Acquisition of Hindi's laryngeal contrast by Meiteilon speakers

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ABSTRACT

Though Meeteilon does not have phonemic contrast in voicing, native speakers can accurately recognize voiced stops and aspirated voiced stops in word-initial positions and categorically distinguish these from voiceless stops and aspirated voiceless stops. However, they are unable to perceive any of these laryngeal contrasts in word-final position. We explain these facts by proposing that tone and aspiration being phonemic in Meeteilon, these cues from L1 can be re-recruited by native speakers for learning laryngeal contrasts in a second language like Hindi. Since these cues from L1 cannot be used to perceive laryngeal contrasts in word-final position, the contrasts are not perceived in these positions.

1 Introduction

In this paper, we explore how a phonological contrast is perceived in a second language scenario by adult native speakers of a first language lacking the contrast. In this second language interaction, we use two phonological contrasts where one of them is present in both L1 and L2 of the speakers and the second one is present in L2 but not L1. The two languages we have selected for this setup are Meiteilon and Hindi.

Hindi has four types of laryngeally specified stops whereas Meiteilon has a two-way distinction. The participants in our study are all native speakers of Meiteilon who are well exposed to Hindi as a second language.

	L1 Meiteilon	**L2 Hindi**	
		Voiceless	Voiced
Unaspirated	T	T	D
Aspirated	TH	TH	DH

Table 1: Laryngeal Contrasts in Meiteilon and Hindi

In Hindi, this four-way laryngeal contrast is attested in both word-initial and word-final positions. In contrast, in Meiteilon the aspiration contrast is restricted to the word-initial position. These differences are shown in table 2.

Meiteilon has a proper subset of laryngeal contrasts present in Hindi and these too are restricted to a subset of positions where the same features are licensed in Hindi. In this scenario, we have two distinct questions in this study.

Position	Feature	Phoneme Class	Hindi	Meiteilon
Initial	Voiceless stop	T	pal 'foster'	pa 'eyelash'
	Voiced stop	D	bal 'hair'	
	Voiceless aspirated stop	TH	p^hal 'steps'	p^ha 'catch'
	Voiced aspirated stop	DH	b^hal 'forehead'	
Final	Voiceless stop	T	d͡ʒap 'recital'	pa 'eyelash'
	Voiced stop	D	d̪ab 'pressure'	
	Voiceless aspirated stop	TH	sap^h 'clean'	
	Voiced aspirated stop	DH	lab^h 'profit'	

Table 2: Positional distribution of Hindi and Meiteilon laryngeal contrasts

a. Would Meiteilon speakers with Hindi L2 differ in their accurate perception of aspiration, a phonological feature present in their L1, and a new phonological contrast of voicing?

b. With respect to aspiration, would they show a difference in their perception of aspiration in the word-final and word-initial positions?

The paper is divided into five sections. Section 1 introduces theoretical concepts used to analyse phonological contrasts in general and laryngeal contrasts specifically. In section 2, we present the predictions based on the theoretical discussion of section 1. Section 3 discusses the details of the experimental design and its implementation, followed by the discussion of the results in section 4. This is followed by the concluding discussion of the study in section 5.

1.1 Phonology of laryngeal contrasts

Plosives in natural languages can exhibit voicing and aspiration contrasts. Phonologically, there are two ways to characterise these contrasts in terms of distinctive features.

a. With respect to Privative Feature Theory (Jacobson 1942), a feature is a mark that is either present or absent. While the absence of the mark does not form a natural set, the presence of the mark constitutes a natural set of sounds that may participate in phonological processes.

b. With respect to Binary Feature Theory (Chomsky and Halle 1968), a feature constitutes of positive and negatively marked counterparts that appear in the specification of sounds. Both positive and negative feature specifications are equipollent and either of them can describe a natural set.

In the privative feature theory, voiced segments are more complex than their voiceless counterparts. This is because the privative feature [voice] is present in D, while the voiceless counterpart T has a null [ø]. Therefore, D will be more marked than T since it has a more complex phonological representation. In the same way, [spread glottis] feature of TH will make it more marked than T with null [ø] specification.

In the binary feature system T and D are equally complex with [-voice] and [+voice] specifications respectively. Therefore, no markedness prediction emerges out from the structural complexity parameter.

Typologically, there are five kinds of phonemic systems in natural languages with respect to the laryngeal feature specifications.

Laryngeal system	**Voicing**	**Aspiration**	**Phoneme Class**	**Example languages**
No contrast	no	no	T	Hawaiian
Voicing	yes	no	T, D	Russian, Turkish
Aspiration	no	yes	T, TH	Mandarin, Meiteilon
Three-way contrast	yes	yes	T, D, TH	Vietnamese, Khmer
Two-way contrast	yes	yes	T, D, TH, DH	Hindi, Gujarati

Table 3: Typology of laryngeal contrasts in languages

Table 3 shows a series of implicational relations between the marked segments and their unmarked counterparts. If the marked phonemes D or TH is present in the phonemic inventory of a language, it will also contain the unmarked counterpart T. Similarly, the presence of the doubly marked DH in Indo-Aryan languages is accompanied by the presence of the relatively unmarked TH. The privative feature theory predicts that no language with DH in their phonemic inventory will lack TH or D. These predictions which follow from the privative feature theory, will not follow from the structural specifications of binary features. In this paper, we use privative features to theoretically characterize the phonemic contrasts of Meiteilon and Hindi, as shown in table 4.

