


ACOUSTICS OF TONE IN INDIAN PUNJABI

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ABSTRACT

This study explores the effects of tone on fundamental frequency in Punjabi, one of few Indo-European languages to have lexical tone. Previous studies present conflicting claims regarding the direction of pitch movement, the location in the word of the tone, and interactions between tone and prosodic structure. For the present study, Punjabi speakers of India were presented with a production task, based on a metrically balanced corpus. Results show that Punjabi tone tends to be most fully realized on stressed syllables, where it occurs as a significant fall in fundamental frequency. On non-stressed syllables, tone can be realized as falling, high, or may not be realized. In some cases, syllable length plays a role in determining where in the word the pitch falls. There are implications for the diachronic trajectory of tonogenesis, which was concomitant with the loss of murmured stops in Punjabi. First, the intrinsic pitch lowering of murmured voicing has led to a falling tone in prosodically prominent positions. Second, tonogenesis in Punjabi has resulted in a privative tone system, in which syllables are either tonal or toneless, rather than a system in which there are multiple tone values, or in which most syllables are specified for tone.

1. INTRODUCTION

Punjabi is one of few Indo-European languages with lexical tone, and is the largest language in a continuum of Indo-Aryan tonal varieties in northwest India and Pakistan (Bailey 1914; Baart 2014). The following minimal pairs, taken from the results of this study, demonstrate the phonemic contrast between a default pitch pattern and a falling pitch on the first syllable of a word. Falling pitch is marked with IPA tone letter [[˥]] (International Phonetic Association 2015).

/paapa/ [pa˥pə] ‘sin’ /paâpa/ [pâpə] ‘steam’
/taana/ [ta˥nə] ‘tune’ /taâna/ [tânə] ‘paddy rice’

Following the definition that in a tone language “an indication of pitch enters into the lexical realization of at least some morphemes” (Hyman 2006), Punjabi qualifies as a tone language. Outside of Punjabi and its neighbouring languages Dogri and Lahnda, tones in Indo-European:

develop[ed] either from a syllabic contraction (as in Scandinavian languages) or from the loss of older laryngeals (as in Lithuanian and Slavic). Punjabi, however, is the only Indo-European language where the tones have developed [. . .] from the loss of a series of initial consonants.
(Haudricourt 1973; cf. Sukač 2013)

The Punjabi tonal distinction arose secondary to the loss of murmured voicing within the obstruent series; thus, ‘steam’ and ‘paddy rice’ are written in Punjabi orthography with murmured initials (ਝ *bh* and ਢ *dh*). Murmur, also known as voiced aspiration, is a typical feature of Indo-Aryan languages, and is often Romanized as *bh*, *dh*, *gh*, etc.

In word-initial position, murmured stops (“*DH”) are reported to have merged with voiceless obstruents (*DH > T), while in non-initial position, they have become plain voiced (*DH > D) (Kanwal & Ritchart 2015). This study focuses on the acoustic properties of plosive-initial syllables in order to uncover the fundamental frequency (F0) effects of historically voiced aspirates, comparing these sounds with F0 properties of T, TH, and D.

Previous works vary in their description of Punjabi tone realization. Claims in the literature about the pitch patterns of Punjabi tone include low (Bhatia 1975, 1993; Gill 1996; Shackle 2003), rising (Malik 1996), falling (Bowden 2012; Kanwal & Ritchart 2015), or both rising and falling (Nara 2015). In spite of differing analyses, the above works all conclude that tone in Punjabi arose from the merger of *DH with non-aspirated stops.

Crosslinguistically, voiced aspirated stops have an effect on the subsequent vowel that can be described as breathy (Gordon & Ladefoged 2001) or murmured (Pandit 1957; Fischer-Jorgensen 1967). Breathy/murmured voice is articulated with vocal folds that are pushed together with less force than during modal voice, and “have little longitudinal tension” (Gordon & Ladefoged 2001). There are several acoustic correlates of breathy voice. Relative to modal voice, breathy voice has more “noisy energy” and a more “jagged appearance” to its waveforms (Gordon & Ladefoged 2001). Breathy voice has both a lowered intensity and lowered F0, relative to modal voice. There is an association between breathy voice and low or lowered tone (Hombert et al. 1979; Abramson 2004; Mazaudon 2005). Turbulence in the signal causes individual pitch pulses to be less well individuated in the spectrogram. The leaking air tends to cause random noise in the higher frequency range, and an overall decrease in intensity (Gordon & Ladefoged 2001). Breathy voiced sounds tend to have a steeply falling spectral tilt; that is, the amplitude of F0 tends to be much greater than the second harmonic, or other higher frequency harmonic, relative to modal voice.

Given the tendency of breathy voiced sounds to have lowered F0, and also given that the tones of Punjabi are young enough that their provenance can be seen in the six hundred year old Gurumukhi orthography, it may be expected that Punjabi tones would involve some F0 lowering, a claim that the data support, although there is more to Punjabi tone than lowering.

Recent studies claim that Punjabi metrical structure is relevant to tone realization. Malik (1996) claims that if tone is conditioned by the word-initial consonant, then tone occurs on the first syllable (σ_1). However, if tone is conditioned by the first consonant (C1) of σ_2 , then σ_2 must be stressed in order to receive a tone. Shackle (2003) claims that tone only appears on stressed syllables. Bowden (2012), perhaps the first quantified acoustic study of Punjabi tone, claims that tones occur on heavy syllables (2+ morae), whether word-initial or not. Kanwal and Ritchart’s (2015) production study found that *DH induces falling tone word-initially in disyllables; possible effects of metrical structure were not investigated. In summary, previous studies are not in agreement about either the conditions for and basic F0 trajectory of Punjabi tone, nor about the effect of metrical structure on tone realization.

In the present study, acoustic analysis of a segmentally and prosodically balanced corpus shows that for most Indian Punjabi speakers, tone yields a significant fall in F0, starting from an elevated pitch. Falling tone is most likely to occur in stressed syllables, which are not always word-initial. In non-stressed syllables, tones may be realized as a fall in F0, or by raised F0 with no statistically significant fall. In some cases, tone is not produced.

In the final section of the paper we explore phonological universals that could have contributed to the change from a low tone (still found in one speaker) to the more prevalent high-falling tone pattern on stressed syllables. Surveys of multiple languages find that

sequences of all low pitches are dispreferred (Cahill 2008), and that speakers tend to raise pitches before low tones (Thai: Potisuk et al. 1994; Mandarin Chinese: Xu 1997). Contour tones are disfavoured in prosodically weak positions, and favoured in stronger positions such as stressed syllables (Zhang 2013). These factors seem to have played a role in the development from an apparent low tone into the extant falling tone of stressed syllables.

2. OVERVIEW OF THE TONOGENETIC PROCESS

Tonogenesis (Matisoff 1973) occurs when a phonological distinction is transphonologized. For example, a distinction that is conveyed via consonant voicing, stress, etc., becomes a pitch distinction. For most tonal Indo-European languages (Swedish, Serbo-Croatian, etc.), tone comes from the inherited accent system. However, for Punjabi, and the closely related languages of Dogri and Lahnda, tone has a consonantal origin, as is typical for East Asian languages in which the origins of the tones can be traced, such as Vietnamese (Haudricourt, 1954).

Consonants have inherent effects on the F₀ of contiguous vowels. For example, vowels following voiced initial consonants tend to begin with lower F₀ than vowels that follow voiceless consonants (Hombert et al., 1979; Kingston, 2011; Maran, 1973). If a laryngeal setting distinction is lost in that position, such as loss of voicing in final obstruents, then speakers may enhance the inherent F₀ distinction in order to maintain a salient difference in pronunciation between pairs of words that would otherwise be homophonous.

It has been hypothesized (Thurgood 2002, 2007) that “registrogenesis” is a necessary step in the development of phonemic tone from consonantal properties. Within the context of Southeast Asian linguistics, “register” refers to vocal qualities such as modal, breathy, and creaky. The breathy voiced Tone 2 in Burmese, which comes from loss of voicing on initial obstruents, has a high-falling pitch contour. This tone has undergone registrogenesis, followed by tonogenesis without loss of the breathy feature.

