Phonation differences in the stop laryngeal contrasts of Jangli (Indo-Aryan)

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Abstract

Jangli is an under-studied Indo-Aryan language spoken in Punjab, Pakistan. The present study investigates phonation differences in Jangli's four-way stop laryngeal contrast (voiceless unaspirated, voiceless aspirated, voiced unaspirated, and voiced aspirated). A wide range of acoustic correlates were measured including H1*-H2*, H1*-A1*, H1*-A2*, and H1*-A3*. The findings indicated that voiceless aspirated and voiced aspirated stops are characterized by higher H1*-H2*, H1*-A1*, H1*-A2*, and H1*-A3*, compared to voiceless unaspirated and voiced unaspirated stops. These results suggest that Jangli is among those languages which have a raising effect of aspiration on the spectral tilt onsets of the following vowels. The classification results showed that H1*-H2* is the most important acoustic correlate for distinguishing the four laryngeal categories of Jangli. The findings of this study will contribute to the phonetic and phonological typology of the rich laryngeal contrasts of Indo-Aryan languages.

1 Introduction

Jangli is an Indo-Aryan language spoken by small communities scattered around Punjab, Pakistan. It shares lexicon with both Punjabi and Siraiki. However, unlike both of these languages which have three or five laryngeal categories (Hussain et al. 2019), Jangli contrasts four laryngeal categories (e.g., /p p^h b $b^ɦ$/) at five places of articulation (bilabial, dental, retroflex, palatal, and velar). There are few phonetic descriptions of Jangli which mainly investigated the durational properties of the four laryngeal categories and showed that younger Jangli speakers are losing the aspiration contrast in voiced stops (Hussain 2018). Jangli speakers are surrounded by Punjabi speakers. The voiced aspirated stops of Jangli are disappearing as a result of intensive contact with Punjabi which has already lost voiced aspirates and developed contrastive tones (Bhatia 1975, Bhardwaj 2016, Hussain et al. 2019). The current study investigates the phonation differences in the four laryngeal categories of Jangli (voiceless unaspirated, voiceless aspirated, voiced unaspirated, and voiced aspirated). In particular, we ask whether the voiced aspirated stops are merging with the voiceless stops. Moreover, the study examines the importance and contributions of various spectral tilt measures in the classification of the four laryngeal categories of Jangli.

In the current phonetic literature, spectral tilt or phonation measures (H1*-H2*, H1*-A1*, H1*-A2*, and H1*-A3*) have been extensively used to investigate the effect of voicing and/or aspiration on the neighboring vowels (Esposito 2006, Kirby 2018a, Hussain 2021a,b). Among the four spectral tilt measures, H1*-H2* is the most widely-studied acoustic correlate (Brunelle et al. 2019, Kirby and Hyslop 2019). Aspirated consonants are characterized by higher spectral tilt at the onset of the following vowels than unaspirated consonants (Gao et al. 2020, Seyfarth and Garellek 2018). For example, in Dzongkha, aspirated consonants show higher H1*-H2* and H1*-A1* at the onset of the following

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vowels compared to voiced unaspirated consonants (Kirby and Hyslop 2019). Similarly, in other languages of the world, aspirated consonants have been reported to show higher H1*-H2* at vowel onsets (Burushaski: Hussain 2021b; Hindi/Urdu: Schertz and Khan 2020; Gujarati: Esposito et al. 2020; Marathi: Dmitrieva and Dutta 2020, Berkson 2019).

A number of studies have also discussed the role of different acoustic correlates in the classification of laryngeal contrasts. In Burushaski, for example, H1*-H2* and Voice Onset Time (VOT) are the best descriptors of the three laryngeal categories (voiceless unaspirated, voiceless aspirated, and voiced unaspirated; Hussain 2021b). Durational differences among the four laryngeal categories of Jangli have already been examined (Hussain 2018). The aim of the current study is to investigate the phonation differences in the four laryngeal categories of Jangli. It is predicted that aspirated stops (voiceless and voiced) would be characterized by higher spectral tilt than unaspirated stops (Kirby and Hyslop 2019, Seyfarth and Garellek 2018). H1*-H2* would be the most important variable in distinguishing aspirated stops from unaspirated stops (Hussain 2021b, Garellek 2019).

