Optionality in Hindi schwa deletion: interaction between weighted prosodic constraints

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1 Introduction

Markedness theory (Trubetzkoy, 1939) defines the concept of markedness in terms of phonological reduction and neutralization processes. Specifically, the input of the process is considered to be more marked than the output and the application of the process has the functional implication of transforming an ill-formed structure into a well-formed one. This concept underlies one of the central assumptions of Optimality Theory; namely, the assumption that the violation of faithfulness constraints is tolerated in order to avoid the violation of (a) higher ranked/weighted markedness constraint(s). Given this assumption, there are three logical possibilities:

Assumption: Input is more ill-formed than output.

- Well-formedness process applies:

$$\Sigma\text{*M violations of Cand}_I{}^{1} > \Sigma\text{Faith \& *M violations of Cand}_O$$

- No well-formedness process applies:

$$\Sigma\text{Faith \& *M violations of }\neg\text{Cand}_I > \Sigma\text{*M violations of Cand}_I$$

- Well-formedness process applies optionally:

$$\Sigma\text{Faith \& *M violations of Cand}_O = \Sigma\text{*M violations of Cand}_I$$

In order for this model to work, we need to make two further assumptions:

(a) The weight of a constraint is a particular value rather than a normal distribution within a range.

(b) The weight of a constraint remains constant within a language speaking community.

[1] Cand_I : Output candidate that is identical to the Input, i.e. no faithfulness violation
Cand_O : Optimal output selected after evaluation
$\neg\text{Cand}_I$: Any output candidate that is not CandI

In this paper we study the particular case of a well-formedness process, namely schwa deletion in Hindi, and the contexts in which this process applies optionally. Ohala (1983) has noted that Hindi has a process of schwa deletion in morphologically derived environments, which applies optionally in some underived and derived environments. Pandey (1990) further observes that the schwa gets deleted from unstressed syllables if and only if the residual phonetic string forms a legitimate syllable structure in the language.

The paper is divided into four sections. The first section is a theoretical discussion on the process of schwa deletion in Hindi explaining why schwa is the only target of this process. The second section models the various scenarios that could result in optional deletion of schwa in Hindi. In each case, the candidate with the schwa should be as good in phonological structure as the candidate without schwa. In the third section we report the results of a small production experiment that was carried out to test the (optional) deletion of schwa. It shows that in the particular environment that we selected, the structure with the unstressed schwa was consistently better than that without the schwa, and it was not deleted. However, in a subset of these contexts where the schwa failed to delete, it surfaced with significant increase in F1 formant frequency. The last and final section of the paper presents a theoretical analysis of this observation.

2 Schwa Deletion in Hindi

The analysis of trans-derivational correspondence between derived words in Hindi reveals the deletion of unstressed /ə/ in polysyllabic words (1 and 2).

(1) a. pɪcək + -na ⟶ pɪcək-na flatten-INF
    b. pɪcək + -a ⟶ pɪck-a flatten-AGR

(2) a. cɪpək + -na ⟶ cɪpək-na stick -INF
    b. cɪpək + -a ⟶ cɪpk-a stick -AGR

When followed by a –CV and –V suffixes, the root surfaces a CVCVC and CVCC respectively.

2.1 Ill-formedness to well-formedness: What motivates vowel deletion?

Vowels being the sonority peak of syllables, the deletion of a vowel amounts to the deletion of a syllable. Consequently, it is possible if and only if the other non-deleted segments in the deleted syllable can be accommodated in the preceding or following syllables to produce a well-formed output. Thus, the phonological environments that (dis)allow vowel deletion can be theoretically deduced from the phonological grammar and need not be listed.

The Syllable Minimization Principle, presented in Selkirk et al. (1981) captures the theoretical insight that there is a phonological cost to word length, and a universal preference for minimizing the number of syllables. This cost has been translated into the form of a gradient constraint *STRUC (σ) by Zoll (1993, 1994, 1996) to form a universal constraint that incurs one violation for each syllable in the output candidate.

(3) *STRUC (σ)

a. ¬∃x (Syllable (x))

b. Assess one mark for each value of (x) for which (a) is false

c. Effect: Minimise syllables

Since all well-formed phonological outputs will have to contain at least one syllable, this constraint is never fully satisfied. Its theoretical utility is to express the idea that increasing the number of syllables decreases phonological well-formedness and vice-versa. We propose that the vowel deletion in Hindi is triggered by the phonological effort to minimise the number of syllables.