For Punjabi, during the historical period when *DH sounds were pronounced as voiced aspirates, the vowels following these sounds would have been pronounced with breathy or murmured voicing. Breathily or murmured voice tends to lower F₀, due to the slackness of the vocal cords, whereas creaky voice tends to raise F₀ due to tightness of the vocal cords.

Once one or more tones have entered the phonology, they are subject to the phonetic and phonological pressures that are common across the world’s tone systems. For example a Low tone, whatever its origin, could have a high target inserted preceding the Low target, as has been observed for Mandarin Chinese (Xu, 1997). This may be the reason that in Punjabi, while aerodynamic factors would suggest a low tone arising from breathy voicing, falling tone is most frequently observed in the data collected from Indian speakers.

3. METHOD

3.1. Material

Two Punjabi dictionaries (<http://dic.learnpunjabi.org/>, Maṅḍala et al. 1992) were searched for words with target consonants (T, TH, D, *DH) as the C₁ of either the initial, medial, or ultimate syllable. Target initials were drawn from the bilabial, dental, and velar stops. Non-target syllable C₁’s were restricted to stops or sonorants (nasal, lateral /l/, or semi-vowel). Vowels following target consonants were one of /a: a/ [a ə]. For the initial and ultimate conditions, disyllabic words were used. For the medial condition, trisyllables were employed, with the first syllable always consisting of /C+a/. This vowel was chosen because it is the most common vowel in Punjabi. The vowels /i e u o/ were not used due to potential confounding

inherent effects on F0, and the added challenge of constructing a balanced corpus with fewer lexical items.

Words with all four laryngeal settings were chosen (*DH, D, T, TH), so that the study could document any differences in F0 that correlate with changes in laryngeal setting. Target consonants were also balanced among bilabial, dental, and velar places of articulation. Furthermore, the dataset was designed to capture differences due to metrical structure. Stress is reported to occur on the left-most syllable of Punjabi lexical words as the default (Dhillon 2007, 2010). In words where the first two syllables are short-long ($\# \mu . \mu \mu$), stress still tends to fall on the first syllable (Dhillon 2007). Crosslinguistically, metrically prominent positions attract tone, especially high tone (Bickmore 1995; de Lacy 1999) and contour tones (Zhang 2013: 62). Punjabi syllables can be light (μ), heavy ($\mu \mu$), or superheavy ($\mu \mu \mu$, as in /ʃɑːɾ/, [ʃɑːɾ], ‘four’; Dhillon 2007, 2010). Various references cited above suggest that Punjabi tone would be more likely to occur in metrically strong locations, such as stressed syllables, initial syllables, and/or non-short syllables. The study did not test speaker’s perception of stress, but relied on the description in Dhillon (2007). Words were chosen from a varied mora structure in order to yield a dataset that is balanced across the range of possible mora combinations.

Two hundred words fitting the above criteria were chosen, as well as one hundred filler words. The two hundred stimuli were divided into four sub-groups according to disyllabic metrical structures: $\mu . \mu$, $\mu . \mu \mu$, $\mu \mu . \mu$, $\mu \mu . \mu \mu$. Trisyllabic words have an initial monomoraic syllable preceding the above disyllabic pattern. The subgroups are not equal in size, due to varying quantity of available words; the category $\mu . \mu$ has 64 words, $\mu . \mu \mu$ has 57 words, $\mu \mu . \mu$ has 46 words, and $\mu \mu . \mu \mu$ has 33 words. Table 1 exemplifies the sets of words used and their phonological oppositions. The words were printed onto pieces of paper about 10 cm × 14 cm in size. Each card contained one word in Gurumukhi script, and an English gloss.

3.2. Speakers

Five male native speakers of Indian Punjabi were recruited for the study (no fluent female speakers could be located in Taiwan), and were informed in writing of their rights as research subjects. All subjects have a minimum of a college degree and demonstrated proficiency in reading Punjabi. All subjects were born in Punjab state, India except for Speaker 3. Speaker 3 was born in a Punjabi-speaking family and grew up in a Punjabi-speaking neighbourhood in Uttar Pradesh province, where many Punjabi families immigrated after the partition of India. Punjabi is the dominant language he used in daily life until entering college. Each subject grew up in a Punjabi-speaking home, and continues to speak Punjabi regularly with family and friends. No subjects indicated hearing, reading, or speech impairment. Subjects ranged in age from 26 to 47 years old (mean = 32.2, s.d. = 8.7). Their ages and places of birth are presented in Table 2.

3.3. Recordings

Stimuli and fillers were shown in Punjabi orthography to speakers in pseudo-random order, with two randomized stimuli, followed by one randomized filler. Looking at one stimulus card

Table 1. Examples of stimuli used in study

	$\sigma 1 \mu - \mu$		$\sigma 2 \mu \mu - \mu$	
*DH	/kâla/	gang of robbers	/kâ:la/	intense effort
D	/gala/	throat; neck	/ga:la/	curse, expletive
T	/kala/	machine; component	/ka:la/	time, era
TH	/k ^h ala/	wicked	/k ^h a:la/	channel, trench

Table 2. Age and place of birth of subjects

Speaker	Age (years)	Place of birth
S1	26	Bathinda, Punjab
S2	47	Armritsar, Punjab
S3	32	Dalit, Uttar Pradesh
S4	30	Moga, Punjab
S5	26	Ropar, Punjab

at a time, subjects said each word in isolation, then in a carrier sentence /os ne tin vari ____ keha/ “*He said ____ three times*”, and then said the word in isolation again. The entire list was read twice, yielding six samples of each word; each reading took about thirty to forty minutes. We used the isolation – carrier sentence – isolation paradigm in order to avoid a list reading intonation pattern on ultimate syllables, to extract stimuli in two different prosodic domains, and to be able to get a larger set of samples without tiring the subjects. There were no measurable differences between the F0 patterns of the isolation forms and those in the carrier sentences.

Stimuli were recorded with a Zoom 4n recorder at a sampling rate of 48k in a quiet room at the Institute of Linguistics, Academia Sinica.

3.4. Acoustic measures

All acoustic analyses were processed in *Praat* (Boersma & Weenink 2017). Acoustic measurements included F0 of all vowels. F0 measurements were taken from the middle 80% of the vowel duration via the ProsodyPro script (Xu 2013). The result was a time-normalized F0 contour based on ten equidistant measurements for each syllable; *Praat* was set to locate F0 between 75 and 200 Hz; F0 measurement accuracy was checked visually during the text-gridding process. The extracted time-normalized F0 data were plotted in Hz in order to directly reflect speaker behaviour. Because the goal of the analysis was description of each speaker’s tonal realization, no transformations were performed on the data (semitones, z scale, etc).

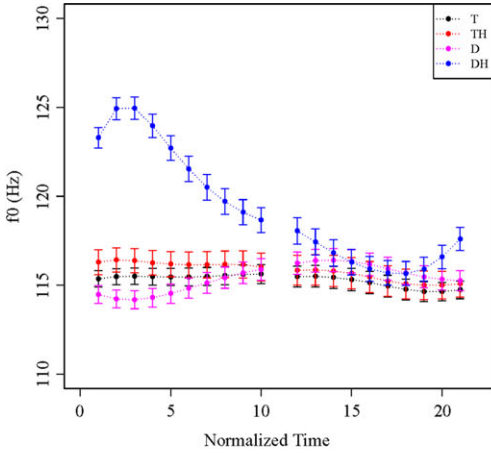
4. RESULTS

Tones were easiest to identify acoustically in the initial syllable condition, followed by medial and ultimate syllables, respectively. The following three sections examine tonal effects on F0 of initial, medial, and ultimate syllables. Each section discusses the impact of metrical structure on tone realization, in those cases where changes in mora structure correspond with significant divergence from the main F0 pattern.