2 Methods

2.1 Speakers

Five male Jangli speakers (range: 20–42 years; mean age: 30) were recruited from Faisalabad, Pakistan. All the participants were native speakers of Jangli and could also speak Punjabi and Urdu.

2.2 Speech materials and recording procedure

A word list of Jangli was created, where word-initial C represented a stop consonant (/p pʰ b bʱ t̪ t̪ʰ d̪ d̪ʱ ʈ ʈʰ ɖ ɖʱ ʧ ʧʰ dʒ dʒʱ k kʰ g gʱ/), followed by vowel /a/ (e.g., /pa/, /pʰa/). A portable Zoom digital voice recorder with a built-in microphone was used to make audio recordings (44.1 kHz, encoded in 16-bit). Each word was repeated five times. All the words were produced in citation form.

2.3 Acoustic and statistical analyses

A total of 500 tokens were segmented in Praat (Boersma and Weenink 2007; 6 tokens were excluded due to background noise, mispronunciations, and/or missing repetitions; 494 tokens were used for the final analysis). H1*-H2*, H1*-A1*, H1*-A2*, and H1*-A3* were measured from the onset to the mid-point of the following vowel /a/, using Praat-Sauce (Kirby 2018b).[2] The statistical analyses of the data were conducted in *R* (R Core Team 2013). Separate Linear Mixed Effects Regression (LMER) models were performed for all the acoustic measures, using the *lme4* package (Bates et al. 2015). The *lmerTest* package was used to obtain p values for all the LMER models with Satterthwaite approximations for degrees of freedom (Kuznetsova et al. 2017). In all the LMER models, Laryngeal (voiceless unaspirated, voiceless aspirated, voiced unaspirated, and voiced aspirated) was included as a fixed factor, and Speaker as a random factor (alpha value: $p =$

[2] Asterisks indicate that the measurements were corrected for the boosting effects of formants (Iseli et al. 2007).

0.05). By-speaker random slopes for Laryngeal were included in all the models. Pairwise comparisons were performed using the *emmeans* package (Lenth 2016). Classification of the four laryngeal categories was performed using the *rpart* package (Therneau and Atkinson 2019) and *predict()* function in R. The key information regarding a laryngeal category is encoded at the onset of the following vowel. Therefore, all the LMER and classification modeling are based on the onset of the following vowel. Results are collapsed across places of articulation.

3 Results

Figure 1 presents spectral tilt onsets (H1*-H2*, H1*-A1*, H1*-A2*, and H1*-A3*) across four laryngeal categories of Jangli. Table 1 shows pairwise comparisons. The results indicate that H1*-H2* onsets reliably differentiated voiceless unaspirated vs. voiceless aspirated ($p < 0.001$), voiceless unaspirated vs. voiced unaspirated ($p < 0.001$), voiceless aspirated vs. voiced unaspirated ($p < 0.001$), voiceless aspirated vs. voiced aspirated ($p < 0.001$), and voiced unaspirated vs. voiced aspirated ($p < 0.001$). However, there were no significant differences in H1*-H2* onsets between voiceless unaspirated vs. voiced aspirated ($p = 0.907$). It can be observed that voiceless aspirated stops were characterized by the highest H1*-H2* onsets, followed by voiced aspirated, voiceless unaspirated, and voiced unaspirated stops (see Figure 1). This suggests that both unaspirated categories (voiceless and voiced) entailed lower H1*-H2* onsets than the two aspirated categories.

