An Investigation of Indian Native Language Phonemic Influences on L2 English Pronunciations

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Abstract

Speech systems are sensitive to accent variations. This is a challenge in India, which has numerous languages but few linguistic studies on pronunciation variation. The growing number of L2 English speakers reinforces the need to study accents and L1-L2 interactions. We investigate Indian English (IE) accents and report our observations on regional and shared features. Specifically, we observe phonemic variations and phonotactics in speakers' native languages and apply this to their English pronunciations. We demonstrate the influence of 18 Indian languages on IE by comparing native language features with IE pronunciations obtained from literature studies and phonetically annotated speech. Hence, we validate Indian language influences on IE by justifying pronunciation rules from the perspective of Indian language phonology. We obtain a comprehensive description of generalised and region-specific IE characteristics, which facilitates accent adaptation of existing speech systems.

Index Terms: Phonetics and phonology, L1-L2 interaction, Indian English, Pronunciation analysis, Accent adaptation

1. Introduction

India has over 1,600 languages and dialects from five language families – Indo-Aryan, Dravidian, Austro-Asiatic, Tai-Kadai and Tibeto-Burman [1]. Besides languages native to India, English is a lingua franca in education, law and administration [2, 3], gaining importance as a second language. However, existing speech systems cannot handle the increasing English use, as people impose their native language (L1) behaviours on spoken English (L2). These influences result in extensive diversity in spoken English. On the other hand, Indian languages possess similar phonology due to shared region or language family. The diversity of native languages influences English in each region, with the collection of spoken English varieties within India being referred to as *Indian English* (IE).

Many measures have been attempted to handle IE speech. [4, 5] proposed models to automatically extract pronunciation rules mapping American English to IE. [6, 7, 8, 9] described IE data and provided lexicons at different levels of phonetic variation. [10] used voice conversion to generate IE speech, and discovered that the pronunciation model is vital for good performance. Existing linguistic studies describing IE characteristics examined single varieties, failing to handle the full variation. A thorough investigation involving Indian language phonology is crucial. By observing L1 phonology, their influence on L2 English speech can be determined. To address this, we investigate Indian native language influences on English, using a diverse IE corpus [7]. By describing IE behaviour, one can handle un-

seen IE varieties, either adapting existing systems to specific varieties or handling unusual pronunciations due to L1 influence. This also assists in tasks like accent recognition, mispronunciation detection and diagnosis (MDD), and native language recognition. Consequently, this will enable the development of speech applications designed for the diverse varieties of IE.

In this paper, we perform linguistic analysis on IE pronunciation by considering the speakers' native languages. We organise the behaviours of 18 Indian languages using phonemes and phonotactics, apply them to English, and categorise the pronunciations as 'general' or 'regional'. We use Indian language characteristics to validate IE pronunciation rules compiled jointly from data and prior linguistic studies. Hence, we derive linguistic rules to empirically verify intuitions about Indian language influence on IE speech from the perspective of both L1 and L2. Our results can help develop speech systems robust to Indian variation. The general characteristics are helpful for custom lexicons and tasks like Indian accented ASR and TTS; regional characteristics provide detailed accent information for MDD, accent conversion and accented lexicon adaptation.

2. Preliminary Study

Indic TIMIT corpus is considered, with IE speech recordings of 80 L2 speakers of English from different demographic regions with a few Indian states each – East, Northeast, North, Central, West and South [7]. Since state boundaries were linguistically motivated, geopolitical and linguistic boundaries are aligned [11]. Hence, the speakers' native languages are among those prominent in the respective region. Languages were divided into the following, with an equal number of speakers:

- **Group 1**: (East, Northeast) Maithili, Nepali, Oriya, Bengali, Assamese, Dimasa, Mog, Manipuri
- **Group 2**: (North, Central) Malwi, Marwari, Hindi, Punjabi
- **Group 3**: (West) Gujarati, Marathi, Konkani
- **Group 4**: (Upper South) Kannada, Telugu
- **Group 5**: (Lower South) Malayalam, Tamil

Groups 4 and 5 are Dravidian; Manipuri, Mog and Dimasa are Tibeto-Burman; and the rest Indo-Aryan. The Austro-Asiatic family influences Bengali, Assamese and Nepali, and the Indo-Aryan family influences Kannada and Telugu. Assamese is further influenced by the Tibeto-Burman family.