Position	**Feature**	**Phoneme class**	**Hindi**	**Meiteilon**
Initial	[ø]	T	pal ‘foster’	pa ‘eyelash’
	[voice]	D	bal ‘hair’	
	[spread glottis]	TH	p^{h}al ‘steps’	p^{h}a ‘catch’
	[voice] ∧ [spread glottis]	DH	b^{h}al ‘forehead’	
Final	[ø]	T	d͡ʒap ‘recital’	tʃak ‘rice’
	[voice]	D	d̪ab ‘pressure’	
	[spread glottis]	TH	sap^h ‘clean’	
	[voice] ∧ [spread glottis]	DH	lab^h ‘profit’	

Table 4: Privative feature distribution in Hindi and Meiteilon phonemes

The two-way contrast languages are typologically divided into true voicing and aspirating languages, depending on whether the stops are produced with a voicing lead or a voicing lag (Iverson and Salmons 1995, Beckmen et al. 2013). The true voicing and aspirating languages employ different dimensions of laryngeal articulation. According to Laryngeal Realism in Honeybone (2005), since the true voicing languages exhibit active (effortful) voicing, they make use of the [voice] feature. In contrast, since the aspirating languages exhibit prominent aspiration, they use the [spread glottis] feature.

Some laryngeal inventories use both the [voice] and [spread glottis] feature. However, many of these systems do not use both the feature specifications simultaneously on the same phonological segment. All Indo-Aryan languages have the four-way laryngeal contrast, like Hindi, where the [voice] and [spread glottis] features can co-occur on individual plosive segments (Pandey 2014).

The characterization of DH with a doubly marked [voice] and [spread glottis] feature, is asynchronous with the phonetic characterizations of [spread glottis] feature, by Kim (1970) and Keating (1984), with the articulatory gesture of vocal folds spread wide apart during the oral occlusion. Consequently, they have been phonetically characterized as breathy voiced segments. However, if the phonological features of DH are different rather than more complex than D and TH, we should expect to see languages with the inventories of [T, D, DH] and [T, TH, DH] as well. The absence of such cases suggests that phonologically DH corresponds to the doubly marked laryngeal specification.

Meiteilon is an aspirating language, just like many other Tibeto-Burman languages. The unaspirated stops are produced with near zero VOT suggesting that the segment is unspecified for any laryngeal feature. The aspirated stops on the other hand are produced with significant VOT indicating the existence of a prominent distinctive cue represented with the feature [spread glottis] (Ashem 2018). Of these two segments, the aspirated stop does not occur word finally. Word initially, both the segments form a contrastive pair.

Between Hindi and Meiteilon, both languages use [spread glottis] as a contrastive phonological feature, but only Hindi uses [voice] as a contrast. This theoretical characterization of their laryngeal inventory leads to two direct implications:

a. While [spread glottis] feature can occur in both Meiteilon and Hindi word-initially, in word-final position it can be present only in Hindi and not in Meiteilon.

b. [voice] feature can occur in Hindi in all positions, in Meiteilon the contrast does not exist in any position.

Alternatively, segmental property is theoretically represented with respect to primes in Government Phonology (Kaye 1987, Kaye et al. 1990). In this theory, each phoneme, known as an element, is represented using a combination of primes where a particular prime could be the either a head or an operator. For stop sounds the head is the stricture-based prime |ʔ| that another location gesture may accompany. Table 5 shows side by side comparison of these two characterizations.

In both the feature-based and prime-based perspectives, the DH is more complex than D and TH, which are more complex than T. Further, there are two ways in which the Meiteilon repertoire segmentally differs from Hindi.

Phoneme	Feature-based	Prime-based
T	Root Oral Place Laryngeal ∅	| ʔ |
TH	Root Oral Place Laryngeal [Spread Glottis]	| ʔh |
D	Root Oral Place Laryngeal [Voice]	| ʔA |
DH	Root Oral Place Laryngeal [Voice] [Spread Glottis]	| ʔAh |

Table 5: Prime-based versus feature-based contrasts

a. The Laryngeal node in Meiteilon does not dominate the feature [voice]. In terms of element theory, the operator |A| does not co-occur with the head |ʔ|.

b. The features [voice] and [spread glottis] do not co-occur.

In section 3 we discuss what these differences in Hindi and Meiteilon specifically predict for the phonemic recognition of Hindi's laryngeal contrast by the native Meiteilon speakers. In the next subsection we discuss the basis of the feature specification and how this may influence phonemic recognition.

