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A phonetic investigation of some temporal properties of Paite obstruents*

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Ngaihte, Chiin Ngaihmuan, Jeffrey J. Holliday and Kelly H. Berkson. 2020. A phonetic investigation of some temporal properties of Paite obstruents. *Studies in Phonetics, Phonology and Morphology* 26.2. 341-363. Voice Onset Time has been successfully used to capture stop contrasts in a variety of languages, but much of the existing work has focused on 2-category languages, meaning those with 2-way laryngeal contrasts. Data for 3-category languages remain somewhat limited. Almost completely unrepresented in the existing literature is the Kuki-Chin sub-branch of the Tibeto-Burman language family. Kuki-Chin languages generally contain three stop types, contrasting voiced, voiceless, and aspirated stops (e.g. /d/ vs. /t/ vs. /t^h/). This study presents an instrumental analysis of data from 12 speakers of Paite, an under-documented Kuki-Chin language from Northern India. We report the distribution of VOT across the three stop types and places of articulation, along with data that shed light on two unresolved issues in previous phonological descriptions: (1) both stop and fricative realizations have been reported for the sound generally referred to as the aspirated velar stop; (2) similarly, phonetically variable realizations have been reported for two affricate graphemes, <c> and <ch>. As previous reports of variability have been largely impressionistic, the data presented here help clarify the nature of the variation. In addition to representing the first-ever corpus of acoustic data in Paite, the current work is also, to the best of our knowledge, the first substantive study of VOT in a 3-category Kuki-Chin language. **(Korea University, PhD Student and Assistant Professor and Indiana University, Assistant Professor)**

Keywords: Kuki-Chin, Paite, 3-category stop contrast

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1. Introduction

As observed by Lisker and Abramson in a seminal 1964 article, the temporal relationship between constriction release and onset of vocal fold vibration can be used to categorize stop contrasts of varying types with great cross-linguistic utility. The acoustic measure they proposed, Voice Onset Time (VOT), has since been used in countless acoustic investigations of stop consonants (e.g. Berkson 2016, Cho and Ladefoged 1999, Fischer-Jørgenson 1954, Hussain 2018, Kirby 2018, Morris et al. 2008, Nearey and Rochet 1994) to accurately capture distinctions between the three stop types most robustly observed in the world's languages—namely, voiced stops produced with closure voicing, voiceless unaspirated or short-lag stops, and voiceless aspirated or long-lag stops.

Much of the existing work on VOT has focused on 2-category languages, those with a binary opposition between two of the three most common stop types.[1] This trend may reflect that, cross-linguistically, it is most common for languages to contrast two stop types. Two-category languages containing either a voiced/voiceless (/d/ vs /t/) or a plain/aspirated voiceless contrast (/t/ vs /t^h/) account for 50% of the 451 languages indexed in the UCLA Phonological Segment Inventory Database (UPSID). Three-category languages (contrasting /d t t^h/) are next most common, accounting for 24% of the languages in UPSID, while 15.8% contain one stop type and fewer than 10% contain four or more (Maddieson 1984).

In the past several decades a vast amount of data related to VOT trends—for example, with regards to systematic differences based on place of articulation—has been accumulated. Though 3-category languages account for roughly a quarter of the attested systems if the UPSID data are representative, data for them remain limited and Thai is very often the language held up as an example of a 3-category language[2] (e.g. in phonetics textbooks, Laver 1994, Reetz and Jongman 2020). A 2018 Journal of Phonetics volume published in honor of the 50th anniversary of the advent of VOT addressed this gap in part: it included data for eight 3-category languages (see

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1 In this paper, 2-category and 3-category are terms used to identify the number of laryngeal contrasts in a language. There are additional contrasts as well, e.g. of place of articulation.

2 Korean is another language with a 3-way stop contrast that is very well documented, but its contrast is typologically rare in that all three members of the contrast are voiceless in word-initial position, and thus quite different from the 3-category languages of interest in the current study (Lee et al. 2020).

Table 1). These works represent an invaluable expansion of the existing pool of data for 3-category languages, but a great deal more work is needed.