The H1*-A1* onsets distinguished voiceless unaspirated vs. voiceless aspirated ($p < 0.001$), voiceless unaspirated vs. voiced aspirated ($p = 0.007$), voiceless aspirated vs. voiced unaspirated ($p < 0.001$), voiceless aspirated vs. voiced aspirated ($p < 0.001$), and voiced unaspirated vs. voiced aspirated ($p = 0.042$). However, H1*-A1* onsets did not differentiate voiceless unaspirated vs. voiced unaspirated ($p = 0.701$). Voiceless aspirated stops exhibited the highest H1*-A1* onsets, and voiceless unaspirated stops were characterized by the lowest H1*-A1* onsets (voiceless aspirated > voiced aspirated > voiced unaspirated > voiceless unaspirated). This again suggests that both unaspirated categories (voiceless and voiced) entailed lower H1*-A1* onsets than the two aspirated categories.

The H1*-A2* onsets reliably differentiated voiceless unaspirated vs. voiceless aspirated ($p < 0.001$), voiceless unaspirated vs. voiced aspirated ($p < 0.001$), voiceless aspirated vs. voiced unaspirated ($p < 0.001$), voiceless aspirated vs. voiced aspirated ($p < 0.001$), and voiced unaspirated vs. voiced aspirated ($p = 0.042$). However, H1*-A2* onsets did not differentiate voiceless unaspirated vs. voiced unaspirated ($p = 0.991$). These results are also reflected in Figure 1. Voiceless aspirated stops exhibited the highest H1*-A2* onsets, and voiceless unaspirated stops showed the lowest H1*-A2* onsets. The H1*-A2* onsets of the two unaspirated categories (voiceless and voiced) appeared to be merged but a large difference can be observed around 20% and 30% of the vowel duration.

The H1*-A3* onsets distinguished voiceless unaspirated vs. voiceless aspirated ($p < 0.001$), voiceless unaspirated vs. voiced aspirated ($p < 0.001$), voiceless aspirated vs. voiced unaspirated ($p < 0.001$), voiceless aspirated vs. voiced aspirated ($p < 0.001$), and voiced unaspirated vs. voiced aspirated ($p < 0.001$). However, there were no significant differences in the H1*-A3* onsets of voiceless unaspirated vs. voiced unaspirated ($p = 0.988$). Voiceless aspirated stops exhibited the highest H1*-A3* onsets, and voiceless