Indic TIMIT also has phonetic transcriptions for 2,342 recordings, annotated by two linguists. A recent study [12] obtained annotations for 15,974 recordings, with over 190 recordings from native speakers (sans Manipuri speakers). These covered the entire TIMIT stimulus material spoken by each region's speakers. Uniform influence from the languages was assumed.

A few works characterised IE pronunciation relative to Re-

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ceived Pronunciation (RP) [13, 14, 15, 16, 17]. [12] analysed the variations of IE against RP by validating pronunciation rules from literature with rules obtained in a data-driven manner from the phonetic transcriptions of 15,974 recordings, and also reporting rules newly derived from the data. The comparison was done at word level between canonical RP transcriptions and manually annotated IE transcriptions. A set of rules describing IE variations relative to RP was obtained and segregated into three categories. These have been consolidated here in Table 1.

- **Category 1**: Rules mentioned in literature which were also obtained from the data-driven approach.
- **Category 2**: Rules obtained from the data-driven approach, but absent from existing literature.
- **Category 3**: Rules which occurred in literature, but were not obtained from the data-driven approach. These were not obtained for either of two reasons – the rules derived from data contradicted those from literature, or the phones mentioned in the rules were absent from the data.

Table 1: *IE pronunciation rules relative to RP. '*' indicates native language specific rules*

No.	Category 1		Category 2		Category 3	
	RP	IE	RP	IE	RP	IE
1	/ɛ/	/e/	/ʊ/	/u/	/n/	/ən/
2	/ʌ/	/ə/	/aʊ/	/au/	*\/ʃ/	/s/
3	/d/, /t/	/ɖ/, /ʈ/	/jʊ/	/u/	*\/v/	/bʰ/
4	/θ/	/t̪ʰ/, /t̪/	/ɜ/	/ər/	*\/f/	/pʰ/
5	/ð/	/d̪/	/ɑ/	/ar/	/oʊ/	/oː/
6	/l/	/əl/	/ɪd/	/eɖ/	/eɪ/	/eː/
7	*\/z/	/s/	/ʃn/	/ʃən/	/ɒ/	/ɔː/
8	*\/ɪ/	/i/	/ən/	/en/	/əʊ/, /ɛə/, /ɪe/, /ɑː/, /ɔː/	-

Although [12] considered a large number of phonetic transcriptions, the rules of Category 2 were absent from literature. This has two possible reasons: (1) existing literature failed to consider all IE varieties; or (2) the new data-driven rules were incorrect. To analyse this, we study the influences of Indian native languages (L1) on IE (L2) and validate the new rules. We also analyse how these influences could result in the rules reported in literature as seen in Categories 1 and 3. In our analysis, we consider the data-driven study as representative of the full population of native speakers for each language.

3. Observations

To analyse L1 influence on IE (L2), we study L1 sound properties. We posit that observing L1 sounds and their changes provides insights into pronunciation variations in L2. Hence, we study each language individually and in relation to geographically or genealogically close languages. We study L1 phonemes to understand fundamental variations, and categorise phonemes based on their occurrence; the greater the number of languages with a phoneme, the greater the salience of the phoneme in the L2 accent. We also study L1 phoneme interactions via phonotactics, which determines valid phoneme sequences. Speakers enforce L1 phonotactics on L2 speech, so by observing these we can understand pronunciation variations in L2 due to L1.

Table 2 details the 18 native Indian languages with their group, region of origin, language family, and phoneme count.

Table 2: *Native Indian languages of the speakers*

Region	Lang. Family	L1	$n(L1)$
East	Tibeto-Burman	Dimasa	21
		Mog	36
		Maithili	56
East, Northeast	Indo-Aryan	Oriya	49
		Bengali	47
Northeast		Assamese	40
		Nepali	46
North	Indo-Aryan	Punjabi	51
		Marwari	50
North, Central		Hindi	55
Central		Malwi	46
West	Indo-Aryan	Gujarati	47
		Marathi	48
		Konkani	55
Upper South	Dravidian	Kannada	50
		Telugu	55
Lower South	Dravidian	Malayalam	54
		Tamil	37

3.1. General characteristics

Most major Indian languages show an overlap in their phoneme inventories, including those here [18]. We call the shared properties general characteristics. Some examples are the existence of retroflex (/ʈ/, /ɖ/) and dental (/t̪/, /d̪/) stops in place of alveolar stops (/t/, /d/) and dental fricatives (/θ/, /ð/), and the phonemic aspiration of consonants. Indian languages also possess a greater number of vowels, though there is not much overlap with native English vowels. Additionally, Indian languages have syllabic orthography with the inherent vowel schwa (/ə/).