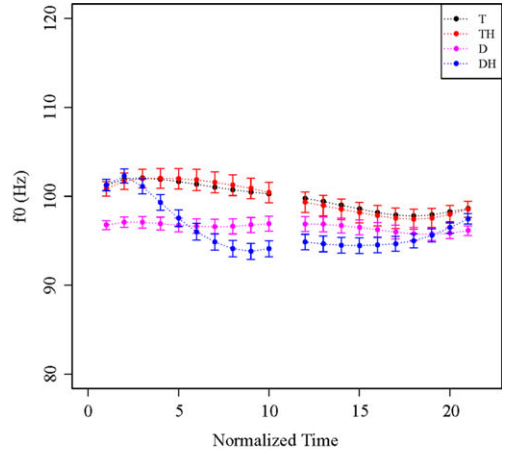
The $\Delta F0$ were subjected to two factor one-way F and Tukey’s post hoc tests for analysis. ANOVA was performed, rather than multiple *t* tests in order to reduce Type I error. Two-factor-one-way ANOVA was used because the study checked for significant difference of $\Delta F0$ between laryngeal setting groups. When a difference was identified, Tukey’s post hoc test revealed which groups were significantly different. The nature of the experiment, in which subjects did not know what we were looking for (verified through post-experiment interview), and the randomization of the data presented to the subjects, ensured that the basic assumptions of ANOVA and Tukey’s post hoc tests were met.

4.1. Tone and pitch on initial syllables

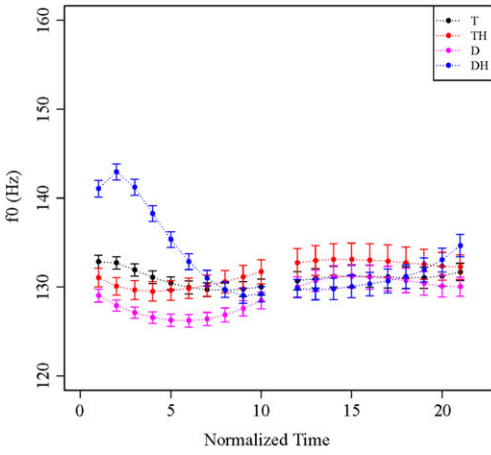
Visual inspection of F0 plots suggests that the Punjabi tone is realized as a fall in F0. Figure 1 presents F0 summaries of the first syllable condition for each speaker. All metrical



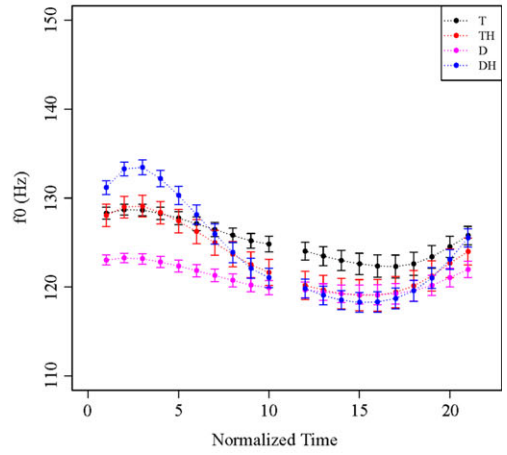
S1



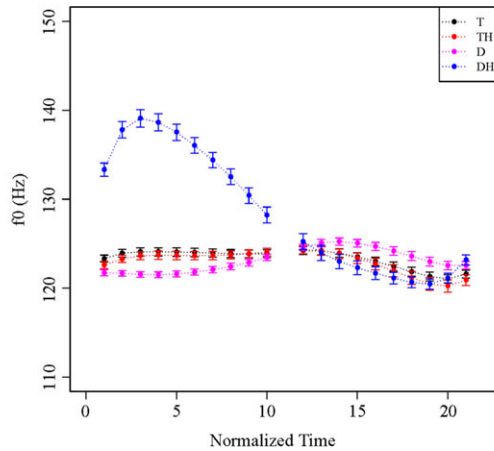
S2



S3



S4



S5

Figure 1. Time-normalized F0 plot showing the occurrence of falling tone on the first syllable of disyllabic words in which the initial syllable C1 is the conditioning consonant for tone. Blue curve shows the effect of *DH on F0. [Colour figure can be viewed at wileyonlinelibrary.com]

combinations are present in the averaged figures (μ , μ , $\mu\mu$, μ , $\mu\mu$, $\mu\mu$); that is, differences in F0 patterns corresponding to changes in mora structure are ignored. The curves corresponding to *DH initial consonants (blue curves) appear to show a tonal distinction, forming (near-) minimal pairs with the T condition words (cf. Table 1).

In Figure 1, S1, S3, and S5 appear to produce a high-falling tone on the *DH words, while S2 shows a tendency to produce a mid-falling tone. For S4, the tone also appears to be mid-falling, but the tendency is not as clear as for S2. In order to confirm the existence of a falling tone, the output of the ProsodyPro script was subjected to statistical analysis via R (R Core Team 2017). In looking for a significant fall in pitch, the global maximum F0 in hertz in a given word was identified, as well as the next F0 local minimum; the difference in F0 ($\Delta F0$) was taken as the measurement of pitch fall. The $\Delta F0$ of *DH words were compared with $\Delta F0$ of D, T, and TH forms. Pitch falls, if present, could occur on any syllable(s) of the word. In this way, the data determined the presence and location of significant pitch fall, if any. Each speaker's plot is scaled to reflect the F0 range present in their recordings. The break in each plot represents a syllable boundary.

Taking the amalgamated F0 data represented in Figure 1, a two-factor one-way ANOVA F test was performed on the values of F0 fall. This test was followed by Tukey's post hoc tests. The results show that for the initial condition as a whole, *DH pitch fall is significantly different from T, TH, and D (Table 3, first line bold to highlight tonal distinction and minimal contrast). In order to save space, comparisons among T, TH, D are not shown in this and subsequent tables; F0 falls for these three consonant types are not significantly different from one another in almost all cases.

Table 3 presents the test results, the average maximum and subsequent minimum F0 values, along with the average normalized time point on which the maximum/minimum occurs. These values show not only the magnitude of the pitch excursion, but also the normalized timing and duration of the fall, as these vary both across speakers and also across mora conditions.

The values in Table 3 confirm what is impressionistically observable in Figure 1; that *DH associated pitch fall is significant when the conditioning consonant occurs word-initially, while the other initial consonants condition a relatively flat F0 contour. In the rest of the present section, words are grouped according to mora structure, allowing a more nuanced picture to emerge (figures are in Appendix A). For different metrical structures, pitch falls are not significant in all cases (especially for S2), and do not always occur on the initial syllable.

For the long-short condition ($\mu\mu$), the T-*DH pitch fall contrast is significant for speakers S2 through S5, as can be seen in Table 4 and Figure A-1, with S1 demonstrating a clear trend. The pitch fall starts within the first 30 per cent of the first syllable, and for all of the speakers except S5 the fall tends to be completed during the initial long syllable (minimum F0 at time 10 or earlier).

For the long-long condition ($\mu\mu$), all speakers except S2 have a significant pitch fall distinguishing T-*DH (Table 5, Figure A-2). S2 produces a flat F0 contour, as evidenced by

Table 3. Test results for F0 drop by laryngeal class of word-initial consonants. Significant results for target group in bold.

	S1	S2	S3	S4	S5
T-*DH	p < 0.0001****	p = 0.0003***	p < 0.0001****	p < 0.0001****	p < 0.0001****
TH-*DH	p < 0.0001****	p = 0.0001***	p < 0.0001****	p = 0.0002***	p < 0.0001****
D-*DH	p < 0.0001****	p < 0.0001****	p < 0.0001****	p < 0.0001****	p < 0.0001****
*DH max(Time)	125 Hz (3)	102 Hz (2)	133 Hz (3)	143 Hz (2)	139 Hz (3)
*DH min(Time)	116 Hz (17)	94 Hz (9)	118 Hz (14)	129 Hz (9)	120 Hz (18)

Table 4. Test results for F0 drop by laryngeal class of word-initial consonants with a metrical structure of $\mu\mu.\mu$. Significant results for target group in bold.