Table 1. 3-category languages included in 2018 *Journal of Phonetics* special volume on VOT

Language	Family	Authors	No. of speakers
Khmer	Austroasiatic – Khmer	Kirby 2018	14 (5 female, 9 male)
Central Thai	Kra-Dai – Tai	Kirby 2018	12 (6 female, 6 male)
Vietnamese	Austraoasiatic – Vietic	Kirby 2018	14 (6 female, 8 male)
Yerevan Armenian	Indo-European	Seyfarth and Garellek 2018	8 (6 female, 2 male)
Dawoodi	Indo-Aryan	Hussain 2018	5
Punjabi	Indo-Aryan	Hussain 2018	5 male
Shina	Indo-Aryan	Hussain 2018	5
Burushaski	Isolate	Hussain 2018	4 male

Still absent from the literature is a treatment of Voice Onset Time in Kuki-Chin, a subgroup of the Tibeto-Burman language family consisting of 50 or more languages spoken in Chin State in western Myanmar and in adjacent parts of Bangladesh and Northeast India (Eberhard et al. 2020, Lotven et al. 2020). For a variety of reasons, Kuki-Chin languages are almost without exception under- and un-resourced. They represent a valuable opportunity to contribute to the VOT literature on 3-category languages, however, as they generally contain three series of stop types. All ten of the Kuki-Chin languages indexed in the Phonological Inventories of Tibeto-Burman Languages, for example, contain three stop types in their inventories (Namkung 1996).

With these facts in mind, the current work presents the results of an instrumental investigation of Paite, an under-documented 3-category Kuki-Chin language spoken in northeastern India, mainly in the state of Manipur, and in neighboring parts of Burma/Myanmar (Singh 2006). By conducting systematic investigation of the temporal properties of Paite obstruents, we extend investigation of VOT trends in 3-category languages to a new language family while simultaneously creating novel analytical resources for an under-resourced language.

2. Background

2.1 Temporal characteristics of obstruents in 3-category languages

As noted in Section 1, Voice Onset Time is a temporal measurement relating two events—namely, the release of a stop closure and the onset of vocal fold vibration. Proposed by Lisker and Abramson (1964), the measure has since been used to characterize the acoustic realization of stop consonants in many different languages (e.g. Cho and Ladefoged 1999, Holliday and Kong 2011, Kong et al. 2012). VOT measures are negative when stops are voiced, and positive when closure voicing is absent. Two-category languages are often subdivided: In true voicing languages, voiced stops produced with closure voicing contrast with short-lag voiceless stops, yielding a VOT difference between long negative and short positive values; in aspirating languages, the contrast is often between plain and aspirated voiceless stops produced with short vs. long positive VOT values, respectively.

In a 3-category language that contrasts voiced stops, plain voiceless stops, and aspirated voiceless stops, VOT values occupy three distinct ranges in the VOT continuum. Voiced stops are produced with long negative VOTs, plain voiceless stops with short positive VOTs at or near zero, and aspirated voiceless stops with long positive VOT values. This trend is illustrated in Table 2 with sample VOT data for a subset of the 3-category languages from Table 1.

Table 2. VOT data (in ms) for coronal stops in 3-category languages

Language	Authors	Voiced /D/ mean (SD)	Voiceless /T/ mean (SD)	Aspirated /T^h/ mean (SD)
Khmer	Kirby 2018	-69 (22)	12 (4)	87 (21)
Central Thai	Kirby 2018	-74 (27)	12 (7)	94 (19)
Vietnamese	Kirby 2018	-60 (22)	14 (5)	75 (21)
Dawoodi	Hussain 2018	-126 (44)	18 (6)	80 (22)
Punjabi	Hussain 2018	-125 (47)	15 (6)	79 (15)
Shina	Hussain 2018	-123 (34)	19 (6)	61 (20)
Burushaski	Hussain 2018	-131 (53)	16 (4)	91 (16)

That VOT values vary systematically according to place of articulation has been established by a variety of researchers working on distinct languages with differing inventories (Fischer-Jørgenson 1954, Nearey and Rochet 1994, Cho and Ladefoged 1999, Morris et al. 2008, Berkson 2016). The most robust observation is that velar stops tend to be characterized by the longest VOT values, with bilabial stops often — but not always — characterized by the shortest VOT values. This trend, apparent in Lisker and Abramson's original study and replicated in a number of other studies since, received crosslinguistic validation in Cho and Ladefoged's (1999) analysis of VOT data for voiceless stops in 18 languages from a variety of language families. Velar stops—and, in three languages which contain them, uvulars — have longer VOT values than coronals and labials in 17 of the 18 languages. For ten of the thirteen languages that contain labials, labial VOTs are longer than coronal VOTs (Cho and Ladefoged 1999).

