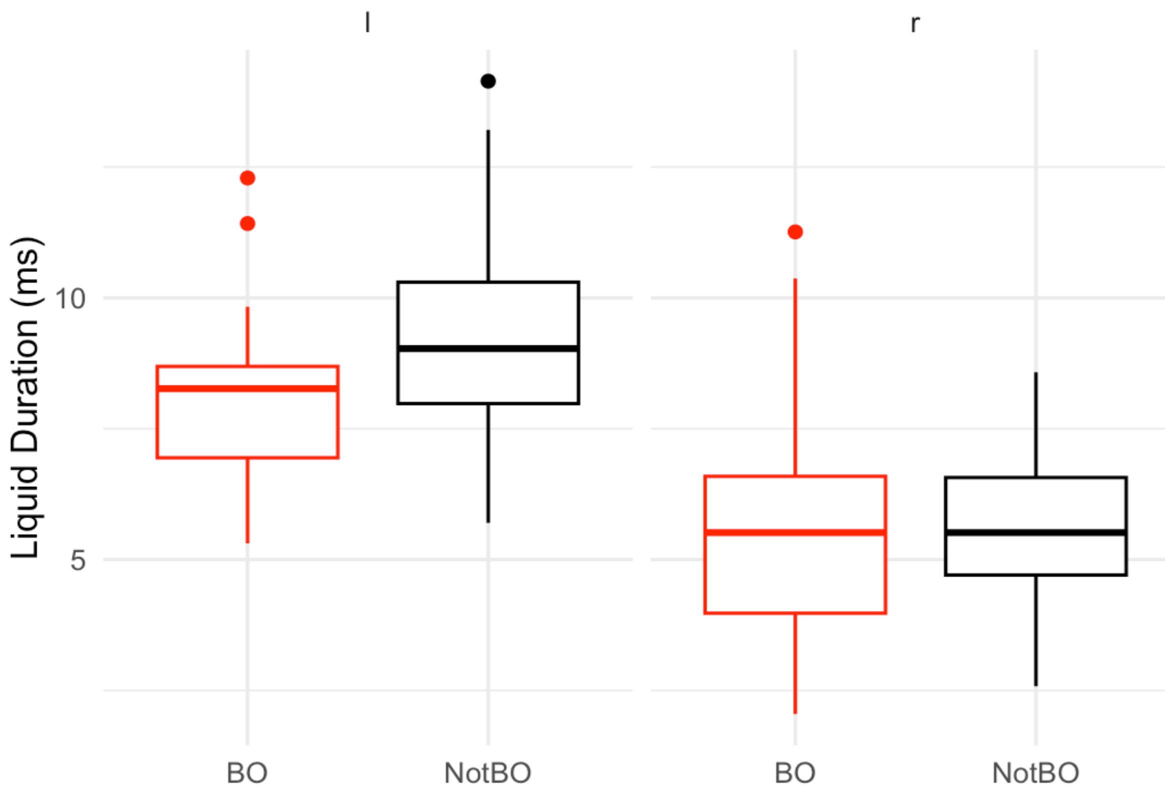
  CV.CLV < CV.CØ.LV

Prediction 3:

- V preceding branching onsets and strings with intervening empty nucleus should not differ in duration since they are both in open syllables:

  CV.CLV ≈ CV.CØ.LV

Results: Duration of L

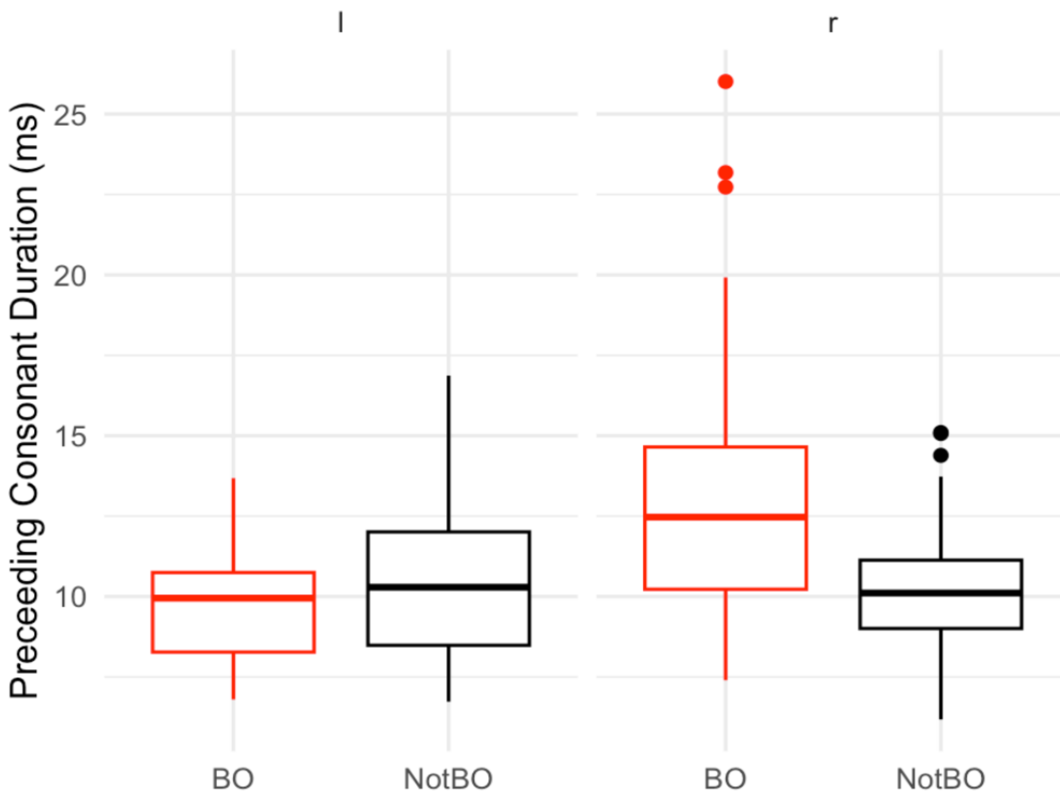


Predictors	Estimates	Confidence Intervals	p
Intercept	6.85	6.19 – 7.51	<0.001
Syll condition	**-0.23**	**-0.45 – -0.01**	**0.040**
Liq condition	1.59	1.18 – 2.01	<0.001
Long V condition	-0.09	-0.30 – -0.13	0.420

L is shorter in BO than in NotBO

- Consistent with Prediction 1

Results: Duration of C preceding L

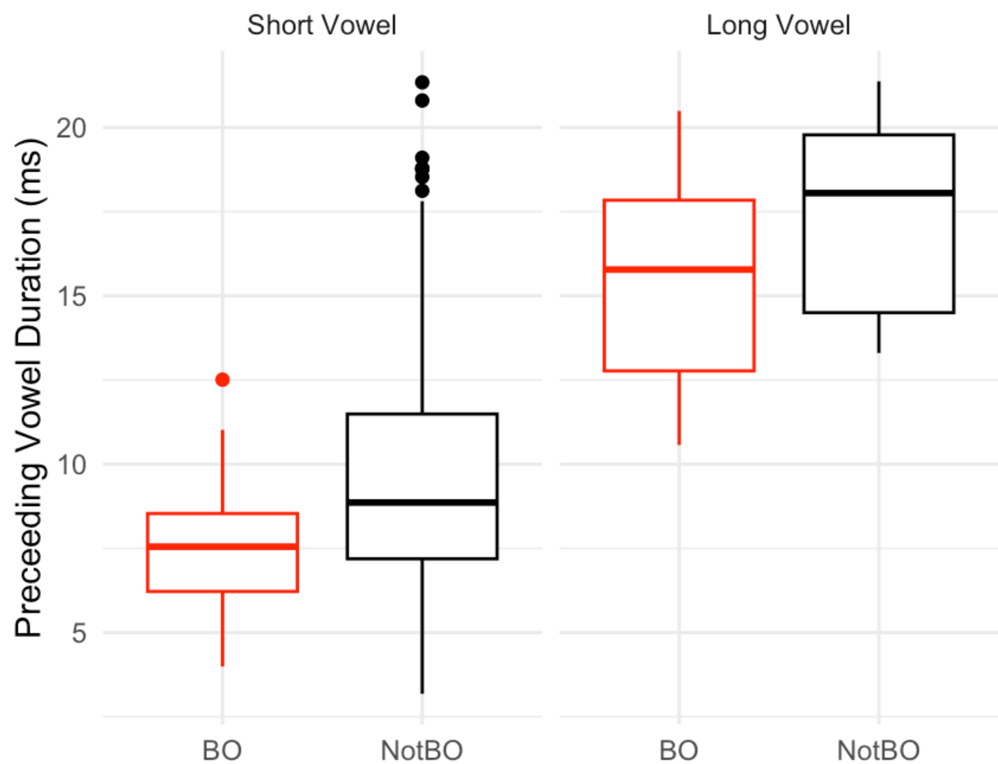


Predictors	Estimates	Confidence Intervals	p
Intercept	11.21	9.98 – 12.43	<0.001
Syll condition	**1.14**	**0.54 – 1.74**	**<0.001**
Liq condition	-0.48	-0.80 – -0.16	0.003
Long V condition	-0.90	-1.24 – -0.56	<0.001