Figure 1 shows the frequency corresponding to the occurrence of phonemes in the 18 Indian languages. The phonemes are arranged in orthographic convention with vowels followed by consonants. The stops are arranged by place of articulation (velar, palatal, retroflex, dental, bilabial) and glottal characteristics (unvoiced-unaspirated, unvoiced-aspirated, voiced-unaspirated, voiced-aspirated)[1]. In the figure, the left side, "General", refers to the common phonemes part of the phoneme inventories of most Indian languages. The right side, "Regional & Other", includes region-specific and foreign language phonemes. Borrowed phonemes (e.g. Perso-Arabic /q/) and regional phonemes (e.g. Bengali vowel /oi/) are kept parallel associated standard phonemes (/k/ and /ai/ respectively).

In total, 70 unique phonemes were observed in the 18 languages. After noting the number of languages each phoneme occurred in, we calculated the percentile to determine their degree of prevalence in Indian languages. This indicates whether the phoneme is general, frequent or rare, by applying a uniform threshold on their frequencies. In this case, the top one-third ($\geq$66.7 percentile) phonemes occurred in 16 or more languages and the middle one-third ($\geq$33.3 percentile) phonemes occurred

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[1]The second row of stops contains postalveolar affricates, but is kept with the stops to keep consistent with the nasals.

GENERAL						REGIONAL & OTHER				
VOWELS										
/ʌ/ 15	/a:/ 17	/i/ 18	/i:/ 16	/u/ 18	/u:/ 16	/ɒ/ 6				
/e/ 17	/e:/ 7	/ai/ 11				/æ/ 5	/ɛ:/ 7	/oi/ 3		
/o/ 17	/o:/ 7	/au/ 13						/ɔ:/ 6		
VOCALICS										
/r̩/ 15	/r̩:/ 6	/l̩/ 4	/l̩:/ 3							
STOPS										
/k/ 17	/kʰ/ 17	/g/ 17	/gʰ/ 15	/ŋ/ 18		/q/ 2	/x/ 5	/ɢ/ 2	/ɣ/ 2	
/tʃ/ 16	/tʃʰ/ 15	/dʒ/ 16	/dʒʰ/ 14	/ɲ/ 16				/z/ 16	/ʑ/ 3	
/ʈ/ 16	/ʈʰ/ 15	/ɖ/ 15	/ɖʰ/ 15	/ɳ/ 16		/t̪/ 2		/ɽ/ 7	/ɽʰ/ 6	/n̠/ 2
/t̪/ 17	/t̪ʰ/ 17	/d̪/ 17	/d̪ʰ/ 15	/n/ 18						
/p/ 17	/pʰ/ 17	/b/ 17	/bʰ/ 15	/m/ 18			/f/ 13			
SEMIVOWELS										
/j/ 18	/r/ 18	/l/ 18	/ʋ/ 17			/ɾ/ 3	/ɭ/ 10	/ɻ/ 2		
FRICATIVES										
/ʃ/ 15	/ʂ/ 12	/s/ 17	/ɦ/ 18							
AFFRICATES										
/t͡s/ 1	/d͡z/ 1									

Figure 1: *Phonemes with their frequencies in Indian languages (dark blue: high; medium blue: moderate; light blue: low)*

in 10 or more languages, while the bottom one-third phonemes occurred in fewer than 10 languages. In the figure, darker shade implies a higher frequency of occurrence of the phoneme. Of the 70 phonemes, 9 phonemes occurred in all 18 languages; surprisingly only 2 of these were vowels.

Despite many similarities, Indian languages also have features distinct from general characteristics, like tonality, phonemic stress, and vowel harmony. The greatest reason for deviation is difference in phoneme inventories – seen in native speakers of Tibeto-Burman languages (Mog and Dimasa), whose English is distinct from that of other Indian languages.

3.2. Regional characteristics

We consider L2 English speech by L1 Indian language speakers from each region. The languages of a region are expected to exhibit similarities due to either geography or genealogy. They do not typically deviate from the general characteristics, but each region exhibits some unique features. Further, the behaviour of a few languages differs from the rest in the region. This could be due to genealogy and the influence of neighbouring languages.

Lower South The prominent characteristics of Malayalam and Tamil are *vowel length distinction*, and the *lack of phonemic aspiration* [19]. While Malayalam orthography has both aspirated and unaspirated consonants, pronunciation of the aspiration does not affect communication and is understood from context. On the other hand, Tamil lacks aspirated consonants entirely. The Tamil character set also lacks the provision for voiced consonants; all such sounds occur due to the language phonotactics [20, 21]. Both languages possess several consonants (mostly *trills and flaps* like /ʈ/, /n̠/, /ɾ/, /ɭ/), which are not observed in other Indian languages [22].