Taken together, these previous works make clear two basic observations. First, stop series in a 3-category language with voiced, voiceless, and aspirated stops are expected to cover negative, short-lag, and long-lag VOT ranges, respectively. Second, systematic VOT differences based on place of articulation are likely. While 3-category languages are abundant in Kuki-Chin, there is very little published VOT data for these Kuki-Chin languages. The goal of the current study is to address this lack of empirical data. An overview of Kuki-Chin in general and Paite in particular is presented next, followed by a review of the methods, data, and results.

2.2 Kuki-Chin

Like other sub-groups of Tibeto-Burman, there has been a fair amount of scholarship devoted to understanding the internal organization of the Kuki-Chin (KC) subgroup. Van Bik (2009) and Peterson (2016) both divide KC into Central, Maraic, and Peripheral subgroups, with the Peripheral group further split between Northern and Southern languages. A 3-way stop contrast (/*p *p^h *ɓ/, /*t *t^h *ɗ/, /*k *k^h/, /*ʔ/) and a two-way affricate contrast (/*ts *ts^h/) is reconstructed for Proto-Kuki-Chin (PKC) (Van Bik 2009, where * indicates a reconstructed category, following convention in historical linguistics), and is attested in many PKC daughter languages across all KC sub-groups. PKC is not reconstructed as having contained a voiced velar stop, and /ɡ/ is attested in just a few daughter languages where it has been innovated (Lotven et al. 2020).

Paite, the language of focus in the present work, belongs to the Northern branch of the Peripheral sub-group (Eberhard et al. 2020, Lotven et al. 2020, Van Bik 2009). Of relevance to the current work is the observation that PKC /*k^h/ has been lenited in some Northern Chin languages such that the velar contrast is now between /k/ and /x/ (Button 2011). Also relevant is the fact that the sibilant affricates have been subject to some diachronic loss. While a two-way contrast is retained in a number of Central and Maraic languages, it is sometimes realized as /ts tʃ/ instead of /ts ts^h/ (e.g. in the Central Chin language Hakha Lai, Lotven et al. 2020). Furthermore, the aspirated sibilant affricate has reportedly been lost in at least some Peripheral Chin languages (Lotven et al. 2020, Van Bik 2009).

2.3 Paite

Paite is primarily spoken in the northeast Indian states of Assam, Manipur, and Mizoram, and in Chin state in Myanmar (Kamkhenthang 1988: 7, Zamzachin 1992: 5, Khan 2000, Nianglianmoi 2016). There are various local dialects, such as Lamzang, Dapzal, Lamka, Bukpi, and Lousau (Singh 2006, Nianglianmoi 2016, Eberhard et al. 2020), the first three of which will be examined in more detail in the current study. The first of these, Lamzang, is spoken mainly in Manipur state, and is in contact with Tedim Chin. The second dialect, Dapzal, is spoken in both Manipur and Mizoram states (Singh 2006), and has greater contact with Mizo. Lastly, the Lamka dialect, which is considered to be non-standard, arose through language contact as various villagers using different dialects settled in Lamka town in Churachandpur district in Manipur (Nianglianmoi 2016). The specific differences among these dialects are not all documented in detail, but among the two most widely spoken, Lamzang and Dapzal, some phonological and morphological differences have been noted (Singh 2006). A survey of previous studies reveals several unanswered questions related to the phonological inventory of Paite.

First, it is generally recognized that Paite presents a 3-way phonological contrast among bilabial stops /b, p, p^h/ and coronal stops /d, t, t^h/ (Khan 2002, Singh 2006, Devi 2010, Nianglianmoi 2016). Example words from Paite containing these stops are provided in Table 3. However, conflicting claims have been made for the velar contrast. Some scholars have noted an analogous 3-way stop contrast /g, k, k^h/ (Khan 2000, Devi 2010), while others report that, as in some other Northern Chin languages

(Button 2011), lenition of the aspirated velar stop has yielded a different 3-way contrast /g, k, x/ (Singh 2006, Nianglianmoi 2016).

Table 3. Examples of Paite words containing each stop

	Voiced	Voiceless Unaspirated	Voiceless Aspirated
Bilabial	/bum/ ‘sorcery’	/pum/ ‘body’	/p^{h}um/ ‘bury’
Alveolar	/dum/ ‘blue’	/tum/ ‘drown’	/t^{h}um/ ‘pray’
Velar	/gum/ ‘bold’	/kum/ ‘age’	/k^{h}um/ ‘sweet’