C preceding L is shorter in notBO than in BO

- Inconsistent with Prediction 2

Results: Duration of V preceding CL



Predictors	Estimates	Confidence Intervals	p
Intercept	10.66	9.44 – 11.88	<0.001
Syll condition	**-1.18**	**-1.65 – -0.71**	**<0.001**
Liq condition	0.03	-0.41 – 0.46	0.900
Long V condition	3.25	2.79 – 3.71	<0.001

V preceding CL is shorter in BO than in notBO

- Inconsistent with Prediction 3

Experiment 2
Questions revisited

- Are there duration differences in L, medial C and preceding V in branching onset (CV.CLV) strings vs. empty nucleus (CV.CØ.LV) strings?
  - all three segments differ in duration across the two types of strings, consistent with different syllabifications for each.

- If the relative durations are different, are the latter strings truly represented with an empty nucleus (CV.CØ.LV) or could they instead be coda+onset (CVC.LV)?
  - coda+onset parse is inconsistent with preceding vowel duration: it should be longer in CVC.LV than in CV.CLV.

Conclusion

- We have proposed four representations for CAV strings in Hindi:
  - CA forms branching onset;
  - AV forms diphthong;
  - A is simultaneously part of branching onset and diphthong (dual representation);
  - C and A are separated by empty nucleus.

- Evidence for alternative representations comes from:
  - phonotactic constraints on sonority and place;
  - stress placement from pilot study;
  - duration of segments from production task on medial CL strings.

- Alternative representations cannot be predicted based on type of approximant: glide vs. liquid.
- Our analysis motivates an approach to syllabification that is both structured and abstract.

Thank you!

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References

Anderson, J.M. (1986). Suprasegmental dependencies. In J. Durand (ed.), *Dependency and non-linear phonology.* London: Croom Helm, pp. 55-133.

Bates, D., M. Mächler, B. Bolker & S. Walker (2015) Fitting Linear Mixed-Effects Models Using lme4. *Journal of Statistical Software* 67(1): 1-48.

Clements, G.N. (1990). The role of the sonority cycle in core syllabification. In J. Kingston & M.E. Beckman (eds.), *Papers in Laboratory Phonology I: Between the grammar and physics of speech.* Cambridge: CUP, pp. 283-333.

Davidson, L. (2006). Phonology, phonetics, or frequency: Influences on the production of non-native sequences. *Journal of Phonetics* 34: 104-137.

Davis, S., & M. Hammond (1995). On the status of onglides in American English. *Phonology* 12: 159-182.

Goldsmith, J. (1990). *Autosegmental and metrical phonology.* Oxford: Blackwell.

Giegerich, H. (1992). *English phonology: An introduction.* CUP

Harris, J. (1994). *English sound structure.* Oxford: Wiley-Blackwell.

Harris, J.W. (1983). *Syllable structure and stress in Spanish: A nonlinear analysis.* Cambridge, MA: MIT Press.

Haspelmath, M. (2009). II. Lexical borrowing: Concepts and issues. In *Loanwords in the World's Languages: A Comparative Handbook.* Berlin: De Gruyter Mouton, pp. 35-54.

Hayes, B. (1995). *Metrical stress theory: Principles and case studies.* Chicago: University of Chicago Press.

Hayes, B. & C. Wilson (2008) A maximum entropy model of phonotactics and phonotactic learning. *Linguistic Inquiry* 39: 379-440.

Hussain, S. (1997). *Phonetic correlates of lexical stress in Urdu.* PhD thesis, Northwestern University.

Hyman, L.M. (1970). The role of borrowing in the justification of phonological grammars. *Studies in African linguistics* 1: 1-48.

Kager, R. (2012). Stress in windows: Language typology and factorial typology. *Lingua* 122: 1454-1493.

Kaye, J.D. (1985). On the syllable structure of certain West African languages. In D. Goyvaerts (ed.), *African linguistics: Essays in memory of M.W.K. Semikenke.* Amsterdam: John Benjamins, pp. 285-308.

Kaye, J.D., J. Lowenstamm & J.-R. Vergnaud (1990). Constituent structure and government in phonology. *Phonology* 7: 193-231.

References

Kelkar, A.R. (1968). *Studies in Hindi-Urdu. Volume 1: Introduction and word phonology.* Poona: Deccan College.

Klein, M. (1991). *Vers une approche substantielle et dynamique de la constituance syllabique: le cas des semi-voyelles et des voyelles hautes dans les usages parisiens.* PhD thesis, Université Paris VIII.