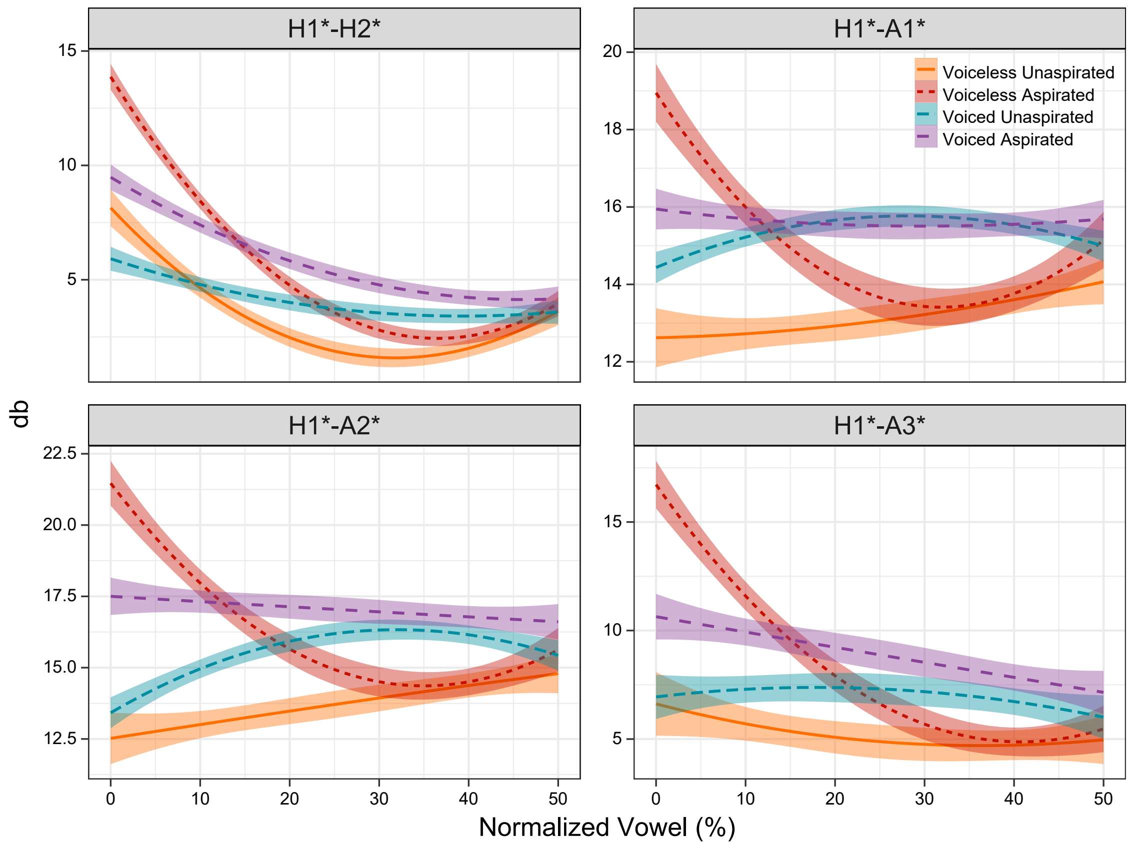

Figure 1: Spectral tilt of Jangli's stop consonants across four laryngeal categories. X-axes indicate normalized time (%) of the following vowels. Ribbons show 95% confidence intervals.

unaspirated stops entailed the lowest H1*-A3* onsets. Nevertheless, voiceless unaspirated and voiced unaspirated stops showed no clear differences at the onsets.

It can be observed that the voiceless aspirated category consistently showed the highest H1*-H2*, H1*-A1*, H1*-A2*, and H1*-A3*. The most striking results of the current study are the realization of voiced aspirated stops with higher spectral tilt onsets than voiced unaspirated stops. It should also be noted that the key differences in all the four spectral tilt measures are neutralized at the offset. This indicates that if there are phonation differences, they are more likely to appear at the onset of the following vowels.

3.1 Classification of laryngeal categories

Figure 2 shows the classification matrix of the four laryngeal categories of Jangli. The rate of correct classifications of voiceless unaspirated stops was 21%. However, 19% of the voiceless unaspirated stops were misclassified as voiceless aspirated stops, 41% as voiced unaspirated stops, and 19% as voiced aspirated stops. A large number of voiceless aspirated stops (87%) were correctly classified as voiceless aspirated stops, 2% as voiceless unaspirated, 5% as voiced unaspirated, and 6% as voiced aspirated stops. The rate of correct classifications of voiced unaspirated stops was 83%. The classification rate of the voiced aspirated stops was only 48%, and this category was frequently misclassified as voiceless aspirated (31%). These findings suggest that voiceless unaspirated stops were the least correctly classified stops in Jangli. Figure 3 shows that H1*-H2* is the most

Table 1: Pairwise comparisons of the four laryngeal categories of Jangli (significant results in bold).