Second, there have also been divergent claims regarding the affricate inventory of Paite. Nianglianmoi (2016) described Paite as having only the dental voiceless affricate /ʦ/ as a full phoneme. The “pre-palatal” voiceless /ʧ/ and voiced /ʤ/ are referred to therein as marginal phonemes, presumably due to their use in only a few names. Other scholars describe Paite as having the phoneme /c/, which Khan (2000) describes as an affricate, Singh (2006) describes as a stop, and Devi (2010) describes as an alveopalatal stop. Meanwhile, written Paite has two graphemes, <c> and <ch>, which are used to represent affricate phonemes, but they are understood to be used interchangeably[3] (Kamkhenthang 2011), suggesting that there exists only a single affricate phoneme. For example, the word for ‘decorate’ could be spelled as <cei> or <chei>, and the word for ‘handshake’, is spelled both <cibai> and <chibai>. It is quite possible that only a single affricate phoneme exists, given that—as previously noted—loss of the aspirated sibilant affricate is attested for some Peripheral Chin languages (Van Bik 2009, Lotven et al. 2020).

Because none of these studies have reported phonetic data on the segmental properties of Paite, two points remain unclear. The first is whether the aspirated velar stop is realized as [k^h] or [x]. The second is whether Paite speakers indeed produce <c> and <ch> as the same sound. Previous studies of Paite have been based on speakers of different ages and dialects, which may have contributed to the discrepancies. For example, the data in both Singh (2006) and Khan (2000) come

[3] The policy and decision was made by the Paite Literature Society on February 1, 1997 to modify Paite language (Paite Pau) as one of the Modern Indian Languages (M.I.L) under the Board of Secondary Education, Manipur.

from Lamzang speakers, whereas Nianglianmoi (2016) based her study on the Dapzal dialect as spoken in Lamka town, by informants who were university students in Delhi at the time of recording. Therefore, it is possible that variation in the realization of the aspirated velar stop or the affricate phoneme could vary either within or across speakers, and could be correlated with speaker age, gender, or dialect.

2.4 Research questions

While Khan (2000) and Singh (2006) offered phonological descriptions of Paite, they did not report any phonetic data, which led us in the current study to answer the following questions. First, can the 3-way contrast in Paite stops be captured using VOT alone? Second, are there significant differences in VOT across place of articulation? For these first two questions, very clear predictions can be made. Paite is expected to align with the cross-linguistic trends evident in many previous studies. Voiced stops will be produced with long negative VOT values, plain voiceless stops with short lag VOTs, and aspirated stops with long-lag VOTs. Velar stops are expected to exhibit the longest VOT values.

Our remaining questions are more exploratory, as they are intended to clarify some questions that have been raised by previous reports about Paite. Third, is the aspirated velar stop /k^h/ realized as a stop [k^h] or a fricative [x], and is there variation across vowel context, speaker gender, or dialect? Fourth, are the orthographic variants <c> and <ch> produced as the same affricate, or is there variation across speaker gender or dialect?

3. Method

3.1 Participants

The recordings used in the current study were made in mid-December 2018 in Bungmual village, Churachandpur district, Manipur, India, by the first author, a native speaker of Paite. Recordings were collected from 15 participants, data from 12 of whom are presented here. The 12 participants selected for inclusion in the current study were chosen based on the quality of the recordings and to maintain balance between female and male participants.

The participants' ages ranged from 19 to 30. All were born in Lamka town, Churachandpur district, and were residing therein at the time of the recording. One participant reported having lived for 2 years in Shillong, Meghalaya, and another participant for 3 years in Imphal, Manipur. Participants self-reported three different dialects of Paite (Dapzal, Lamka, or Lamzang), and were raised in Paite-speaking homes. All but one participant reported having two parents whose native language was also Paite; one participant (p03) reported that their mother's native language was Vaiphei. Lastly, all participants started learning English at age 4 in school, and reported using English "sometimes" or "often". This sort of multilingualism is standard in the region. None of the participants reported proficiency in Hindi. Information for each participant is provided in Table 4.

Table 4. Demographic information about participants

ID	Gender	Age	Other residence	Paite dialect	English use frequency
p01	F	21	Shillong (2 yr)	Dapzal	Sometimes
p03	F	21		Dapzal	Sometimes
p04	F	24		Dapzal	Sometimes
p05	F	19		Lamzang	Often
p06	F	19		Lamka	Often
p07	F	21		Lamka	Sometimes
p09	M	23		Dapzal	Sometimes
p10	M	24		Dapzal	Sometimes
p11	M	30		Dapzal	Sometimes
p12	M	25		Lamka	Sometimes
p13	M	24		Lamzang	Sometimes
p15	M	24	Imphal (3 yr)	Lamzang	Sometimes

3.2 Materials

The recording session lasted approximately 1 hour and included different lists designed to elicit most of the consonant, vowel, and tone contrasts in Paite. Each session began with productions of isolated CVs, which are the source of the data presented in the current study.