Klein, M. (1993). La syllabe comme interface de la production et de la réception phoniques. In B. Laks & M. Plénat (eds.), *De natura sonorum. Essais de phonologie.* Vincennes-Saint-Denis: Presses Universitaires de Vincennes, pp. 101-141.

Mohanan, K.P. (1986). *The theory of Lexical Phonology.* Dordrecht: Reidel.

Ohala, M. (1983). *Aspects of Hindi phonology.* Delhi: Motilal Banarsidass Publishers.

Ohala, M. (1999). The syllable in Hindi. In H. van der Hulst & N. Ritter (eds.), *The syllable: Views and facts.* Berlin: Mouton de Gruyter, pp. 93-112.

Pandey, P. K. (1989). Word accentuation in Hindi. *Lingua* 77: 37-73.

Pierrehumbert, J. & R. Nair (1996). Implications of Hindi prosodic structure. In J. Durand & B. Laks (eds.), *Current trends in phonology: Models and methods.* Salford, UK: University of Salford Press, pp. 549-584.

R Core Team (2024) R: A language and environment for statistical computing. Retrieved from http://www.R-project,org/

Selkirk, E.O. (1982). The syllable. In H. van der Hulst & N. Smith (eds.), *The structure of phonological representations, Part 2.* Dordrecht: Foris, pp. 337-383.

Steriade, D. (1988). Review of CV Phonology: A generative theory of the syllable. *Language* 64: 118-129.

Steriade, D. (1999). Alternatives to syllable-based accounts of consonantal phonotactics. In O. Fujimura et al. (eds.), *Proceedings of the 1998 Linguistics and Phonetics Conference.* Prague: Karolinum, pp. 205-242.

Vennemann, T. (1988). *Preference laws for syllable structure and the explanation of sound change: With special reference to German, Germanic, Italian, and Latin.* Berlin: Mouton de Gruyter.

Wright, R. (2004). A review of perceptual cues and cue robustness. In B. Hayes, R. Kirchner & D. Steriade (eds.), *Phonetically based phonology.* Cambridge: CUP, pp. 34-57.

Yip, M. (1993). Cantonese loanword phonology and optimality theory. *Journal of East Asian Linguistics* 2: 261-291.

Appendix: What data count for Hindi?

Stop+liquid (branching onset):

Constraints	V unrestricted			
			no [sg]	no/marginal [vce]+[sg]
	pl	bl	*phl	*bhl
	pr	br	*phr	?bhr
no place sharing	*tl	*dl	*thl	*dhl
	tr	dr	*thr	?dhr
no place sharing	*ṭl	*ḍl	*ṭhl	*ḍhl
no retroflex	??ṭr	??ḍr	*ṭhr	*ḍhr
no affricate	*čl	*ǰl	*čhl	*ǰhl
no affricate	*čr	*ǰr	*čhr	*ǰhr
	kl	gl	*khl	*ghl
	kr	gr	*khr	??ghr

Key:
Green = productive
Orange = illicit
Yellow = marginal

Appendix: What data count for Hindi?

Stop + [w] (dual representation):

Constraints	V restricted			
			no [sg]	no/marginal [vce]+[sg]
no place sharing	*pw	*bw	*phw	*bhw
	tw	?dw	*thw	??dhw
no retroflex	*ṭw	*ḍw	*ṭhw	*ḍhw
no affricate	*čw	??ǰw	*čhw	*ǰhw
no place sharing	??kw	??gw	??khw	*ghw

Key:
Green = productive
Yellow = marginal
Orange = illicit

Appendix: What data count for Hindi?

Stop + [j] (palatal glide in nucleus):

Constraints	V restricted			
			no [sg]	no~marginal [vce]+[sg]
	py	by	??phy	*bhy
	ty	dy	*thy	??dhy
no retroflex	*ṭy	*ḍy	*ṭhy	*ḍhy
no affricate	??čy	??ǰy	*čhy	*ǰhy
place sharing ok	ky	gy	??khy	*ghy

Key:
Green = productive
Orange = illicit
Yellow = marginal

Appendix: Novel words for Experiment 1: Pilot study on stress

सर्पतली	[sarpat(ə)liː]
खिल्पदला	[k^{h}ilpad(ə)laː]
कोन्देतली	[kondet(ə)liː]
किर्बुतवा	[kirbut(ə)waː]
सल्कतरी	[salkat(ə)riː]
बोम्पेकरा	[bompek(ə)riː]
देन्खोपला	[deŋk^{h}op(ə)laː]
रन्तपवा	[rantap(ə)waː]

Appendix: Liquid duration in Experiment 2