1.2 Articulatory basis of laryngeal phonology

Feature-based representation of phonological contrast in SPE (Chomsky and Halle 1968) is rooted in the articulatory implementation. The range of complexity in laryngeal stricture during plosive articulation is directly represented as features. These direct correlations between phonetic execution and phonological features are reinforced in approaches such as Laryngeal Realism (Honeybone 2005). For example, phonetically, with respect to articulatory gestures English has four types of stops. Of these, only aspiration is produced with consistent effort. Consequently, the phonological laryngeal contrast is reduced to "aspirated" and "unaspirated":

Phonetic contrast	**Phonological contrast**
[T]: voiceless unaspirated	[T], [TH] aspirated
[TH]: voiceless aspirated	
[D̥]: modal voiced	[D̥], [D] unaspirated
[D]: voiced	

Table 6: Collapsing gradient phonetic contrasts to categorical phonological contrasts

Extending the analysis in table 6 to the context of our study, we expect that both voicing and aspiration will be actively maintained in Hindi in order to facilitate a four-way phonological contrast, while Meiteilon would need a single active feature of aspiration to be consistently maintained. Ladefoged and Maddieson (1996) shows that the four-way laryngeal system subsumes the laryngeal systems of the two-way voicing and aspirating languages. While the degree of strictures and oral settings may vary from language to language, the general pattern is the same. Based on Ladefoged and Maddieson (1996), a schematic of the laryngeal aperture plotted against oral release is presented in figure 1. It has been slightly modified to reflect Hindi's stops /p/, $/p^h/$, /b/, $b^h/$.

Laryngeal distinctions can also be positionally restricted in natural languages. For example, although stops are attested in both onset and coda positions in Meiteilon, the aspirated-unaspirated distinction is restricted to onset positions. With respect to articulation, as the subglottal pressure diminishes over time due to exhalation, less air is available for breathy articulations. This could be one of the factors that are responsible for the loss

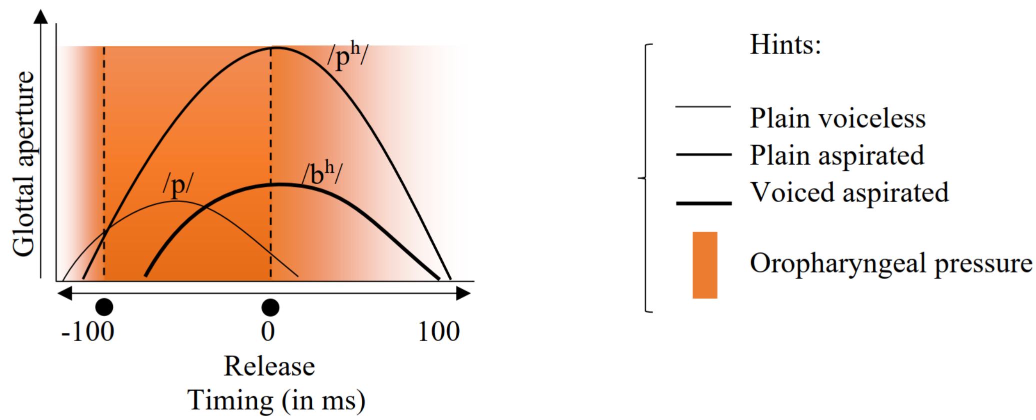

Figure 1: Glottal aperture with oral occlusion in Hindi stops

of laryngeal contrast in syllable and word final positions. The word initial position is generally the position unadulterated by this factor which could be the reason why phonologists generally use this position as evidence for characterizing the featural matrix of a laryngeal contrast.

Similarly, some articulatory strictures are more compatible with certain phonological positions. For example, lead voice onset (pre-voicing) is effectively produced in the word medial and final position since the air has to pass from the vocal folds in order to vibrate them for voicing. Due to the lack of free air passage, this can become a problem in word initial problem and language users have to resort to other strategies to produce voicing such as resorting to lowering of the larynx or expanding the oropharyngeal cavity (Ladefoged and Maddieson, 1996). Similarly, word-final stops may remain unreleased and give the impression that the aspiration is unavailable as a contrast word finally. These limitations are universal, however, languages may find alternative routes to compensate for these limitations. For example, Dixit (1980) hypothesizes that in the native Hindi speakers can actively lower their larynx to induce voicing when subglottal pressure is low and voicing induction is necessary. Meiteilon on the other hand does not contain phonemic voicing and therefore need not employ strategies to maintain the voicing contrast. Further, Hindi speakers produce aspiration word-finally but Meiteilon speakers do not. Can the Meiteilon speakers switch to some other cue while recognising aspiration in word final position through acoustic cues alternative to VOT? In the next subsection we discuss the acoustic cues to the laryngeal articulation and how it may influence phonemic recognition.

1.3 Acoustic cues to phonological knowledge

Native speakers may associate certain acoustic cues to certain laryngeal contrasts. These may vary from language to language and sometimes even person to person. Researchers have identified several cues that can be used to detect phonetic differences between a pair of segments (Haggard et al. 1975, Abram and Lisker 1985, Jensen 2004 among others).