	S1	S2	S3	S4	S5
T-*DH	p = 0.06	p = 0.001**	p = 0.0007***	p = 0.037*	p < 0.0001****
TH-*DH	p = 0.01*	p < 0.0001****	p = 0.064	p = 0.333	p < 0.0001****
D-*DH	p = 0.063	p < 0.0001****	p = 0.0003***	p < 0.0001****	p < 0.0001****
*DH max(Time)	126 Hz (2)	102 Hz (2)	132 Hz (2)	145 Hz (2)	138 Hz (3)
*DH min(Time)	115 Hz (10)	90 Hz (8)	115 Hz (10)	125 Hz (9)	118 Hz (17)

Table 5. Test results for F0 drop by laryngeal class of word-initial consonants with a metrical structure of $\mu\mu.\mu\mu$. Significant results for target group in bold.

	S1	S2	S3	S4	S5
T-*DH	p < 0.0001****	p = 0.226	p = 0.047*	p = 0.002**	p < 0.0001****
TH-*DH	p < 0.0001****	p = 0.111	p = 0.056	p = 0.003**	p < 0.0001****
D-*DH	p < 0.0001****	p = 0.171	p = 0.017*	p < 0.0001****	p < 0.0001****
*DH max(Time)	129 Hz (4)	100 Hz (3)	133 Hz (3)	139 Hz (2)	141 Hz (3)
*DH min(Time)	116 Hz (17)	97 Hz (9)	113 Hz (15)	131 Hz (9)	121 Hz (18)

Table 6. Test results for F0 drop by laryngeal class of word-initial consonants with a metrical structure of $\mu.\mu$. Significant results for target group in bold.

	S1	S2	S3	S4	S5
T-*DH	$\Delta F0$ p = 0.495	p = 0.996	p = 0.068	p = 0.042*	p < 0.0001****
	max F0 p = 0.18	p = 0.797	p = 0.75	–	–
TH-*DH	p = 0.654	p = 0.995	p = 0.11	p = 0.208	p < 0.0001****
D-*DH	p = 0.744	p = 0.34	p = 0.067	p = 0.004**	p < 0.0001****
*DH max(Time)	123 Hz (4)	105 Hz (3)	137 Hz (3)	141 Hz (2)	142 Hz (4)
*DH min(Time)	115 Hz (16)	92 Hz (14)	121 Hz (14)	128 Hz (14)	121 Hz (18)

the difference of only 3 Hz between maximum and subsequent minimum. S1, S3, S4, and S5 begin the fall during the first 30% of the first syllable, while only S4 completes the pitch fall during the first syllable. For the other speakers (S1, S3, S5), minimum pitch occurs at the midpoint or later in the second syllable.

For the short-short condition ($\mu.\mu$), only S4 and S5 demonstrate significant pitch falls (Table 6, Figure A-3). Even though the initial syllable is monomoraic, F0 maxima occur during the first half of the first syllable for all speakers. Minimum F0 occurs near the center or later of the second syllable. A two-factor one-way ANOVA F test was also performed on F0 maxima, to determine if S2 might use F0 height as a signal for the presence of *DH; however, S2's F0 maximum was not significantly different from that of T (Table 6). Visual examination of the F0 values suggests that S2 might signal tone in these conditions with a rapid fall in F0 during σ_1 , although our statistical tests did not indicate significance.

For those words with a short σ_1 and a long σ_2 ($\mu.\mu\mu$), the tone tends to start later, as indicated by the location of F0 maxima during the second half of the first syllable for S1, S3, and S5 (Figure A-4, Table 7). TH words are not attested with $\mu.\mu\mu$ metrical pattern, thus do not appear in Figure A-4 and Table 7. For all speakers except S2, *DH pitch fall contrasts significantly with the F0 movement of T, yielding (near-) minimal pairs distinguished by pitch. S2 does not show a significant pitch fall difference when *DH is compared with T in the short-long condition. A subsequent two factor one-way ANOVA F test was performed to compare pitch maxima for S2's *DH and T conditions, yielding $p = 0.052$, which approaches

Table 7. Test results for F0 drop by laryngeal class of word-initial consonants with a metrical structure of μ . μ . Significant results for target group in bold.

		S1	S2	S3	S4	S5
T-*DH	$\Delta F0$	$p < 0.0001****$	$p = 0.178$	$p = 0.006**$	$p = 0.008**$	$p < 0.0001****$
	max F0	–	$p = 0.052$	–	–	–
D-*DH	$\Delta F0$	$p < 0.0001****$	$p = 0.038*$	$p = 0.011*$	$p = 0.0008***$	$p < 0.0001****$
*DH max(Time)		124 Hz (8)	102 Hz (5)	138 Hz (6)	146 Hz (3)	142 Hz (8)
*DH min(Time)		113 Hz (18)	95 Hz (17)	117 Hz (17)	126 Hz (13)	125 Hz (19)

significance. This suggests that S2 may use enhanced F0 height to signal the tonal contrast for these syllables.

Thus, in the short-long pattern, for four of the speakers *DH > T correlates with a statistically significant F0 fall compared to orthographic *T.

Pitch fall is clearest in tone conditioned by word-initial consonants. The following two subsections demonstrate that tone realization on medial and final syllables tends to be less overt.

4.2. Tone and pitch on medial syllables

Figure 2 shows F0 summary plots for each speaker's medial condition, ignoring differences in mora structure; mora-based plots are in Appendix B.

Taking all syllable combinations together, all speakers except S4 show a pitch contrast between *DH and D (Table 8, recall that murmured stops have become plain voiced stops in non-word-initial position). Although S4 does not show a significant F0 fall in the pair D-*DH, there is an F0 maximum contrast between *DH and D. Visual examination of Figure 2 shows that S4's summary curves are roughly parallel, with the *DH curve higher than the D curve at every point.

For the medial condition, there are no comparisons of pitch patterns on the long-long (μ . μ . μ) condition, because too few lexical items fit the required segmental and metrical requirements. For the long-short medial condition (μ . μ . μ), F0 drop was significantly different for D-*DH for all speakers (Table 9, Figure B-1). The F0 peaks tended to occur between the latter half of the initial syllable and the first half of the second syllable. For S2 and S4 the pitch fall began and was completed within the second syllable, while for S1, S3, and S5, F0 minima typically occurred during the ultimate syllable.

For the short-long medial condition (μ . μ . μ), only S1's F0 falls significantly, distinguishing D-*DH (Table 10, Figure B-2). S3 and S5 distinguish D-*DH by maximum F0 height, with the pitch curve of *DH higher than the curve of D in both cases. For S3, S4, and S5, the average *DH F0 curve is higher than that of D throughout the entire word. For S2, *DH F0 is higher than D for the medial and ultimate syllables, which are the part of the word that follows the conditioning environment.

For words in the medial short-short category (μ . μ . μ), only S5 produces a significant pitch fall on *DH, separating it acoustically from D (Table 11, Figure B-3), and also from T, TH. Speaker S4 distinguishes *DH-D on the basis of pitch height with a nearly significant probability of 0.051.

4.3. Tone and pitch on ultimate syllables

Ultimate condition words have a disyllabic structure, in which C1 of the second syllable is under consideration. For example, for an ultimate condition word with the structure μ . μ , the