Upper South As in the Lower South, Telugu and Kannada exhibit *vowel length distinction* and *lack phonemic aspiration* [19]. Both are similar to Malayalam, since aspirated consonants exist in their orthographies but are undifferentiated in speech. Word-initial *vowels are also sometimes preceded by semivowels*. For example, front vowels /i/ and /e/ are preceded by /j/, and back vowels /u/ and /o/ are preceded by /ʋ/. Telugu exhibits vowel harmony with /u/ [23], and also fre-

quent voicing of medial consonants similar to Tamil [24].

West The Western languages, Konkani, Marathi and Gujarati, exhibit *schwa deletion* in a limited form, occurring word-finally in all, but also word-medially in Gujarati [25]. Konkani exhibits vowel length distinction (Marathi does so only in orthography) and is also the only language with a different inherent vowel /ə/. Other unique properties are schwa fronting in Gujarati [26], lack of vowel nasalisation in Marathi, and consonant palatalisation in Konkani [27].

North and Central Like Gujarati, these languages (Malwi, Marwari, Hindi and Punjabi) possess both *vowel nasalisation* as well as word-medial and word-final *schwa deletion* [25]. Hindi is more similar to Gujarati than the other languages, as it exhibits schwa fronting [28]. The commonality between them, observed across regions, can be attributed to close genealogical relations. Punjabi is distinct from the others due to tonality, gemination of consonants, and a unique form of vowel contrast. Punjabi vowels exist in three distinct groups (front, central, back), contrasted primarily by quality (central or peripheral) and secondarily by vowel length [29].

East and Northeast Unlike other groups, this has three further segments. The first (Maithili and Nepali) exhibits the general characteristics with the addition of *interchangeable vowels and semivowels* [30, 31]. The second segment (Oriya, Bengali and Assamese) possesses a *different inherent vowel /ɔ/* [25]. Both segments also exhibit limited *schwa deletion* and *vowel nasalisation*. The third segment (Mog and Dimasa) differs considerably [32, 33] – the languages have *reduced phoneme inventories* compared to other regional languages, with fewer vowels and consonants. They also have different phonotactics with stricter sound rules [34, 35, 36, 37, 38, 39]. Thus, their phonemes and behaviour are quite distinct. Due to geographical proximity to them, Assamese also bears some of their characteristics, especially the different consonants and vowel harmony [40, 41].

On observing South, it is clear that **non-phonemic aspiration**, **vowel length distinction** and **consonant voicing** are properties characteristic of Dravidian languages, notwithstanding region. Comparison of West, Central, North and East indicates

that Indo-Aryan characteristics are **schwa deletion** and **vowel nasalisation**, with each region showing unique properties. In contrast, Tibeto-Burman languages here are characterised only by a **reduced phoneme set**. The impact of geographical proximity is evident in the regional features common within each group (like the different inherent vowel of Eastern Indo-Aryan languages), and also in the properties shared by unrelated but neighbouring languages. As an example, the vowel harmony in Assamese is due to Tibeto-Burman influence. Dravidian influence on Konkani and Marathi is also clear in their vowel length distinction and lack of vowel nasalisation respectively.

4. Discussion

We hypothesise that IE pronunciation variation (in Table 1) is due to L1 influence and exploit L1 behaviour to understand it. Since the pronunciation rules are derived from data that is unevenly distributed among the speakers of the 18 Indian languages, they are subject to statistical bias from languages with more speakers. By linking recorded IE behaviour to the characteristics observed in L1, we can attribute these characteristics to the number of associated languages, instead of number of speakers, which is balanced only by region. Consequently, we can determine whether these characteristics are general or region-specific. Thus, the rules verified against L1 phonotactics will accurately describe the speakers' behaviour.[2]

4.1. Pronunciation rules verified by L1 and L2

The first observation is consonant substitution. Indian languages lack alveolar stops and dental fricatives, so speakers substitute these with retroflex and dental stops, respectively. This is well accepted, corroborated by both data-driven and literature study of IE ($C_1R_{3,4,5}$) and examination of Indian languages (Section 3.1). Thus, these are general IE characteristics.