If syllable minimization is the objective, then it is expected that the language will project exactly as many syllables as will be necessary to parse every input segment into a well-formed output prosody. In order to evaluate the prosodic well-formedness, we use the concept of Sonority Sequencing Principle, henceforth SSP. The observation that the sonority of segments within a syllable rises towards the nucleus and falls towards the margins has a long history that extends at least as early as Sievers (1881). In this paper, SSP is formalized as a markedness constraint since it evaluates the output candidates with respect to syllable structure, and the input lacks syllable structure. We do not assign syllabic structure to the input representation because:

a. Following Chomsky & Halle (1965) unpredictable information needs to be encoded in the lexical input, while all predictable information should follow from the model of grammar. Syllabification is both universal as well as predictable, and therefore need not be lexically encoded.

b. b. Following the argument of Inkelas (1994), input strings with syllabification would incur more faithfulness violations than those without and therefore by the principle of Lexicon Optimization in Smolensky & Prince (1993), the latter will be posited as input representations.

Thus, SSP maps the relative sonority of immediately adjacent segments in the output string with respect to the syllable structure and incurs a violation if it is not in consonance with the sonority sequencing principle.

(4) SSP For any two string adjacent elements α and β, if the relative sonority of α is greater than β, then β precedes α in the first demisyllable and α precedes β in the second demisyllable.

The application of SSP allows for the input/base in examples (1a, b) to be configured as either /pick/ or /picək/. By Richness of the Base, we have considered the base to be /pick/ in Table 1 and /picək/ in Table 2 respectively.

Table 1 A				
[pick]+[-na]		SSP	IDENT-IO	*STRUC(σ)
	a. pic.kna	*!		**
	b. pick.na	*!		**
☞	c. pi.cək.na		*	***

Table 1 B				
[pick]+[-a]		SSP	IDENT-IO	*STRUC(σ)
☞	a. pic.ka			**
	b. pick.a	*!		**
	c. pi.cə.ka		*!	***

Table 2 A				
[picək]+[-na]		SSP	IDENT-IO	*STRUC(σ)
	a. pic.kna	*!	*	**
	b. pick.na	*!	*	**
☞	c. pi.cək.na			***

Table 2 B				
[picək]+[-a]		SSP	IDENT-IO	*STRUC(σ)
☞	a. pic.ka		*	**
	b. pick.a	*!	*	**
☞	c. pi.cə.ka			***

The faithfulness violations in Table 1 are DEP violations where the vowel /ə/ is inserted in order to syllabify the sequence of c-k-n. In contrast the faithfulness violations in Table 2 are MAX violations incurred due to the deletion of /ə/. Both these analyses are theoretically compatible with the Hindi data, though these have been largely described in phonological literature as a process of schwa deletion. Further, ranking faithfulness equal to *STRUC in this standard OT analysis results in the candidates (a) and (c) being evaluated as equally good in Table 2B, but not in the case of 1B. We will return to a discussion of these in §2 where we discuss optionality.

2.2 What prevents non-schwa from deleting?

Hindi has ten oral vowels contrasting in height, backness/roundness and length/weight. These are as follows.

	Sound		Relevant features
a.	/i/	⟹	[+High, +Front, 1μ]
b.	/i:/	⟹	[+High, +Front, 2μ]
c.	/u/	⟹	[+High, +Back, +Round, 1μ]
d.	/u:/	⟹	[+High, +Back, +Round, 2μ]
e.	/e/	⟹	[-High, +Front, 1μ]
f.	/o/	⟹	[-High, +Back, +Round, 1μ]
g.	/a/	⟹	[+Low, -Round, 2μ]
h.	/ɛ/	⟹	[-High, +Front, 2μ]
i.	/əo/	⟹	[-High, +Back, 2μ]
j.	/ə/	⟹	[-High, -Front, -Back, -Round, 1μ]

Table 1: Hindi Oral Vowels

All the vowels with the exception of schwa are peripheral vowels with at least one positive distinctive feature. Assuming schwa to be underspecified for place features would entail that the insertion or deletion of schwa would not incur violation of place faithfulness constraints. Thus, the fact that only schwa participates in this deletion process entails the following:

Table A

Input with [i]	IDENT PLACE	*M	IDENT-IO
a. Cand. with i		*	
b. Cand. without i	*!		*

Table B

Input with [ə]	IDENT PLACE	*M	IDENT-IO
a. Cand. with ə		*!	
b. Cand. without ə			*