The target CVs consisted of each of 15 consonants /b, p, p^h, d, t, t^h, g, k, k^h, c, c^h, s, z, f, v/[4] combined with each of 6 vowels /a, e, i, o, u, ɔ/. In the current study, we only present data from the stops and affricates combined with a subset of the vowels, /a, e, i, u/, resulting in 44 target CVs per talker (11 consonants × 4 vowels). The CVs were elicited by reading from a printed list written in Paite, which was grouped by consonant. Talkers were instructed to read each consonant set twice, resulting in 88 unique CV productions per talker. All written and oral instructions were given in Paite. Each talker was recorded individually in a sound-proof recording studio using a Zoom H4N digital recorder.

3.3 Analysis

Using Praat (ver. 6.0.37, Boersma and Weenink 2018), a textgrid was annotated for each sound file, in which acoustic events were marked by the second author. For each stop- or affricate-initial CV, three events were tagged: the burst (i.e. release of oral occlusion), the onset of voicing, and the end of the vowel. For consonants with pre-voicing, the onset of voicing was marked at the appearance of a voicing bar during the closure preceding the burst, whereas for consonants with lag voicing it was marked at the onset of periodicity in the waveform following the burst. For /k^h/-initial targets that were auditorily judged to be fricatives and were visually confirmed to not contain a stop burst, the onset of frication was marked in place of the burst, and a note was made in the textgrid indicating that the token was realized as a fricative. The times for each of these acoustic events were extracted using a script, and then read into R (version 3.6.2; R Core Team 2019) as a dataframe for further analysis. All analyses were carried out using RStudio (version 1.2.5033, RStudio Team 2015).

The dataframe was manipulated into wide format using the Tidyverse package (version 1.3.0, Wickham et al. 2019), with a separate row for each production. Thus, each row in the dataframe contained the talker who produced the token, the target C, the target V, the times associated with each acoustic event recorded in Praat, and whether or not the token was realized as a fricative (in the case of /k^h/ targets). Next,

4 For the sake of simplicity we are representing the two graphemes <c> and <ch> as separate phonemes in the stimuli list, /c/ and /c^h/, but this should not be interpreted as support of a view that they are phonologically contrastive, or that /c/ is the most suitable IPA symbol.

tokens from the three talkers not included in the current study were discarded. Finally, four /c/ tokens that were mistakenly produced as /s/, all from talker p01, were discarded as well. The resulting dataframe contained 1046 tokens.

Using this dataframe, VOT was calculated for each stop token as the distance from the burst to the onset of voicing (positive in the case of lag voicing, and negative in the case of pre-voicing). For affricates, the distance between these two events was interpreted as the duration of frication (although many tokens included aspiration in this period as well).

Using the acoustic events marked in the textgrids described above, an additional spectral analysis was conducted on the affricate productions to determine whether any talkers produced a difference between /c/ and /c^h/. For each affricate production, the period between the burst and the onset of voicing was extracted. This portion was then divided into ten slices of equal length, and ten individual spectra were calculated from rectangular windows spanning each of these slices. Each of these spectra was then pass band filtered from 500 to 10,000 Hz, over which the centroid frequency was calculated. These ten centroid frequency measurements were then used to quantify spectral changes in each affricate over the course of the frication portion.

4. Results

4.1 VOT in stops

The first question addressed in our analysis was whether the 3-way contrast in Paite stops can be captured using VOT alone. Figure 1 shows the distribution of VOT across stop productions from each laryngeal category, excluding /k^h/ tokens that were realized as fricatives. The results indicate a clear separation between the three stop types, with voiced, unaspirated, and aspirated stops showing mean VOTs of -113, 23, and 89 ms, respectively. A small percentage of phonologically voiced stops (3.19%) were realized with short lag VOT, and a small percentage of phonologically voiceless unaspirated stops were realized with pre-voicing (1.74%). A repeated measures ANOVA revealed significant differences in VOT according to stop type ($F(2,20) = 324.1$, $p < .001$) but no significant effect of gender, nor a significant interaction between gender and stop type.