	H1*-H2*				
Comparisons	Est.	SE	*df*	*t*	*p*
Voiceless Unaspirated vs. Voiceless Aspirated	-4.49	0.66	394	-6.85	< **0.001**
Voiceless Unaspirated vs. Voiced Unaspirated	3.96	0.66	394	6.04	< **0.001**
Voiceless Unaspirated vs. Voiced Aspirated	0.45	0.67	394	0.67	= 0.907
Voiceless Aspirated vs. Voiced Unaspirated	8.45	0.53	394	15.92	< **0.001**
Voiceless Aspirated vs. Voiced Aspirated	4.94	0.54	394	9.08	< **0.001**
Voiced Unaspirated vs. Voiced Aspirated	-3.51	0.54	394	-6.46	< **0.001**
	H1*-A1*				
Comparisons	Est.	SE	*df*	*t*	*p*
Voiceless Unaspirated vs. Voiceless Aspirated	-7.21	1.04	395	-6.91	< **0.001**
Voiceless Unaspirated vs. Voiced Unaspirated	-1.13	1.05	396	-1.08	= 0.701
Voiceless Unaspirated vs. Voiced Aspirated	-3.42	1.06	395	-3.23	**= 0.007**
Voiceless Aspirated vs. Voiced Unaspirated	6.08	0.85	394	7.18	< **0.001**
Voiceless Aspirated vs. Voiced Aspirated	3.79	0.87	395	4.37	< **0.001**
Voiced Unaspirated vs. Voiced Aspirated	-2.29	0.87	395	-2.65	**= 0.042**
	H1*-A2*				
Comparisons	Est.	SE	*df*	*t*	*p*
Voiceless Unaspirated vs. Voiceless Aspirated	-9.64	1.02	395	-9.42	< **0.001**
Voiceless Unaspirated vs. Voiced Unaspirated	-0.30	1.03	395	-0.29	= 0.991
Voiceless Unaspirated vs. Voiced Aspirated	-4.81	1.04	395	-4.63	< **0.001**
Voiceless Aspirated vs. Voiced Unaspirated	9.34	0.83	394	11.26	< **0.001**
Voiceless Aspirated vs. Voiced Aspirated	4.84	0.85	395	5.69	< **0.001**
Voiced Unaspirated vs. Voiced Aspirated	-4.51	0.85	395	-5.30	< **0.001**
	H1*-A3*				
Comparisons	Est.	SE	*df*	*t*	*p*
Voiceless Unaspirated vs. Voiceless Aspirated	-11.18	1.14	394	-9.82	< **0.001**
Voiceless Unaspirated vs. Voiced Unaspirated	-0.37	1.14	394	-0.32	= 0.988
Voiceless Unaspirated vs. Voiced Aspirated	-4.46	1.16	394	-3.86	< **0.001**
Voiceless Aspirated vs. Voiced Unaspirated	10.81	0.92	394	11.71	< **0.001**
Voiceless Aspirated vs. Voiced Aspirated	6.71	0.95	394	7.10	< **0.001**
Voiced Unaspirated vs. Voiced Aspirated	-4.10	0.95	394	-4.33	< **0.001**

important whereas H1*-A2* and H1*-A3* are the least important acoustic correlates for distinguishing the four laryngeal categories of Jangli (variable importance: H1*-H2* > H1*-A1* > H1*-A2* = H1*-A3*).

4 Discussion

The current study investigated phonation differences in the four laryngeal categories of Jangli (voiceless unaspirated, voiceless aspirated, voiced unaspirated, and voiced aspirated). The importance and contributions of various spectral tilt measures were examined. The findings indicate that voiceless aspirated and voiced aspirated stops are characterized by higher H1*-H2*, H1*-A1*, H1*-A2*, and H1*-A3* than voiceless unaspirated and voiced unaspirated stops. Classification results show that H1*-H2* is the most important acoustic correlate for distinguishing the four laryngeal categories of Jangli. These results suggest that Jangli is among those languages which have a raising effect of aspiration on the spectral tilt onsets of the following vowels. Other typologically-distinct languages of the world have shown similar effects of the word-initial aspirated stops on the following vowels (Burushaski: Hussain 2021b; Chru: Brunelle et al. 2019; Dzongkha: Kirby and Hyslop 2019; Madurese: Misnadin and Kirby 2020, Misnadin 2016; Shina: Hussain 2021a; Yerevan Armenian: Seyfarth and Garellek 2018). In some languages, breathiness may appear as a distinctive phonological feature of vowels. It might be the case that word-initial aspirated stops gradually lose their defining feature of aspiration but its traces are still found on the following vowels. The above-mentioned languages which show the effect of aspiration on the following vowels, may, at some point, develop