The lack of place features on schwa prevents candidate (b) in Table B incurring a faithfulness violation of IDENT PLACE while the candidate (b) in Table A is blocked by the crucial violation of IDENT PLACE. This result follows from the concept of Preservation of the Marked (De Lacy, 2004). However, unlike de Lacy we do not use faithfulness constraints with a harmonic scale. Rather, our constraint configuration is similar to the Positional Faithfulness analysis of Lombardi (1999). The positionally parameterized faithfulness constraint, ranked higher than the markedness with the general faithfulness constraint ranked lower produces the effect of neutralization/reduction processes targeting weak positions. Similarly, the faithfulness constraint parameterized with place feature ranked higher the *M with the general faith ranked lower produces the effect of blocking deletion in all vowels except schwa, the only vowel that is underspecified for place.

2.3 Harmonic grammar analysis of schwa deletion

Harmonic Grammar (Pater, 2008) differs from standard OT in two respects. First, instead of ranking the constraints with respect to each other, they are assigned relative weights. Thus the impact of multiple violations of a lower weighted constraint can surpass the single violation of a higher weighted constraint in harmonic grammar. Second, the evaluator calculates the harmonic value of each candidate as the summation of the product of weight of constraint and its violations. The candidate with the highest harmonic value is then selected as the optimal candidate.

Tables 1 and 2 from section 1.1 have been repeated below to produce somewhat different predictions in the theoretical framework of Harmonic Grammar.

Table 3 A

[pick]+[-na]	SSP	IDENT-IO	*STRUC(σ)	H
Weights	3	1	1.5	
a. pic.kna	-1		-2	-6
b. pick.na	-1		-2	-6
☞ c. pi.cək.na		-1	-3	-5.5

Table 3 B

[pick]+[-a]	SSP	IDENT-IO	*STRUC(σ)	H
Weights	3	1	1.5	
☞ a. pic.ka			-2	-3
b. pick.a	-1		-2	-6
c. pi.cə.ka		-1	-3	-5.5

Table 4 A

[picək]+[-na]	SSP	IDENT-IO	*STRUC(σ)	H
Weights	3	1	1.5	
a. pic.kna	-1	-1	-2	-7
b. pick.na	-1	-1	-2	-7
☞ c. pi.cək.na			-3	-4.5

Table 4 B					
[picək]+[-a]		SSP	IDENT-IO	*STRUC(σ)	H
Weights		3	1	1.5	
☞	a. pic.ka		-1	-2	-4
	b. pick.a	-1	-1	-2	-7
	c. pi.cə.ka			-3	-4.5

Table 3 and 4 correspond to the tables 1 and 2 in section 1.1. However, unlike Table 2B, in Table 4B there is no optionality, and Tables 4A and 4B produce outputs identical to Tables 3A and 3B. Thus, weighted constraints allow us to model the context of non-optional schwa deletion which the ranked constraints failed to do.

3 Optionality in Schwa deletion

The Hindi data as presented in Ohala (1983) shows that the process of schwa deletion in Hindi is optional in some cases but obligatory elsewhere. Pramod Pandey (personal conversation in 2019) however maintains that rather than being lexically specified, the process is optional in all words if one looks at the entire Hindi speaking area and across all kinds of pragmatic contexts. We interpret this observation in conjunction with the earlier observation in Pandey (1990) that schwa only deletes from unstressed syllables in Hindi, to hypothesise that optional stress placement in different pragmatic/morpho-syntactic contexts could contribute to the optionality of schwa deletion.

Nevertheless, the theoretical issue of modelling multiple optional output candidates with the same grammar remains. In this section we discuss two more factors which could contribute to the optionality of the schwa deletion process in Hindi.

3.1 Bisyllabicity bias

The cases of optional schwa deletion listed in Ohala (1983) are mostly cases of trisyllables alternating with disyllables.

(5) a. ɟjot̪.sna ~ ɟjot̪.sə.na ‘moonlight’
b. us.t̪ra ~ us.t̪ə.ra ‘razor’
c. wjəw.har ~ wjə.wə.har ‘behaviour/use’

In metrical phonology, the bias towards building rhythmic contrast between contiguous syllables in a prosodic string has been encoded as a well-formedness condition. Formally, tracing its origin from Prince (1980), Kager (1989, 2007), and Smolensky & Prince (1993), it is defined as follows:

(6) Ft-Bin: Feet are binary under moraic or syllabic analysis.