Pinget (2022) discusses that laryngeal contrasts can be perceived through the help of one or more cues from the following acoustic cues:

i. VOT: it is a temporal continuum of voicing induction in relation to the oral occlusion. Active voicing is realized acoustically as negative VOT, i.e., occurrence of voicing before the release of the stop and aspiration is known to be induced by the wide glottal aperture during oral release, resulting in sizeable glottal friction (Lisker & Abramson 1964). Extensive research has shown that VOT is indeed a reliable cue for perceiving laryngeal distinctions. However, voiced aspirates have been outside the scope of VOT based analysis since a unary voicing continuum cannot account for voicing and aspiration overlap.

ii. Previous vowel length: generally, the same vowels preceding voiced segments surface as shorter than vowels preceding voiceless segments. Therefore, languages may take cognizance of this regularity and use it as a reliable predictor of the voicing contrast (Raphael 1972).

iii. f0 perturbation: the glottal setting during the oral articulation "perturbs" the f0 of the following vowel. Generally, voiceless segments induce higher f0 at the onset of the following vowel while voiced segments lower the f0 (Kirby & Ladd 2018). Recent research has shown that f0 can indeed be used as an independent phonetic cue for perceiving laryngeal contrasts despite other so called dominant cues being available such as VOT (Ladd & Schmidt 2018). Hindi also shows this perturbation (Dixit 1980).

iv. Closure duration: the duration of closure of stops may vary according to the type of voicing the stop has. Voiceless stops tend to have larger closures compared to the voiced stops (Lisker 1957, Port 1979). Language users may use this cue to identify the laryngeal contrast, however, these cues tend to be dominated by the presence of closure voicing and aspiration (Price & Lisker 1979, Wardrip-Fruin 1982).

In much of the research on laryngeal phonetics, however, VOT has been a dominant paradigm for characterising laryngeal contrasts. While being sophisticated in its predictions, VOT is not an appropriate paradigm for analysing a four-way laryngeal contrast: Since VOT is a temporal continuum, it does not allow for an overlap of voicing and voicelessness which is a necessary condition in voiced aspirates. In their extensive review of VOT based research, Cho et al. (2018) discusses this limitation and suggest that a richer manifestation of VOT is needed to account for the four-way laryngeal systems.

Research has also shown that VOT may not always be the determinant of laryngeal contrasts despite it being present in the language. For example, multiple studies have shown that the fundamental frequency of the vowel following the stop may consistently vary in languages (Hanson 2009, Kohler 1982; Kingston 2007, Löfqvist, Baer, McGarr & Story 1989) and may be used as a reliable contrastive cue for laryngeal distinction (Ladd & Schmid 2018, Kirby & Ladd 2018). Interestingly, languages that use lexical tones are more prone to using the fundamental frequency as the primary cue for laryngeal contrast (Kirby 2018). Since in tonal languages the tonal and consonantal gestures overlap and compete for the control of f0, the phonemic status for the f0 perturbation may make it worthy of greater perceptual "attention". As a result, it could be that the native speakers of tonal languages are more sensitive to even the minor perturbations in f0 and therefore can effectively deploy it as one of the primary cues for laryngeal distinction.

Hindi is non tonal language exhibiting an exhaustive four-way laryngeal contrast with all the contrasts present in word initial as well as final position. Hindi also has released stops therefore word final aspiration is produced, albeit with poorer quality. It is then likely that Hindi uses prominent voicing cues such as VOT to distinguish segments. If f0 was the primary cue, then word final segments would not be distinguishable as there is no following vowel to carry the pitch. On the other hand, Meiteilon is tonal language with no final aspiration therefore it is possible that Meiteilon either does not use VOT in word final position or does not use VOT as a cue altogether since it is a tonal language. We can expect an interplay of the alternative cues to laryngeal distinction when Meiteilon speakers perceive the laryngeal distinctions of Hindi, especially voicing. In an event where the cues mismatch, can Meiteilon speakers pay attention to supplementary acoustic cues when the primary cues are not available? In the next section we explore the interaction between the laryngeal systems of Hindi and Meiteilon and generate a few hypotheses based on the factors we elaborated above.

2 Interaction between the laryngeal systems of Hindi and Meiteilon

Since Meiteilon does not have voicing distinction in its native repertoire, we predict the following correlations between laryngeal gesture and phonological category in L1.

Phonetic Contrast	**Phonological Contrast in Onset**	**Phonological Contrast in Coda**
[T] voiceless unaspirated	[D̥], [T] unaspirated	[D̥], [T], [TH] No Contrast
[D̥] modal voiced		
[TH]voiceless aspirated	[TH] aspirated	

Table 7: Laryngeal contrast in Meiteilon

In case of the Hindi, the correspondence between phonetic and phonological contrasts in the laryngeal system for L1 speakers could be either of the options in Table 8.

While two of the phonological contrasts in option (1) matches with the L1 phonological contrasts of Meiteilon in the onset position, only one of the representations of option (2) [TH] finds a correspondent in the laryngeal system of Meiteilon. Either way, based on this characterization, we would predict that the Meiteilon speakers would perform as well as native Hindi speakers in accurately identifying voiceless aspirates in the word-initial position.