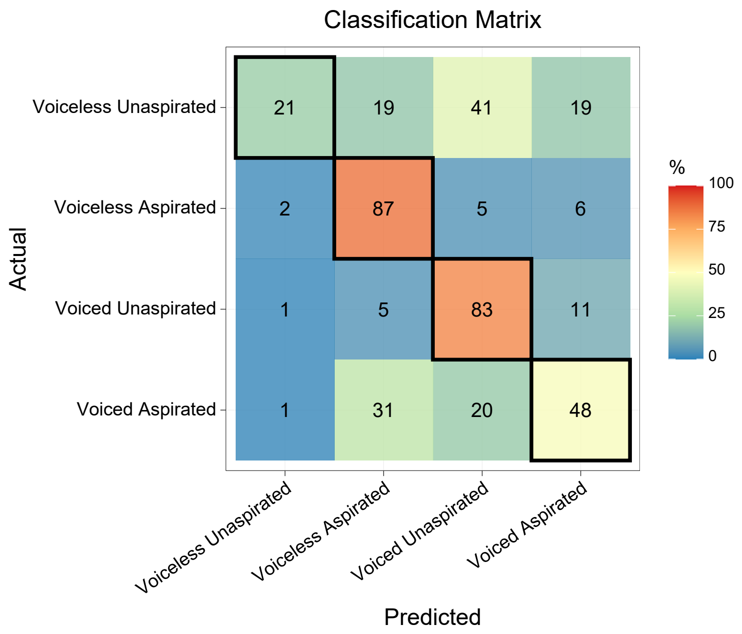

Figure 2: Classification matrix of Jangli's four laryngeal categories. Values represent the classification rates in percentage (%).

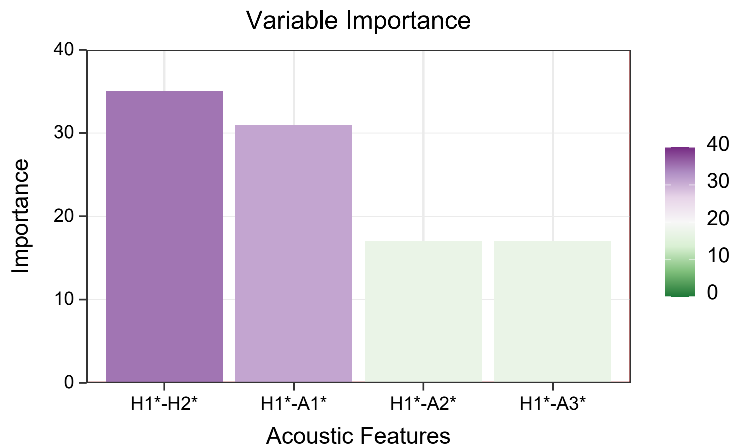

Figure 3: Variable importance generated by the *rpart()* classification model (importance values are unitless).

contrastive breathy vowels or tones (Hussain 2018, 2021a).

Previous studies of Jangli noted overlap among the VOTs of voiced aspirated and voiceless (un)aspirated categories and suggested that Jangli is in the process of collapsing the voiced aspirated stops with the voiceless (un)aspirated stops (Hussain 2018). The results of spectral tilt in the current study further confirm this ongoing sound change in Jangli. The younger generation of Jangli speakers is also fluent in Punjabi which has a three-way laryngeal contrast. The voiced aspirated category of Punjabi was merged with either the voiceless or voiced categories, depending on the position of the stop consonant in a word (Bhatia 1975, Bowden 2012, Hussain et al. 2019, Hussain 2020). The voiced aspirated category of Jangli is frequently misclassified as voiceless aspirated which suggests that at some point Jangli will also lose the voiced aspirated category, and will probably develop contrastive tones. The results of this study will contribute to the phonetic description of the rich laryngeal systems of Indo-Aryan languages which are scarcely documented in the current phonetic literature.

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