Similarly, the idea that words with even number of syllables are considered prosodically better than those with odd number of syllables, follows from this requirement of foot binarity. However, it had been independently observed as a well-formedness bias by Hayes (1980) and Halle & Vergnaud (1987). Smolensky & Prince (1993) use the markedness constraint PARSE-SYL to formalize this idea. This constraint incurs a violation for every syllable output candidate that is left unparsed into foot-structure.

(7) Parse-Syl(σ)
   a. ¬∃x(Syllable(x) and Unparsed (x))
   b. Assess one mark for every case where (a) is false.
   c. Effect: Maximize building of foot structure from syllabic structure.

Thus, the observation, that the string of phonological segments is structured into hierarchical prosodic levels of syllable, foot and prosodic word, has been theorized in the Strict Layering Hypothesis in Selkirk (1980, 1986). It has also been noted that these prosodic domains are edge oriented and are built either from the right or left edge of the string. In OT this notion of aligning a prosodic domain to a particular edge of the phonological string is denoted using the formal mechanism of Generalized Alignment (McCarthy & Prince, 1993).

(8) Align (Cat1, Edge1, Cat2, Edge2)
   a. ∀ Cat1 ∃ Cat2 such that Edge1 of Cat1 and Edge2 of Cat2 coincide.
   b. Cat1, Cat2 ∈ Prosodic Category ∪ Grammatical Category
   c. Edge1, Edge2 ∈ Right, Left

Following the stress allocation rules in Hindi from Pandey (1990), we deduce that in the case of Hindi the foot is aligned to the right edge of the prosodic word. This implies that every foot that is not aligned to the right edge of the prosodic word incurs violation marks equal to the number of syllables that intervene between the right edge of the prosodic word and the right edge of the foot. In this paper we will use it in the following format:

(9) Align-Ft-R
   a. ∀ Feet ∃ Prosodic word such that the Right edge of the Foot and the Prosodic word coincide.
   b. Effect: Build one feet.

Further, there is also a restriction on two consecutive stressed or two consecutive unstressed syllables. These are encoded as *CLASH and *LAPSE in Optimality Theory. In pre-OT literature this had been observed and incorporated into a number of theoretical frameworks such as Auto-segmental phonology and Metrical Phonology (Goldsmith, 1976; Liberman, 1975; Prince & Liberman, 1977; Hammond, 1984; Selkirk, 1984; Kager, 1992, 1995).

(10) *Clash

a. ¬∃xy[[Syllable(x) and stressed (x)] and [Syllable(y) and stressed (y)] and Adjacent (xy)]

b. Assess one mark for every case where (a) is false.

c. Effect: No adjacent syllables are stressed.

(11) *Lapse

a. ¬∃xy[[Syllable(x) and unstressed (x)] and [Syllable(y) and unstressed (y)] and Adjacent (xy)]

b. Assess one mark for every case where (a) is false.

c. Effect: No adjacent syllables are unstressed.

If we add these constraints to our Harmonic Grammar from section 1.3 and implement it for the data in (5a), we get the following results:

Table 5 A

ɟjot̪sna	ID-IO	PARSE-SYL	*STRUC(σ)	FT-BIN(σ)	*CLASH	*LAPSE	ALN-FT-R	H
Weights	20	20	5	5	5	2.5	2.5	
☞ a. (**ɟjot̪**.sna)[2]			-2					-10
💣 b. (**ɟjot̪**).(**sə**.na)	-1		-3	-1	-1		-2	-50
c. (**ɟjot̪**).(sə.na)	-1	-1	-3			-1	-1	-55
d. **ɟjot̪**.(**sə**.na)	-1	-1	-3					-50

Table 5 B

ɟjot̪sna	ID-IO	PARSE-SYL	*STRUC(σ)	FT-BIN(σ)	*CLASH	*LAPSE	ALN-FT-R	H
Weights	20	20	5	5	5	2.5	2.5	
☞ a. (**ɟjot̪**.sna)	-1		-2					-30
☞ b. (**ɟjot̪**).(**sə**.na)			-3	-1	-1		-2	-30
c. (**ɟjot̪**).(sə.na)		-1	-3			-1	-1	-40
d. ɟjot̪.(**sə**.na)		-1	-3					-45

Note that the optionality is appearing only in table 5B and not in the case of table 5A. This indicates that for speakers whose mental representation of the word is without the schwa, there will be no optionality in the output. But, for those speakers with the schwa in the input, there is likely to be optional schwa deletion in the output in these contexts. This explains the description of the process in terms of schwa deletion rather than schwa insertion by Shrivastava (1979), Ohala (1983) and Pandey (1990).