Phonetic Contrast	Phonological Contrast 1	Phonological Contrast 2
[T] voiceless unaspirated	[D̥], [T] unaspirated	[T] voiceless
[D̥] modal voiced		[D̥], [D] Voiced
[D]Voiced	[D] Voiced	
[TH]voiceless aspirated	[TH] aspirated	[TH] aspirated
[DH] breathy voiced	[DH] voiced aspirated	[DH] voiced aspirated

Table 8: Laryngeal contrast in Hindi

Although voiceless unaspirated stops corresponding to the phonetic contrasts [T] and [D̯] might match between native Meiteilon and Hindi, it is possible that in Meiteilon data this feature is recognized by the lack of [spread glottis] rather than the presence of an active articulatory gesture. In such a scenario it is possible that the Meiteilon speaking participants fail to categorically distinguish between voiced and voiceless unaspirated plosives to the same extent as Hindi speakers.

With respect to the voiced plosives of Hindi, [D] and [DH], it is an open question how they perform in the phonological categorization task in comparison to the Hindi control group. If they have successfully correlated a phonetic cue to the phonological feature of voicing through their exposure to Indo-Aryan languages with voicing contrast, the Meiteilon speakers will be able to categorically identify [voice] feature in at least word-initial position.

Categorically identifying either [voice] or [spread glottis] in the word-final position will be difficult for all participants, since some of the cues like F0 contour will be absent due to the lack of a following vowel. Further, in some cases the stop might not be released clearly, resulting in degraded VOT information. Despite that it is predicted that Hindi speakers who have the [voice] and [spread glottis] phonological contrast in word-final position, will perform better than Meiteilon speakers whose L1 does not have this contrast.

Features	Position	Hindi	Meiteilon	Prediction
[∅]	Initial	Present in L1	Present in L1	Equal identification
	Final	Present in L1	Present in L1	Equal identification
[vc] D	Initial	Present in L1	Absent in L1	Depends on active cue association
	Final	Present in L1	Absent in L1	Worse than initial
[sg] TH	Initial	Present in L1	Present in L1	Good — active feature recognition
	Final	Present in L1	Absent in L1	Worse than initial
[vc] ∧ [sg] DH	Initial	Present in L1	Absent in L1	Depends on active cue association
	Final	Present in L1	Absent in L1	Worse than initial

Table 9: Meiteilon group's predicted difficulties due to featural mismatch

The **segmental perception** accuracy will inform us how accurately our predictions follow.

Unlike featural specifications, there could be multiple acoustic cues to convey the laryngeal contrast, as discussed in section 1.3. Due to multiple cues being simultaneously available, it is possible that the L2 listener recruits a phonetic cue other than the primary cue used by L1 speakers in encoding a phonological feature. In the context of Hindi and Meiteilon, the acoustic cues of VOT and f0 are likely to be interchanged. Suppose Hindi uses VOT as the primary cue to identify [voice] contrast and L2 Meiteilon speakers of Hindi use f0 as the primary laryngeal cue. Since both positive VOT and f0 perturbations are available word initially, we will not see much difference in their categorical perception results. However, in the word final position VOT cue is weak and f0 perturbation is not available at all. If Meiteilon speakers fail to identify word final aspiration, we can say that VOT is not the primary cue used word finally in Meiteilon.

Contrast	**Position**	**If cues**	**Prediction**
Voicing	Initial	VOT	Good identification
		F0	Good identification
	Final	VOT	Weak identification
		F0	No identification
Aspiration	Initial	VOT	Good identification
		F0	Good identification
	Final	VOT	Weak identification
		F0	No identification

Table 10: Meiteilon group's predicted difficulty due to cue mismatch

The **feature perception** accuracy will inform us how accurately our predictions follow.

3 The experiment

The aim to this experiment is to study the points of variance in the categorial perception of the same phonetic signal between Hindi and Meiteilon speakers. Some of the specific questions we seek to answer are:

a. Can the Meiteilon speakers, who have some exposure to Hindi, consistently identify the voice feature in Hindi despite it being absent in their L1 (i.e., D and DH)?

b. We have theoretically predicted that Meiteilon speakers will identify the voiceless aspirates [TH] accurately based on their L1 exposure. However, given that this contrast is absent in the final position in their L1, would their L1 phonetic cue identification for aspiration help them categorically recognize it in word-final position?

Hindi being a common lingua franca in India, and part of the school curriculum in many areas, it is common for native speakers of other languages (including Meiteilon) to have some degree of exposure to spoken Hindi and its phonemic contrasts. Therefore, a perception experiment designed to differentiate a pair of samples (such as AX or AXB tasks) is expected to show no significant divergence from the control Hindi native speaker group. The question we are interested in is not whether Meiteilon speakers can perceive the phonetic difference between Hindi samples but what would they perceive them as. So, our evaluation of the task is not quantitatively based on how many samples were accurately classified but on what did they classify them as. Therefore, an identification task rather than a discrimination task is better suited for our research objective.

3.1 Design

The design of this study uses two factors.

i. Laryngeal contrast: Four laryngeal contrasts [T, D, TH and DH]

ii. Prosodic Position: Two prosodic positions [word-initial and word-final]

After crossing these factors, we get 8 conditions. For each condition, we used PoA factor with labial and velar as its levels, to counterbalance the inherent biases for shorter VOT lag in labial sounds (Cho and Ladefoged, 1999; Lisker and Abramson, 1964; Volaitis and Miller, 1992).