We also observe several regional characteristics. The prime example is interchangeable voiced and unvoiced consonants, from the data analysis (C_1R_7). Native language study allowed us to verify this as a behaviour of Dravidian language speakers, especially for Tamil or Telugu (Section 3.2). This substitution is frequent due to a large speaker fraction; however, since the number of languages causing this is lower, the characteristic is not general but regional to Upper and Lower South. Lack of aspiration is another regional characteristic, which we again observe in Dravidian language speakers – the speakers substitute the unvoiced dental fricative /θ/ with the unvoiced dental stop /t̪/, while speakers of most other Indian languages use the aspirated unvoiced dental stop /t̪ h/ (C_1R_4).

The main vowel substitutions were the replacement of diphthongs with monophthongs. This is because, despite Indian languages having several diphthongs, few are shared with RP. Thus, they are approximated using known vowels. Prior literature predicted the resultant phones as long vowels, but the rules derived from data showed the substitutions as short vowels ($C_3R_{5,6,7}$). This seems surprising, but observing the native languages justifies the outcome. Of the 18 languages, only one-third distinguish vowel length, making the observed short vowels and predicted long vowels equivalent. Hence, for a general characteristic, it is more important to correctly identify the substituting vowel – usually, the diphthong's first vowel.

The remaining vowel substitutions are as expected, where the vowel used has the most shared properties. For example, most Indian speakers tend to use tense vowels /e/, /ə/, /i/ and /u/

in the place of corresponding lax vowels /ɛ/, /ʌ/, /ɪ/ and /ʊ/. This is seen in the preliminary study, in Table 1 ($C_1R_{1,2,8}$; $C_2R_{1,2}$). All vowel substitution rules are general as they are validated by the general characteristics of the native languages, regional behaviours being statistically insignificant.

4.2. Discarded pronunciation rules

Several predicted substitutions contradicted observed native language behaviours and were discarded. The first is palatalisation, i.e. the insertion of semivowel /j/ (C_2R_3). This is present in transcriptions but only occurs to a minor degree in the English words. Being almost non-existent in Indian languages, palatalisation is not distinguished from non-palatals. As a result, native Indian language speakers only perceive the distinct pronunciation of palatals. This direction requires future exploration for a better conclusion, hence we discard the substitution in this study. Similarly, the limited data and literature regarding gemination and the inconsistent occurrence of schwa insertion (C_1R_6; C_2R_7; C_3R_1) could not be validated from the perspective of L1-L2 interactions. Several rules were excluded due to lack of definite cause ($C_2R_{4,5,6,8}$).

Another kind of substitution discarded was the set of rules which could not be verified by data analysis, despite being observed in descriptions of both IE and L1. We also discarded certain behaviours predicted by L1 phonotactics which were not observed in the data-driven study. The regional characteristics of Oriya, Bengali and Assamese (in Section 3.2), suggested the undifferentiated use of /b/, /v/, /ʋ/, and /w/ in English (C_3R_3). Additionally, literature suggested that Telugu speakers tend to substitute /ʃ/ with /s/ (C_3R_2), and that Gujarati and Marathi speakers tend to substitute /f/ with /p h/ (C_3R_4). However, contrary to expectation, L2 pronunciations in the preliminary study are consistent with those of other regions.

5. Conclusions

Modified lexicons are a popular solution to non-native accents. An IE pronunciation dictionary [9] used basic substitution to convert CMU dictionary [42] codes to the Common Phone Set (CPS) [43], phonetic codes used in Indian multilingual speech systems. However, simple measures fail to deal with IE variation or strong regional accents. Thus, a larger dictionary inclusive of all regional varieties is essential. In this paper, we studied the phonemic variations and phonotactics of 18 Indian languages and analysed them against a data-driven study of IE pronunciations. From this, we compiled the linguistic characteristics which cause general and region-specific pronunciation variations in IE, validated with respect to both L1 and L2.

Hence, we empirically verify intuitions about native language influence on IE. Additionally, our linguistic profile provides details about IE speech which makes it valuable for developing speech systems robust to Indian context. The general characteristics are useful for handling unseen Indian accents, and regional characteristics are useful for either adapting existing systems to IE varieties or handling unusual pronunciations due to native language influence. The linguistic profile can further assist in tasks like accent recognition, mispronunciation detection and diagnosis (MDD), and native language recognition.

The current analysis was done on phonemic space, but future efforts could explore the phonetic space by observing allophones in context. Another area is the development of a phonotactic similarity index, allowing for qualitative assessment of phonemic processes and their influence on other languages.

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[2]We use C_xRy for "Category x, Rule y of Table 1".

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