[2] The syllable with stress is highlighted in bold.

3.2 Derivational bias

While modelling for the optionality in schwa deletion in underived words, we also need to revisit the derived environment non-optional schwa deletion to show that the derivation in section 1.3 is still consistent with the now modified harmonic grammar of Hindi. In this section, we use the same grammar that we used in section 2.1 in order to show that tables 6A and 6B produce identical outputs to tables 7A and 7B, just like tables 3A and B produced identical results to tables 4A and B.

The derivation tables 6 and 7 reveal further empirical facts about the relative importance of the constraints in Hindi Grammar:

a. Input /ɟjot̪səna/ produces optionality but /cipəkna/ does not primarily because the sequence [sn] is a possible onset cluster in Hindi, but neither [pk] nor [kn] can form a coda or onset cluster in the language.

b. It follows that words where cluster reinterpretation is possible, will be more likely to have optional schwa deletion, than words where cluster reinterpretation is not possible.

c. The input representation in the mental lexicon of native speakers will show richness of the base effects in cases like (1) and (2) where there is no optionality in schwa deletion. In other words, it is necessary to posit a schwa in the underlying representation in order to derive optionality of schwa deletion in surface representations.

TABLE 6 A

[pick]+[-na]	SSP	ID-IO	PARSE-SYL	*STRUC(σ)	*LAPSE	ALN-FT-R	H
Weights	60	20	20	5	2.5	2.5	
a. (**pic**.kna)	-1			-2			-70
b. (**pick**.na)	-1			-2			-70
c. (**pi**.cək.)na		-1	-1	-3	-1	-1	-60
☞ d. pi.(**cək**.na)		-1	-1	-3			-55

TABLE 6 B

[pick]+[-a]	SSP	ID-IO	PARSE-SYL	*STRUC(σ)	*LAPSE	ALN-FT-R	H
Weights	60	20	20	5	2.5	2.5	
☞ a. (**pic**.ka)				-2			-10
b. (**pick**.a)	-1			-2			-70
c. (**pi**.cə.)ka		-1	-1	-3	-1	-1	-60
d. pi.(**cə**.ka)		-1	-1	-3			-55

Table 7 A								
[picək]+[-na]		SSP	ID-IO	PARSE-SYL	*STRUC(σ)	*LAPSE	ALN-FT-R	H
Weights		60	20	20	5	2.5	2.5	
	a. (**pic**.kna)	-1	-1		-2			-90
	b. (**pick**.na)	-1	-1		-2			-90
	c. (**pi**.cək.)na			-1	-3	-1	-1	-40
☞	d. pi.(**cək**.na)			-1	-3			-35

Table 7 B								
[picək]+[-a]		SSP	ID-IO	PARSE-SYL	*STRUC(σ)	*LAPSE	ALN-FT-R	H
Weights		60	20	20	5	2.5	2.5	
☞	a. (**pic**.ka)		-1		-2			-30
	b. (**pick**.a)	-1	-1		-2			-90
	c. (**pi**.cə.)ka			-1	-3	-1	-1	-40
	d. pi.(**cə**.ka)			-1	-3			-35

4 Does schwa optionally/obligatorily delete?

We designed a small pilot experiment to verify whether schwa (optionally) deletes in Hindi. This section details the design and findings of the experiment.

4.1 The experimental design

The data collected was based on a nonce-word based production experiment that involved the participants reading aloud a paragraph written in Hindi. The pre-task involved reading similar paragraphs with actual words set in the text. Two actual words were used for this priming, and each was set in the text in three different morpho-syntactic contexts.

Priming word		**Noun**		**Dative/Acc Plural**	
karigər	*'craftsman'*	karigər-i	*'craftsmanship'*	karigər-õ	*'craftsmen'*
səo̯dagər	*'trader'*	səo̯dagər-i	*'trading'*	səo̯dagər-õ	*'traders'*

Since Hindi script does not use any diacritic marking for schwa, the presence or absence of a schwa in production cannot be deduced from the written text and is a requirement of the phonological well-formedness. Nevertheless, in order to control for any lexically specified irregularities, we use nonce-words in the production task.

Each one of the nonce-words are trisyllables, similar to the priming words with the penultimate varying between CV and CVC. We used two such sets and each participant was shown either set 1 or set 2.