3.1.1 Items

The target sounds were placed in the [# _ an] and [a _ #] templates for initial and final positions, respectively. They yielded 16 target nonce words. For constructing the stimuli, these nonce words were placed in grammatical Hindi sentences in preverbal positions to eliminate the list effect while providing a uniform prominence to the target words. Two native Hindi speakers (male and female) produced the sentences 3 times each. Equal number of fillers were also recorded to mask the target items. The sentences were recorded on a studio-grade (Maono) unidirectional microphone in a sound-treated room. The recorded stimuli were spliced out keeping all the cues intact and were normalized for loudness.

Nonce words have been deliberately used in the experiment to counter the effect of lexical familiarity or non-familiarity in non-native speaker population. Further, not all the words created in the [# _ an] and [a _ #] template, turned out to be nonce in Hindi. In such a scenario we had to either trade-off on the template or the nonce paradigm. In this study, we chose to apply the template consistently even if it included a couple of lexical words.

3.1.2 Method

The experiment had three phases.

i. **The Selection phase:** In this phase participants were shortlisted based on their linguistic profile. Only those Meiteilon speakers were selected as participants who had no prior exposure to languages which uses four-way laryngeal contrast other than Hindi. Further, participants with hearing difficulties and knowledge of linguistics were not selected.

ii. **The Familiarization phase:** The recruited participants were given instructions about the experimental procedure. This includes familiarization with the script we have used and how to correlate them with Hindi sounds. Although the participants were aware of the four-way laryngeal contrast in Hindi, it was made clear to them which symbol on the screen corresponded to which sound. They were informed that the data will be presented in four blocks and that they could take a break between each block.

iii. **Implementation phase:** We employed a self-paced forced-choice phonemic recognition task. In this task, an aural stimulus was presented immediately followed by four options as buttons. Each button with orthographic (Roman script) text written on it corresponds to one of the 4-way laryngeal contrast [T, D, TH and DH]. The participant listens to the aural stimulus and selects a button as soon as possible that best matches the aural stimuli heard. Before the actual trials, dummy trials were used to effectively familiarize them with the paradigm. The experiment was conducted on PCIbex PennController 2.0 (Zehr and Schwarz 2018) web-based interface. We obtained three dependent measures through this task: accuracy, response time and error type. In this paper we focus on accuracy.

4 Results

We present the results of the experiment in two ways:

a. Accuracy in segment identification

b. Accuracy with respect to individual feature recognition for [voice] and [spread glottis]

The accuracy data is shown in percentages.

4.1 Accuracy in segment identification

With respect to the accuracy of segment identification we started with the following predictions:

a. For both Hindi and Meiteilon speakers the accuracy of segmental identification in the word-initial position will be higher than their corresponding accuracy in word-final position.

b. While both Meiteilon and Hindi speakers will do equally good with categorically recognising [TH], Meiteilon speakers might be worse at recognising [T].

c. Overall, the recognition of [D] and [DH] will be worse for Meiteilon speakers than the Hindi group.

Features	**Position**	**Hindi**	**Meiteilon**	**Significance**	**Prediction**
[∅] T	Initial	97.5	96.67	$p > .05$	holds
	Final	69	50	$p < .001$**	does not hold
[vc] D	Initial	95.83	85.41	$p < .01$*	holds
	Final	71.66	40	$p < .0001$**	holds
[sg] TH	Initial	93.6	97.08	$p > .05$	holds
	Final	87.67	56.17	$p < .001$**	holds
[{vc} {sg}] T	Initial	97.5	88.75	$p < .001$**	holds
	Final	86.33	53.39	$p < .0001$***	holds

Table 11: Accuracy based on features for the four-way laryngeal contrast

* Kruskal-Wallis rank sum test is used for comparison as the data is heavily skewed rightward.

The results show that there is no significant difference in the recognition of [T] and [TH] in the word-initial position. Both groups performed quite well with the Meiteilon group marginally even performing better than the Hindi control group in the recognition of [TH]. However, the recognition of [T] and [TH] in word-final position is significantly worse than the Hindi group. While the accuracy of both groups is lower in the word-final position, in comparison to the word-initial one, as predicted, both groups perform better at recognising [TH] than [T] in the word-final position.

As predicted the overall accuracy of the voiced segments [D] and [DH] is significantly lower for Meiteilon group than the Hindi group, the results clearly indicate that the most significant difference in accuracy is in the recognition of these segments word-finally.

4.2 Accuracy with respect to individual feature recognition

In this section we have analysed the accuracy of recognizing a particular feature. We have done the response coding as indicated in Table 12.

With respect to individual features, we started out with the following predictions:

a. [voice] feature being absent in Meiteilon, featural recognition of [voice] will be worse in Meiteilon group than the Hindi group.

b. [spread glottis] feature being present in initial position in Meiteilon, its recognition in the initial position will be significantly better than the final position. Word-finally Hindi group is also expected to have higher accuracy.