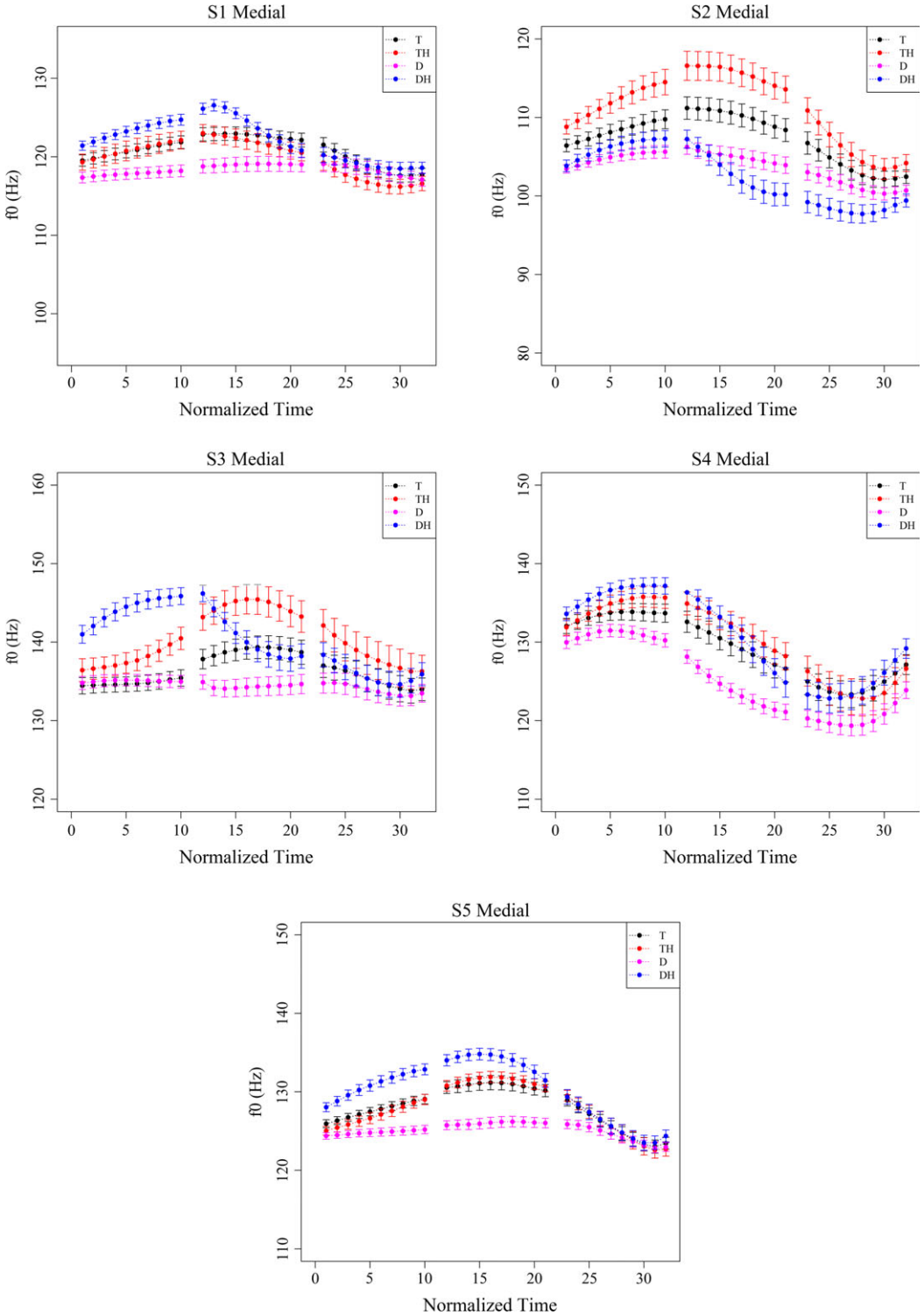


Figure 2. Time-normalized F0 plot showing the occurrence of tone in trisyllabic words in which the medial syllable C1 is the conditioning consonant for tone. Blue curve shows the effect of *DH on F0, breaks in curves mark syllable boundaries. [Colour figure can be viewed at wileyonlinelibrary.com]

Table 8. Test results for F0 drop by laryngeal class of C1 of medial syllables. Significant results for target group in bold.

		S1	S2	S3	S4	S5
T-*DH	ΔF_0	$p < 0.0001^{***}$	$p = 0.043^*$	$p = 0.425$	$p = 0.869$	$p = 0.565$
TH-*DH	ΔF_0	$p = 0.276$	$p = 1$	$p = 0.843$	$p = 0.996$	$p = 0.138$
D-*DH	ΔF_0	$p < 0.0001^{***}$	$p = 0.0005^{***}$	$p = 0.002^{**}$	$p = 0.985$	$p < 0.0001^{***}$
	max F0	—	—	—	$p = 0.0002^{***}$	—
*DH	max(Time)	127 Hz (12)	107 Hz (10)	137 Hz (9)	146 Hz (11)	135 Hz (14)
*DH	min(Time)	119 Hz (28)	98 Hz (26)	123 Hz (23)	135 Hz (27)	124 Hz (28)

Table 9. Test results for F0 drop by laryngeal class of C1 of medial syllables with a metrical structure of $\mu.\mu.\mu.$ Significant results for target group in bold.

		S1	S2	S3	S4	S5
T-*DH	ΔF_0	—	$p = 0.002^{**}$	—	—	$p = 0.036^*$
D-*DH	ΔF_0	$p = 0.005^{**}$	$p = 0.003^{**}$	$p < 0.0001^{****}$	$p = 0.992$	$p < 0.0001^{****}$
	max F0	—	—	—	$p = 0.464$	—
*DH	max(Time)	128 Hz (12)	105 Hz (7)	137 Hz (7)	154 Hz (7)	135 Hz (12)
*DH	min(Time)	115 Hz (23)	87 Hz (19)	114 Hz (21)	122 Hz (18)	121 Hz (27)

Table 10. Test results for F0 drop by laryngeal class of C1 of medial syllables with a metrical structure of $\mu.\mu.\mu.\mu.$ Significant results for target group in bold.

		S1	S2	S3	S4	S5
T-*DH	ΔF_0	$p = 0.381$	$p = 0.163$	$p = 0.902$	$p = 0.912$	$p = 0.434$
TH-*DH	ΔF_0	$p = 0.997$	$p = 1$	$p = 0.931$	$p = 0.995$	$p = 0.999$
D-*DH	ΔF_0	$p = 0.044^*$	$p = 0.088$	$p = 0.672$	$p = 0.96$	$p = 0.793$
	max F0	—	$p = 0.982$	$p = 0.019^*$	$p = 0.431$	$p < 0.0001^{****}$
*DH	max(Time)	125 Hz (21)	107 Hz (10)	134 Hz (11)	148 Hz (19)	131 Hz (22)
*DH	min(Time)	117 Hz (30)	97 Hz (27)	128 Hz (26)	134 Hz (30)	124 Hz (30)

Table 11. Test results for F0 drop by laryngeal class of C1 of medial syllables with a metrical structure of $\mu.\mu.\mu.$ Significant results for target group in bold.

		S1	S2	S3	S4	S5
T-*DH	ΔF_0	$p = 0.088$	$p = 0.988$	$p = 0.013^*$	$p = 0.899$	$p < 0.0001^{****}$
TH-*DH	ΔF_0	$p = 0.823$	$p = 0.739$	$p = 0.657$	$p = 0.96$	$p = 0.003^{**}$
D-*DH	ΔF_0	$p = 0.147$	$p = 0.787$	$p = 0.334$	$p = 1$	$p < 0.0001^{****}$
	max F0	$p = 0.081$	$p = 0.864$	$p = 0.352$	$p = 0.051$	—
*DH	max(Time)	127 Hz (15)	110 Hz (11)	138 Hz (10)	145 Hz (15)	139 Hz (15)
*DH	min(Time)	119 Hz (30)	102 Hz (25)	128 Hz (25)	134 Hz (28)	123 Hz (28)

conditioning consonant appears before the heavy syllable. Figure 3 shows the summary time-normalized F0 plots for the ultimate condition words for all five speakers. Table 12 demonstrates that S3, S4, S5 produce a significant F0 fall distinction between D-*DH, when all syllable combinations are taken into account. If F0 maxima are compared, S1 shows significance, and S2 shows near significance.

For the ultimate short-short ($\mu.\mu$) condition, S2 and S4 show a significant pitch drop that distinguishes D-*DH (Table 13, Figure C-1 in Appendix C). Speaker S5 distinguishes D-*DH via maximum F0 height. S2's F0 maximum occurs near the middle of the first syllable, which precedes the conditioning consonant. S2 and S4 conclude their F0 fall during the latter half of the second syllable. S4 and S5 F0 maxima are near the beginning of the second syllable, shortly after the release of the conditioning consonant.