	Set 1	**Set 2**
CV.CV.CVC	bəɟid̪ər	bəɟad̪ər
	ləpakər	ləpikər
CV.CVC.CVC	kəlɪst̪ər	kəlast̪ər
	məkast̪ər	məkist̪ər

We had 12 participants, four of whom were from the Eastern Hindi speaking regions of Bihar, one from Eastern Uttar Pradesh, and one from Jharkhand, and four from the Western Hindi speaking regions of Rajasthan with one from Haryana. One participant was a Hindi speaker from the Jammu region. Thus the total number of contexts for potential schwa deletion that we recorded was as follows:

	No. words × 2 derivational contexts × No. of iterations × No. of participants	
Priming	2×2×2×12	96
Test set	4×2×2×12	192
	Total data points for potential schwa deletion	288

In all these contexts a CVCV(C)CVC stem was modified with a vowel initial affix [-i] or [-õ] by the participant in a fill-in-the-blank task where the participant believed that the task objective was to produce the correct conjugated form of the nonce-word in the given syntactic context. In all the cases, the addition of the affix is supposed to add a syllable, making the trisyllabic input tetrasyllabic. The deletion of the schwa in all the cases would produce a legitimate onset cluster in Hindi and reduce the number of syllables in the output to three. Thus the crucial output candidates that we are comparing are CVCV(C)CVCV and CVCV(C)CCV.

Given our model of grammar in section 2.2 the results we were expecting was the following:

Table 8 B									
[ləpakər][-i]			ID-IO	PARSE-SYL	*STRUC(σ)	FT-BIN(σ)	*LAPSE	ALN-FT-R	H
Weights			20	20	5	5	2.5	2.5	
☞	a.	(**lə**.pa.)(**kə**.ri)			-4			-2	-25
💣	b.	(**lə**.pa).(**kri**)	-1		-3	-1		-1	-42.5
	c.	(**lə**.pa.)kri	-1	-1	-3		-1	-1	-60
	d.	lə.(**pa**.kri)	-1	-1	-3				-55

Table 9 B									
[məkist̪ər][-i]			ID-IO	PARSE-SYL	*STRUC(σ)	FT-BIN(σ)	*LAPSE	ALN-FT-R	H
Weights			20	20	5	5	2.5	2.5	
☞	a.	(**mə**.kis).(**t̪ə**.ri)			-4			-2	-25
💣	b.	(**mə**.kis).(**t̪ri**)	-1		-3	-1		-1	-42.5
	c.	(**mə**.kis).t̪ri	-1	-1	-3		-1	-1	-60
	d.	mə.(**kis**.tri)	-1	-1	-3				-55

4.2 Results and analysis

Of the 288 potential places where the schwa could have deleted, it deletes in only five cases. These cases of schwa deletion in the derived tetrasyllabic context are statistically insignificant, indicating that the relative well-formedness of the structure with schwa is significantly better than that without the schwa. This was expected from our Harmonic Grammar model of Hindi and the experiment provided further empirical verification for our theoretical proposal.

The results of the production experiment brought forth another hitherto unreported empirical observation about Hindi phonology. The schwa undergoes substantial raising in F1 formant frequency in the derived contexts. The raising in schwa is statistically significant, though native speakers do not readily distinguish between the phonemes /i/ and /ə/ in such contexts. In the following section we present a preliminary analysis of this loss of phonemic distinction between schwa and /i/ in these experimental contexts.

5 Schwa raising

Two possible explanations for the phonetic raising of the F1 formant frequency of schwa are:

a. Reduction in sonority in unstressed syllable.

b. Regressive vowel harmony with the following high vowel [-i].

As per the Universal scale of Sonority Hierarchy (Sievers, 1881; Jesperson, 1904; De Lacy, 2004), the vowel schwa is more sonorous than the [+High] vowels /i/ and /u/. As a result, the latter are more suited to the unstressed position than schwa. However, as per our model of harmonic grammar in the tables 8B and 9B, the schwa in the penultimate syllable is stressed. So, as per our grammar, this is unlikely to be a reduction process.

Further, if it is a reduction process, it will apply to both the derivational contexts of [-i] affixation as well as [-õ] affixation. In the empirical data from our experiment, we find that the raising in the F1 formant frequency is restricted to contexts of [-i] affixation and completely absent from the latter context. Regressive vowel harmony, though a phonological characteristic of eastern Indo-Aryan languages, Bangla and Assamese, has not been noted for Hindi yet. Unlike the other two languages, in case of Hindi, it is both optional as well as non-categorial. Future work in this domain will show how this regressive height assimilation in Hindi relates to categorical perception of phonemes in the language and what are the particular contexts for its application.

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