Input segment	**Choice of option**	**Accuracy coding**
[T]	[T] or [TH]	Accurate [voice] identification
[TH]	[T] or [TH]	Accurate [voice] identification
[D]	[D] or [DH]	Accurate [voice] identification
[DH]	[D] or [DH]	Accurate [voice] identification
[T]	[T] or [D]	Accurate [spread glottis] identification
[TH]	[T] or [D]	Accurate [spread glottis] identification
[D]	[TH] or [DH]	Accurate [spread glottis] identification
[DH]	[TH] or [DH]	Accurate [spread glottis] identification

Table 12: Response coding for featural accuracy

Input	**Position**	**Accuracy of [Voice]**		**Accuracy of [spread glottis]**	
		Hindi	Meiteilon	Hindi	Meiteilon
T	Initial	98.8	98.3	98.3	97.9
T	Final	92.7	70.6	74.7	66.9
D	Initial	96.7	99.6	97.1	86.2
D	Final	97.7	71.5	72.6	57.9
TH	Initial	97.1	97.9	98.3	98.3
TH	Final	97.7	74.6	89.7	70.6
DH	Initial	98.8	98.3	98.3	90.8
DH	Final	96.0	72.4	89.7	66.9

Table 13: Overall accuracy results for Hindi and Meiteilon

The results in Table 13 show that the [voice] feature is recognized at par with Hindi by Meiteilon speakers in word-initial position, but it is significantly worse in the word-final position. Hindi speakers show no significant deviation is the accuracy of recognizing [voice] feature in initial and final positions. This suggests that the primary phonetic cue used by native Hindi speakers to recognise [voice] is consistently available at both initial and final position while the cue associated by some people from the Meiteilon group fails to be distinctively identifiable in word-final position.

With respect to [spread glottis] feature, both groups show lower accuracy in recognizing the feature in word-final position. However, unlike [voice] recognition accuracy which was at par with Hindi for the initial position, the [spread glottis] recognition accuracy of Meiteilon is consistently lower than Hindi in all positions except initial [TH]. The presence [voice] gesture reduces the accuracy in recognising [spread glottis] feature.

5 Discussion

The results of the experiment clearly point to the successful segmental recognition of [T] and [TH] segments that are present in both Meiteilon and Hindi. This shows that Meiteilon speakers recognize those segments better in L2 which are already present in their L1. For the segments absent in their L1, a feature-based analysis of accuracy reveals the following.

Segment absent in L1	**Phonetic cue to recognize**	
	[Voice]	[Spread Glottis]
[D]	Presence of active voicing cue	Absence of aspiration cue
[DH]	Presence of active voicing cue	Presence of active aspiration cue

Table 14: Featural recognition accuracy for Meiteilon speakers

The presence of active voicing cue was accurately detected in initial positions, but not final positions. These results indicate that the Meiteilon group has indeed learnt to distinguish the [voice] contrast in initial position but not in final position. Phonetically this suggests that the phonetic cue they have associated with voicing is perhaps unavailable word-finally resulting in the loss of voice distinction in this position.

Feature	**Position**	**Language**	**Accuracy**	**Phonetic Cue**
[voice]	Initial	Hindi	97.85	Primary VOT + Secondary f0
		Meiteilon	98.52	Primary f0 + Secondary VOT
	Final	Hindi	96.02	Primary VOT (no f0 cue)
		Meiteilon	72.25	Secondary VOT (no f0 cue)

Table 15: [voice] recognition accuracy for Hindi and Meiteilon speakers

Phonologically, this indicates that the mental grammar of Meiteilon speakers that did not tolerate voiced plosives has developed a second L2 grammar for Hindi that tolerates voiced plosives in prosodically strong positions like onsets and word-initial position. This development can be represented theoretically by showing the change in the ranking between the markedness and faithfulness constraints (Boersma & Hamman 2009, Hancin-Bhatt 2008), as shown in table 16.

Markedness constraint	**Faithfulness constraint**
*OBSTRUENT[VOICE]	IDENT[VOICE] IDENT[VOICE]-ONSET

Table 16: Interacting constraints in voicing contrast

In L1 Meiteilon grammar the markedness constraint is ranked higher than faithfulness resulting in no toleration for the voiced obstruent in either initial or final position. To demonstrate this, we have considered the nonce inputs [ban] and [nab] and predicted their corresponding outputs.

(1) L1 grammar of Meiteilon

a.

[ban]	*OBS[VOI]	ID[VOI]-ONS	ID[VOI]
a. ban	∗!		
☞ b. pan		∗	∗

b.

[nab]	*OBS[VOI]	ID[VOI]-ONS	ID[VOI]
a. nab	∗!		
☞ b. nap			∗

The L2 Hindi grammar of Meiteilon speakers shows a re-ranking between the positional faithfulness constraint and the markedness constraint.

(2) Hindi L2 grammar of Meiteilon

a.

[ban]	ID[VOI]-ONS	*OBS[VOI]	ID[VOI]
☞ a. ban		∗	
b. pan	∗!		∗

b.

[nab]	ID[VOI]-ONS	*OBS[VOI]	ID[VOI]
a. nab		∗!	
☞ b. nap			∗

This grammar is in turn distinct from the L1 grammar of Hindi speakers where even the general faithfulness constraint is ranked higher than the markedness constraint.