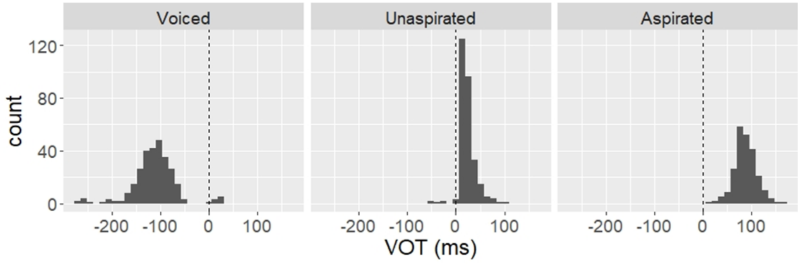

Figure 1. Distribution of VOT across laryngeal category

Our second question was whether there were significant differences in VOT across place of articulation, and whether such differences depended on the laryngeal category. These distributions are illustrated in Figure 2, and suggest that voiceless velar stops may have longer VOT than voiceless bilabial or alveolar stops, but that no difference exists among voiced stops. A linear mixed effects model with fixed effects of laryngeal category and place of articulation and random intercepts for talker confirmed this finding. The output of the model is given in Table 5.

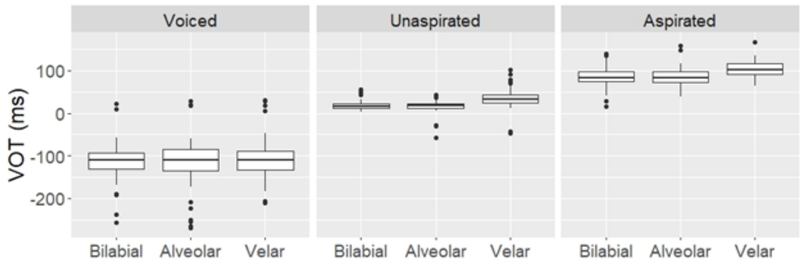

Figure 2. Distribution of VOT across place of articulation within laryngeal category

The results of the model confirmed not only that VOT differed significantly between the three laryngeal categories (as illustrated previously in Figure 1), but that the VOT of velar stops was overall longer than bilabial and alveolar stops when unaspirated or aspirated. This difference in velar stops was mostly erased, however, in voiced stops, as suggested by the negative coefficient and marginally significant interaction between the voiced and velar conditions, as shown in Table 5. This finding may be considered surprising in light of cross-linguistic trends, and certainly deserves additional investigation in future work. One point worth noting, however, is that /g/ is a relatively uncommon phoneme in Kuki-Chin languages – most KC languages have /b/ and /d/ but not /g/. The presence of /g/ in Paite is an innovation, and it is possible that the sound is under-attested in the Paite lexicon.

Table 5. Output of linear mixed effects model showing the effect of laryngeal category and place of articulation on VOT. The intercept represents the unaspirated alveolar level.

Parameter	β	*t*	*p*
Intercept	16.67	4.06	< .001
Voiced	–133.24	–32.25	< .001
Aspirated	67.36	16.30	< .001
Bilabial	0.98	0.24	n.s.
Velar	18.72	4.53	< .001
Voiced : Bilabial	2.18	0.37	n.s.
Aspirated : Bilabial	1.41	0.24	n.s.
Voiced : Velar	–11.44	–1.95	= .051
Aspirated : Velar	0.90	0.13	n.s.

4.2 Realization of /k^h/

Our next question, also related to the stop contrast, was whether talkers realized the aspirated velar stop /k^h/ as a stop [k^h] or a fricative [x]. We were particularly interested in whether there was variation across vowel context, gender, or dialect. Overall, out of 96 /k^h/ productions (8 tokens × 12 talkers), 57 were realized as [x] and 39 as [k^h], suggesting a slight overall preference for [x].

The distributions of realizations across vowel context and gender are shown in Table 6. A chi-squared test of independence did not reveal any meaningful relationship between vowel context and /k^h/ variant ($\chi^2(3) = 0.48$, $p = .924$). There does appear to be a significant effect of talker gender, with female speakers more likely to produce [k^h] and male speakers more likely to produce [x] ($\chi^2(1) = 17.27$, $p < .001$). On the other hand, interpreting the effect of gender is difficult because, unlike vowel context, gender was not equally balanced across dialect: while the six

Dapzal speakers were balanced across genders, there were two female and one male Lamka speaker, versus one female and two male Lamzang speakers. Put differently, do the female speakers produce [k^h] more frequently because they are skewed toward Lamka, or does it appear that Lamka speakers produce [k^h] more frequently because they are represented by more female than male speakers?