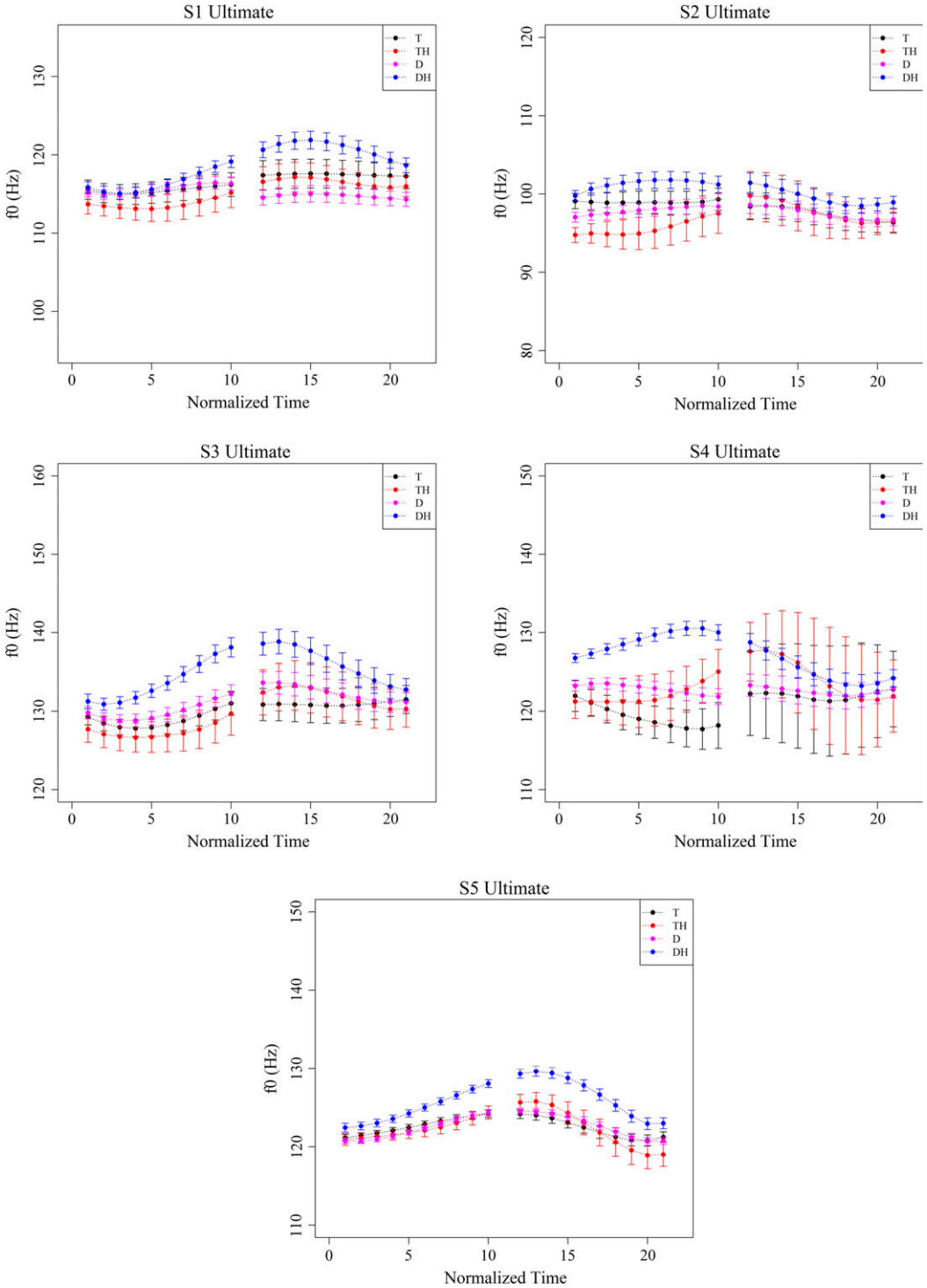


Figure 3. Time-normalized F0 plot showing the occurrence of tone in disyllabic words in which the ultimate syllable C1 is the conditioning consonant for tone. Blue curve shows the effect of *DH on F0. [Colour figure can be viewed at wileyonlinelibrary.com]

Table 12. Test results for F0 drop by laryngeal class of C1 of ultimate syllables. Significant results for target group in bold.

		S1	S2	S3	S4	S5
T-*DH	$\Delta F0$	p = 1	p = 0.04*	p < 0.0001****	p = 0.298	p = 0.0002***
TH-*DH	$\Delta F0$	p = 0.43	p = 0.809	p = 0.002**	p = 0.92	p = 0.41
D-*DH	$\Delta F0$	p = 0.568	p = 0.552	p = 0.036*	p < 0.0001****	p = 0.0009***
	max F0	p = 0.0008***	p = 0.056	p = 0.065	p = 0.015*	p < 0.0001****
*DH max(Time)		122 Hz (14)	102 Hz (7)	131 Hz (9)	139 Hz (12)	130 Hz (12)
*DH min(Time)		119 Hz (20)	98 Hz (18)	123 Hz (18)	133 Hz (20)	123 Hz (19)

Table 13. Test results for F0 drop by laryngeal class of C1 of ultimate syllables with a metrical structure of $\mu.\mu$. Significant results for target group in bold.

		S1	S2	S3	S4	S5
T-*DH	$\Delta F0$	p = 0.907	p = 0.011*	p = 0.3	–	p = 0.105
TH-*DH	$\Delta F0$	p = 0.511	–	p = 0.864	–	p = 0.273
D-*DH	$\Delta F0$	p = 0.999	p = 0.042*	p = 1	p = 0.023*	p = 0.57
	max F0	p = 0.673	p = 0.582	p = 0.901	p = 0.242	p < 0.0001****
*DH max(Time)		118 Hz (16)	105 Hz (6)	131 Hz (6)	138 Hz (11)	131 Hz (12)
*DH min(Time)		117 Hz (20)	97 Hz (16)	123 Hz (16)	134 Hz (19)	124 Hz (19)

For the ultimate long-long condition ($\mu\mu.\mu\mu$), no speaker demonstrates a significant pitch fall difference (Table 14, Figure C-2). Speakers S1 and S4 distinguish the D-*DH pair with a significantly higher pitch on *DH, near the midpoint of the ultimate syllable.

In ultimate long-short words no speakers distinguish D-*DH via degree of pitch fall on *DH (Table 15, Figure C-3). However, for S3 and S5, greater F0 maximum on *DH significantly distinguishes it from D.

For ultimate short-long words ($\mu.\mu\mu$), only *DH and D words could be found that fit the selection criteria. Speaker S5 distinguishes D-*DH with both F0 fall on *DH words and with

Table 14. Test results for F0 drop by laryngeal class of C1 of ultimate syllables with a metrical structure of $\mu\mu.\mu\mu$. Significant results for target group in bold.

		S1	S2	S3	S4	S5
T-*DH	$\Delta F0$	p = 0.066	p = 0.983	p = 0.777	p = 0.983	p = 0.587
TH-*DH	$\Delta F0$	p = 0.86	p = 0.994	p = 0.426	p = 0.938	p = 0.971
D-*DH	$\Delta F0$	p = 0.238	p = 0.935	p = 0.145	p = 0.065	p = 0.134
	max F0	p = 0.002**	p = 0.988	p = 0.23	p = 0.014*	p = 0.082
*DH max(Time)		127 Hz (15)	101 Hz (13)	129 Hz (9)	140 Hz (13)	126 Hz (13)
*DH min(Time)		122 Hz (20)	98 Hz (20)	124 Hz (18)	131 Hz (20)	122 Hz (19)

Table 15. Test results for F0 drop by laryngeal class of C1 of ultimate syllables with a metrical structure of $\mu\mu.\mu$. Significant results for target group in bold.

		S1	S2	S3	S4	S5
T-*DH	$\Delta F0$	p = 0.088	p = 0.753	p < 0.0001****	p = 0.179	p = 0.237
TH-*DH	$\Delta F0$	–	p = 0.984	p = 0.006**	–	p = 0.999
D-*DH	$\Delta F0$	p = 0.993	p = 1	p = 0.155	p = 0.091	p = 0.558
	max F0	p = 0.71	p = 0.782	p = 0.048*	p = 0.461	p = 0.001**
*DH max(Time)		120 Hz (10)	99 Hz (7)	131 Hz (9)	143 Hz (10)	129 Hz (11)
*DH min(Time)		111 Hz (20)	93 Hz (17)	121 Hz (17)	133 Hz (18)	121 Hz (19)

pitch height (Table 16, Figure C-4). No other speakers showed significant differences in the measured F0 properties.