(3) L1 grammar of Hindi

a.

[ban]	ID[VOI]-ONS	ID[VOI]	*OBS[VOI]
☞ a. ban			*
b. pan	*!	*	

b.

[nab]	ID[VOI]-ONS	ID[VOI]	*OBS[VOI]
☞ a. nab			*
b. nap		*!	

The [spread glottis] contrast though present in Meiteilon is not accurately detected in voiced inputs. Phonetically this suggests that again f0 rather than VOT is perhaps the primary cue associated with [spread glottis] in Meiteilon. The absence of f0 cue in the word-final position will explain why this contrast is restricted to the onset position in the L1 grammar of Meiteilon.

Feature	**Position**	**Language**	**Accuracy**	**Phonetic Cue**
[spread glottis]	Initial	Hindi	98.0	Primary VOT + Secondary f0
		Meiteilon	93.3	Primary f0 + Secondary VOT
	Final	Hindi	81.67	Primary VOT (no f0 cue)
		Meiteilon	65.57	Secondary VOT (no f0 cue)

Table 17: [spread glottis] recognition accuracy for Hindi and Meiteilon speakers

Similar to the [voice] feature, the phonological representation of [spread glottis] distribution in L1 Meiteilon, L2 Hindi for Meiteilon speakers and L1 Hindi grammar can be shown through the interaction of the following constraints.

Markedness constraint	**Faithfulness constraint**
*OBSTRUENT[SPREAD GLOTTIS]	IDENT[SPREAD GLOTTIS]
	IDENT[SPREAD GLOTTIS]-ONSET

Table 18: Interacting constraints in aspiration contrast

In L1 Meiteilon the markedness constraint is ranked lower than the positional faithfulness constraint, but higher than the general faithfulness constraint. This results in contrast neutralization in prosodically weak positions.

(4) L1 grammar of Meiteilon

a.

[p^han]	ID[SG]-ONS	*OBS[SG]	ID[SG]
☞ a. p^han		*	
b. pan	*!		*

b.

[nap^h]	ID[SG]-ONS	*OBS[SG]	ID[SG]
a. nap^h		∗!	
☞ b. nap			∗

This same constraint ranking continues in the L2 Hindi grammar of Meiteilon speakers. In contrast, the L1 Hindi grammar has both faithfulness constraints ranked higher than markedness once again resulting in the toleration of the aspiration contrast in both the initial and final position.

(5) L1 grammar of Hindi

a.

[p^{h}an]	ID[SG]-ONS	ID[SG]	*OBS[SG]
☞ a. p^{h}an			∗
b. pan	∗!	∗	

b.

[nap^h]	ID[SG]-ONS	ID[SG]	*OBS[SG]
☞ a. nap^h			∗
b. nap		∗!	

Since L1 Hindi grammar has both the markedness constraints *obstruent[voice] and *obstruent [spread glottis] ranked lower than the faithfulness constraints, the language tolerates outputs with both features simultaneously occurring in initial and final positions. However, given our analysis of the Hindi L2 grammar of Meiteilon speakers, we predict the following two outcomes for the inputs [b^{h}an] and [nab^h]

(6) L2 Hindi grammar of Meiteilon speakers

a.

[b^{h}an]	ID-ONS	*OBS[VOI]	*OBS[SG]	ID
☞ a. b^{h}an		∗	∗	
b. ban	∗!	∗		∗
c. p^{h}an	∗!			
d. ban	∗!∗			

b.

[nab^h]	ID-ONS	*OBS[VOI]	*OBS[SG]	ID
a. nab^h		∗!	∗	
b. nab		∗!		∗
c. nap^h			∗!	∗
☞ d. nap				∗∗

In conclusion the results of the experimental study of the L2 acquisition of Hindi contrast by speakers of Meiteilon reveals the constraint ranking given in table 19.

L1 Meiteilon Grammar	L2 Hindi Grammar of Meiteilon speakers	L1 Hindi Grammar
*OBS[VOICE]	POSITIONAL FAITHFULNESS	POSITIONAL FAITHFULNESS
≫	≫	≫
POSITIONAL FAITHFULNESS	*OBS[VOICE]	FAITHFULNESS
≫	≫	≫
*OBS[SPREAD GLOTTIS]	*OBS[SPREAD GLOTTIS]	*OBS[VOICE]
≫	≫	≫
FAITHFULNESS	FAITHFULNESS	*OBS[SPREAD GLOTTIS]

Table 19: Ranking difference between L1 Meiteilon, L2 Hindi of Meiteilon and L1 Hindi

6 Conclusion

In this paper, we show that laryngeal systems interact at phonological as well as phonetic levels in a second language scenario. At both levels, existing knowledge of L1 interfaces with L2 segmental recognition. This is reflected in our results where the Meiteilon speakers can identify the existing T-TH contrast more accurately than the absent contrasts D-DH. Further, Meiteilon speakers may recruit L1 specific f0 cue to perceive the VOT based L2 voicing contrast. These perceptual adjustments, nonetheless, lead to the acquisition of new laryngeal contrasts, which we formalized in constraint-based Optimality Theoretic models of acquisition.

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