Table 6. Distribution of /k^h/ variants across vowel context and gender

Vowel	[k^h]	[x]
/a/	11	13
/e/	9	15
/i/	10	14
/u/	9	15

Gender	[k^h]	[x]
Female	30	18
Male	9	39

A conclusive answer to this question requires more data, but we may speculate based on the distribution of realizations across genders within each dialect, as shown in Table 7. Overall, there does seem to be a significant effect of dialect, with [k^h] more frequent among Dapzal and Lamka speakers and [x] more frequent among Lamzang speakers ($\chi^2(2) = 7.04$, $p = .030$). And when we look at the distribution of realizations within each dialect across gender, it does appear that Lamzang may differ from Dapzal and Lamka. While male speakers produced [x] more frequently than [k^h] in all dialects, female Lamzang speakers produced only [x], whereas female Dapzal and Lamka speakers produced far more [k^h].

Table 7. Distribution of /k^h/ variants across gender and dialect

	Dapzal		Lamka		Lamzang	
Gender	[k^h]	[x]	[k^h]	[x]	[k^h]	[x]
Female	16	8	14	2	0	8
Male	4	20	0	8	5	11
Total	20	28	14	10	5	19

In summary, the results from the participants tested here suggest that while female speakers produce more [k^h] and male speakers produce more [x], the fricative variant seems to be preferred by speakers of both genders in the Lamzang dialect. These data may be suggestive of a change in progress, in particular lenition of PKC /*k^h/ to /x/

as has been attested for other Northern Chin languages (Button 2011), but more data are needed.

4.3 Realization of affricate contrast

Our last question concerned the production of Paite affricates: although there are two orthographic variants, <c> and <ch>, representing the PKC contrast between /*ts/ and /*ts^{h}/ respectively, reports on whether speakers produce them differently or whether they are phonetically neutralized have varied. To investigate this matter, we first compared the frication duration between <c> and <ch> productions, which is shown in Figure 3. It can be seen that although the two distributions are totally overlapping, the duration of <c> is skewed somewhat lower than the duration of <ch>.

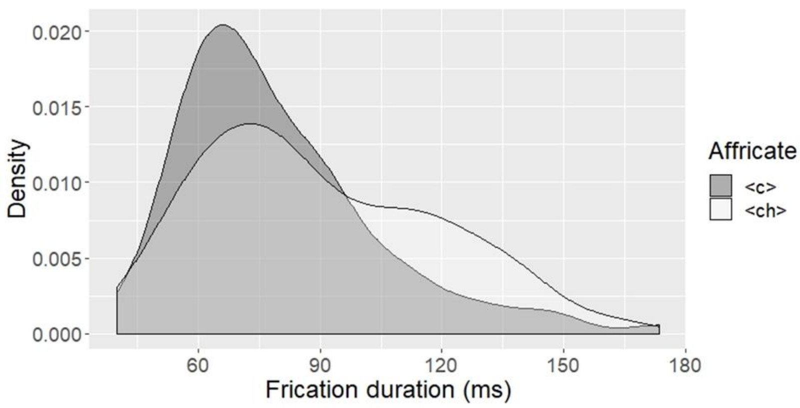

Figure 3. Distribution of frication duration across affricate orthographic variants

This result raises the question of whether there is a general tendency to sometimes produce <ch> with a longer frication duration, or if there is systemic variation among the individual talkers. The same distributions plotted for each individual talker, shown in Figure 4, suggest that while most talkers produce no difference in duration between the two affricates, at least three talkers (p01f, p03f, p09m), produce <ch> with a longer frication duration than <c>.

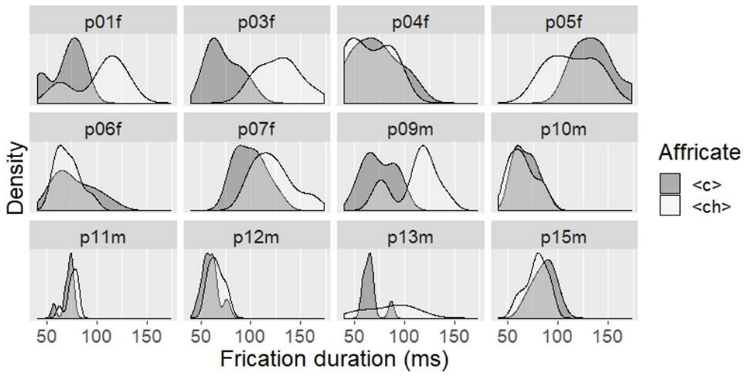

Figure 4. Distribution of frication duration in individual talkers across affricate orthographic variants

A further question raised by these individual differences is whether the difference produced by some of these talkers is purely temporal, or whether it is characterized by spectral difference as well. To investigate this question, we examined the change in centroid frequency over the course of frication. If any of the talkers are producing <ch> with aspiration (that is, as [ts^h]), it should be reflected by a decrease in centroid frequency heading into the vowel. If a speaker is producing a place of articulation difference—that is, [ts] vs. [tʃ]—spectral differences are also expected, as [s] should have a higher centroid than [ʃ] (Berkson 2013, Gordon et al. 2002).