4.4. Summary of results

The acoustic trends for tone realization are summarized in Table 17. The table shows that there is some variation between speakers in their realization of tone in non-initial position. Nevertheless, in most places where *DH occurs in the orthography, a tonal distinction may be observed.

In contrast with the findings in this study, analysis of Pakistani speakers of Punjabi finds more variation between speakers, and infrequent realization of tone (Evans, Jonathan, Wen-Chi Yeh, Rukmini Kulkarni, ms. Pakistani Punjabi: missing tones, maintaining murmur. 31 pp.).

5. DISCUSSION

Tone realization was affected by both the location within the word of the conditioning *DH consonant, and also by the word’s metrical structure. These twin findings raise the question whether there is interaction between stress and tone in Punjabi. The location of stress was not tested through a perception study. However, we summarize in the following paragraph the findings of Dhillon (2007) regarding Punjabi stress, as it pertains to the word structures employed in this study.

Stress in Punjabi is predictable, and left-dominant. Syllables may consist of up to three morae; super-heavy syllables were not used in this study. Words with the structures $\mu(\mu)\text{-}\mu(\mu)$ are always stressed on the initial syllable. The medial condition employed words with a monomoraic initial syllable, followed by the four combinations used for disyllabic words: $\mu\text{-}\mu(\mu)\text{-}\mu(\mu)$. For medial condition words in our study, only those with the moraic structure $\mu\text{-}\acute{\mu}\mu\text{-}\mu$ are stressed on the second syllable, all others had initial stress. The dictionaries consulted did not yield enough words of the form $\mu\text{-}\acute{\mu}\mu\text{-}\mu\mu$ to allow us to test this metrical pattern. Thus, with the exception of the long-short medial condition, all words in the study are stressed on the initial syllable, according to the stress rules in Dhillon (2007).

In the literature, Punjabi tone has been described as phonologically low (Bhatia 1975, 1993; Gill 1996; Shackle 2003), as a rising contour (Malik 1996), as a falling contour (Bowden 2012; Kanwal & Ritchart 2015), and as consisting of both rising and falling realizations, depending

Table 16. Test results for F0 drop by laryngeal class of C1 of ultimate syllables with a metrical structure of $\mu.\mu\mu$. Significant results for target group in bold.

		S1	S2	S3	S4	S5
D-*DH	$\Delta F0$	p = 0.137	p = 0.469	p = 0.439	p = 0.126	p = 0.015*
	max F0	p = 0.695	p = 0.12	p = 0.86	p = 0.415	p < 0.0001****
*DH max(Time)		122 Hz (11)	111 Hz (11)	133 Hz (8)	141 Hz (13)	137 Hz (13)
*DH min(Time)		116 Hz (20)	105 Hz (19)	124 Hz (18)	132 Hz (20)	124 Hz (20)

Table 17. Effects of historical voiced aspirated stops on fundamental frequency, arranged by speaker.

	S1	S2	S3	S4	S5
Initial:	Falling F0	Falling F0	Falling F0	Falling F0	Falling F0
Medial:	Falling F0	Falling F0	Falling F0	High F0	Falling F0
Ultimate:	High F0	–	Falling F0	Falling F0	Falling F0

on context (Nara 2015). The present study found differences in tone realization depending on tone location within the word. Sections 4.1 to 4.3 examine the realization of tone as it is affected by location of the conditioning consonant.

The realization of tone has also been reported to be affected by stress or by syllable length. For example, Malik (1996) reports that if *DH is the initial consonant of the second syllable, tone is only realized if that syllable is stressed. Shackle (2003) claims that tone only occurs on stressed syllables, while Bowden (2012) claims that tone only occurs on heavy syllables. As can be seen from the summary of Dhillon (2007), not all stressed syllables are heavy and/or initial. Other studies either did not investigate metrical effects, or only examined tone on initial syllables (Kanwal & Ritchart 2015). Both of these issues – the F0 characteristics of Punjabi tone and the influence of metrical structure on its realization – were investigated in the present study. In the following three subsections, we discuss the effects of *DH on Punjabi F0, according to the position of the conditioning consonant within the word. For each position the effect of word metrical structure on tone realization is also discussed.

5.1. *Tone conditioned by C1 of the first syllable*

Historically voiced aspirated stops (*DH) in word-initial position have become voiceless unaspirated stops. Taking together all initial condition words used in this study, *DH induces for all speakers a pitch fall that is significantly greater than pitch declinations that correspond with the other types of initial stop ($p < 0.001$, Table 3).

Once the mora structures of disyllables are taken into account, then greater variation in tonal realization can be observed. For disyllabic words in which both syllables are short ($\mu.\mu$), only S4 and S5 show a DH-conditioned pitch fall with $p < 0.05$. However, for each of the other three metrical structures, only one speaker lacks a significant pitch fall difference: $\mu\mu.\mu$ (S1), $\mu\mu.\mu\mu$ (S2), $\mu.\mu\mu$ (S2). Comparing Figures A-1 to A-4 (Appendix A) it can be seen that S2 and S4 tend to use mid-falling pitch rather than high falling pitch, as the other speakers do. It may be that due to pitch compression issues, there is not enough distance in S2's F0 dimension to realize a pitch fall that differs from the default intonation curve with $p < 0.05$.

In the short-long metrical structure, the bulk of the pitch fall tends to occur on the final syllable (S1, S2, S4, S5, Table 7). Cross-linguistically, pitch contours tend to occur word-finally due to final lengthening providing more time for contours to be realized (Zhang 2013).

According to the analysis of stress given by Dhillon (2007, 2010), initial syllables in our study all receive primary word stress. It is our finding that Punjabi tone is most consistently realized on initial syllables. Although Dhillon (2007, 2010) does not address the acoustic realization of Punjabi stress, increased duration is commonly cited as an effect (Bhatia 1993, Malik 1995, Shackle 2003), while Malik (1995) also mentions amplitude, and Bhatia (1993) cites higher pitch. For words in this study in the Initial condition, it may be noted that initial non-tonal syllables, although stressed, tend to have a flatter F0 curve than initial tonal syllables (Figure A-1, Appendix A).

Within the literature, various descriptors have been used to characterize the pitch quality of Punjabi tone. For the five speakers in this study, tone on the initial syllable is realized as a fall in pitch; most speakers used a high-falling pitch, while S2 and sometimes S4 used a mid-falling pitch. This variation in height of the beginning of the fall in F0 might account in part for differences in descriptions of Punjabi tone. We also note that S2 and S4 hail from cities closer to Pakistan, so that their variation could reflect dialect differences.

5.2. *Tone conditioned by C1 of the medial syllable*

Historically voiced aspirated stops in non-word-initial position have become plain voiced stops in Indian Punjabi (*DH > D). In word-medial position, if metrical structure is ignored, four speakers display distinctive F0 fall (Figure 2, Table 8). Although he didn't produce a distinctive F0 fall, S4 maintained a distinction via overall greater F0 height on all three syllables of the word.

The long-short condition (μ.μ.μ), the only medial condition with stress on the tonal syllable, had the clearest indication of falling tone across speakers of any of the medial mora combinations tested (Figure B-1, Table 9). All of the speakers except S4 showed $p < 0.01$ for the test of falling F0 as significant, and also show relatively flat stressed non-tonal medial syllables. For the other medial conditions, both short-long (μ.μ.μ, Table 10) and short-short (μ.μ.μ, Table 11) each have only one speaker who displays a distinctive pitch fall. In the short-long case, two speakers have distinctive F0 maxima, while one speaker shows a trend toward F0 maxima marking of tone in the short-short case. Taken as a set, the medial cases show that the full tone contour is more likely to appear when the tonogenetic syllable is stressed.

5.3. *Tone conditioned by C1 of the ultimate syllable*

In the cases where *DH occurs as the initial consonant of the final syllable of a disyllabic word, there were only three instances of distinctive F0 fall: short-short (μ.μ; S2, S4; Table 13, Figure C-1) and short-long (μ.μ; S5; Table 16, Figure C-4). Distinctive F0 height was displayed by a minority of speakers on short-short (μ.μ; S5), long-long (μ.μ.μ; S1, S4) and long-short (μ.μ.μ; S3, S5) words. There is no evidence for F0 raising on non-tonal words.

Ultimate syllables of disyllabic words do not bear stress in Punjabi (Dhillon 2007). As in the unstressed medial condition words, falling tones are rare on final syllables. However, as mentioned for medial syllables, under some condition-speaker pairs, words with ultimate *DH have higher average F0 at each normalized time point than do words with D: short-short (S1, S3, S4, S5; cf. Figure C-1), short-long (S2, S4, S5; cf. Figure C-4), long-short (S3; cf. Figure C-3), long-long (S3, S4, S5; cf. Figure C-2). Thus, there appears to be an F0 artifact of the *DH-D segmental distinction, but the F0 difference seems to be too small in most cases to be considered a tone, as the two averages are often separated by only a few Hz, and may have overlapping standard errors.

6. CONCLUSIONS AND IMPLICATIONS

Historically murmured stop initial consonants (*DH) trigger F0 fall on stressed syllables in Indian Punjabi. In cases where a non-stressed syllable has an initial consonant of the *DH type, tone realization can be falling, high, or statistically insignificant.

Falling tones occur most commonly on stressed syllables, a finding in agreement with the claims of Shackle (2003). Initial syllables of disyllabic words bear stress (Dhillon 2007); our finding of falling tones in this position agrees with the claims of Kanwal and Ritchart (2015). Analysis of the data in this study also identifies tone in non-stressed and non-initial positions, and on non-heavy syllables (contra Bowden 2012). However, tone in prosodically weaker positions is not always realized with falling F0, so that it may have been missed by previous studies.

Acoustic measurements of a balanced corpus across five speakers confirms the dominant tonal pattern. The Punjabi F0 effects documented in this study present implications for both the diachronic process of tonogenesis, and also for properties of the extant tone system.

6.1. Diachronic implications

Punjabi demonstrates a tonogenetic effect in which loss of murmured voice has resulted in a tone which, in prosodically strong positions, typically falls in F0. Crosslinguistically, breathy voice leads to depression of F0 (Hombert et al. 1979; Abramson 2004; Dutta 2007). Given this observation, it might be expected that the prototypical realization of tone in Punjabi would be low, rather than falling. Speaker S2 (and sometimes S4) tend to employ mid-falling pitch, in which their *DH curves start no higher than the other laryngeal settings' curves, and then fall below them (Figures A-1 to A-4). This pattern could be interpreted as movement from a default pitch setting toward a low pitch target. However, the remaining speakers consistently produce high falling tones in the same context. There are several plausible factors that may have played a role in the development from a low target to a high falling contour, which are explored presently.

Pitch raising of a syllable preceding a low target has been documented in Mandarin Chinese (Xu 1997), where it might be an articulatory technique that enhances the salience of low pitch targets. For speaker S2, who does not display pitch raising before the pitch fall, the initial conditions Long-Long and Short-Long do not present statistically significant pitch falls; hence are less acoustically salient. For most speakers in the study, raising F0 before the low target allows for greater salience of the pitch fall, as indicated by the statistical results.

Stress may also play a role in the change from a low tone to a falling tone. Crosslinguistically, stress has been found to attract high tone (Bickmore 1995; de Lacy 1999). Initial syllables of Punjabi disyllabic words, which are stressed regardless of coda length, display falling tones more consistently than unstressed syllables do. In addition, the mora condition with stress on the medial syllable ($\mu.\acute{\mu}.\mu$) displays falling tones more consistently than the other medial mora patterns do (Table 9, Figure B-1). This last finding suggests that low tone became (high-)falling due in part to the stress marking system.

Cross-linguistically, “all-low words are dispreferred” (Cahill 2008). However, contours in prosodically weak positions are also dispreferred (Zhang 2013). Thus, phonological universals suggest a trend favouring a contour over all low pitches; however, contours are more likely to be expressed on stressed than non-stressed syllables.

Voiceless obstruents, such as the voiceless stops resulting from the merger *DH > T, are documented to cause F0 raising in subsequent vowels (Hombert et al. 1979). It would appear that for the participants in this study, intrinsic effects of the initial consonant do not contribute substantially to F0 raising, because for all speakers other than S2, in the Initial condition, the vowel following *DH begins at a higher F0 than do vowels that follow the other voiceless obstruents (T, TH). In the Medial environment, *DH > D, yielding a voiced stop after which vowel F0 is higher than it is after D (all speakers) and also higher than after T, TH (speakers S1, S3, S4, S5). This finding suggests that the high component of the Punjabi tone does not have its origin in intrinsic F0 effects.

In summary, it would appear that murmured voicing caused F0 lowering in Punjabi, which remained after murmur was lost. Both stress and common production strategies that enhance salience of low tone may have influenced speakers to insert a high pitch target before the low one, yielding a sharp falling contour on stressed syllables for most speakers.

6.2. The extant Punjabi tone system

The end result of tonogenesis in Punjabi is a privative tonal system, in which the contrast is between lexical items that are specified for tone and those that are not (cf. Hyman 2001). The loss of murmured voicing only affected about 10 per cent of Punjabi lexical items, namely those with historically murmured stops (Dhillon 2007). Thus, not only is the Punjabi

Table 18. Three way contrast on disyllables stemming from one Punjabi tone. Phonetic output values taken from Bhardwaj 2013:15

Tone on:	Structure	Gurmukhi	Romanized	Input	Output	Gloss
Ø	μ.μμ	ਘੋੜਾ	ghoṛa	/koṛa:/	[koṛa]	whip
σ1	μ.μμ	ਘੋੜਾ	koṛa	/kôṛa:/	[kôṛa]	horse
σ2	μ.μμ	ਘੋੜਾ	koṛha	/koṛá:/	[koṛá]	leper

distinction one of tonal vs. toneless, but in fact the tonal syllables themselves are relatively infrequent in the lexicon. As a result of these two factors, tones are sparsely indicated. This kind of system differs from those in which the majority of lexical morphemes are specified for tone on most morphemes/syllables (e.g., Chinese, Tamang, Thai, Vietnamese, among many others). One effect of rare tones is that there are few minimal pairs. Nevertheless, the consistency of tonal pitch patterns within and across speakers suggests that Punjabi tone is phonologically real.

Although the present study only found one phonemic tone in Punjabi, some authors claim a three-way tonal distinction, with varying pitch patterns distinguishing sets such as [koṛa] ‘whip’, [kôṛa] ‘horse’, [koṛá] ‘leper’ (Bhardwaj 2013:15; cf. Bailey 1914, Baart 2014). However, because varying pitch patterns come from varying tonal placement (recoverable from the orthography), only one phonemic tone is required in the phonological inventory.

For Punjabi words with tones, typically only one syllable out of a di- or trisyllabic word is specified for tone; words with more than one murmured stop are rare, due to Grassman’s law. Tone is more likely to be fully realized as a pitch fall on stressed syllables, whereas speakers vary in their realization of tones on non-stressed syllables.

There is not enough data to fully ascertain the internal structure of the Punjabi tone. However, the data suggest that the basic structure of the tone is falling, perhaps High-Low for most speakers, but Mid-Low for speakers S2 and S4. In medial and ultimate conditions, in which the tone-conditioning consonant falls on a non-stressed syllable, there is a tendency for some speakers to produce only the High target, without a noticeable fall (cf. Table 17). Contour simplification, in which only one pitch target of the contour is produced, is a common process, especially in prosodically non-prominent positions (Zhang 2013).

Stress is an important factor in Punjabi tone realization. In unstressed syllables, contour tones are less common; in many cases, it is not clear from the acoustic signal whether tone is realized at all. While stressed syllables license H-L contour tones, stress does not appear to directly condition H insertion, because toneless stressed syllables do not tend to show the same high peak that tonal stressed syllables do.

Punjabi provides a case of tonogenesis in which the ensuing tones are privative and occur rather infrequently. In spite of an apparent low functional load, speakers maintain the distinction of falling contours on stressed tonal syllables, and often distinguish tones on unstressed syllables.

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SUPPORTING INFORMATION

Additional Supporting Information may be found in the online version of this article:

Appendix A. Initial Condition Figures.

Appendix B. Medial Condition Figures.

Appendix C. Ultimate Condition Figures.