Figure 5 shows, for each talker, linear regression lines representing the change in centroid frequency over the frication portion of each affricate production, from which we can observe three general patterns. First, some talkers (e.g. p06, p07, p11) produce both <c> and <ch> with decreasing centroid frequency over the course of frication, suggesting that both affricates are produced with at least mild aspiration. Second, other talkers (e.g. p04, p12, p15) produce both <c> and <ch> with a relatively constant centroid frequency, suggesting a more static lingual constriction with little to no aspiration. Lastly, some talkers (e.g. p01, p03, p09, p13) seem to produce a contrast between <c> and <ch>. Talkers p01, p03, and p09—the three speakers who show a clear durational difference between the two affricates—indeed appear to be producing an aspiration contrast: <c> productions have a flatter centroid frequency trajectory, whereas <ch> show a more decreasing trajectory. On the other hand, talker p13 seem to produce both <c> and <ch> with a decreasing trajectory, but <ch> with overall lower frequency. It is also worth noting that the temporal results in

Figure 4 seem to pattern similarly to the spectral results in Figure 5: it was talkers p01, p03, and p09 who showed the clearest temporal distinction between <c> and <ch>, and it was also they who showed the clearest spectral distinction as well. Spectrograms of the frication (and aspiration) portions of <ca> and <cha> tokens from speakers p03 and p04 are shown in Figure 6. The two affricates can be distinguished in speaker p03 by the drop in high frequency energy at the end of the frication portion of <cha>, whereas in speaker p04 there is no drop in high frequency energy in either affricate production.

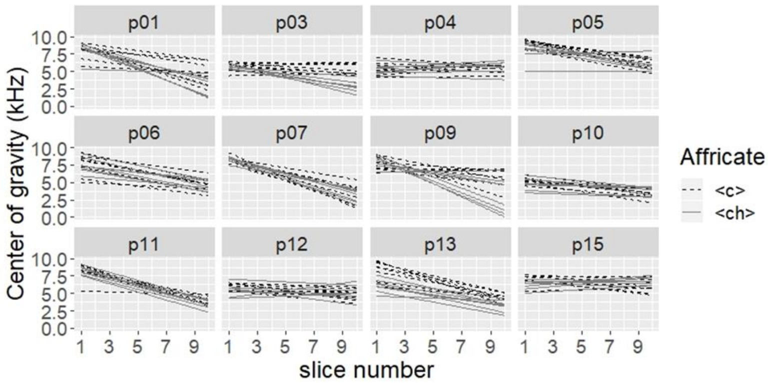

Figure 5. Centroid frequency trajectories for individual affricate productions from each talker

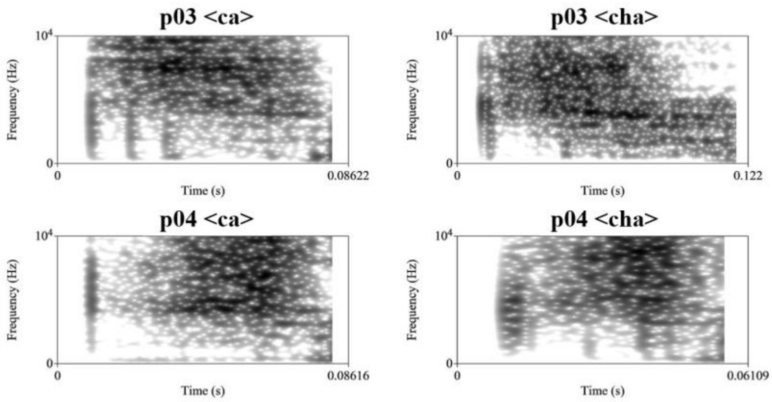

Figure 6. Spectrograms of <ca> and <cha> from talkers p03 and p04

Lastly, do these individual differences correlate with socioindexical categories, such as gender or dialect, and are they mediated by vowel context? First, there do not seem to be any gender- or dialect-related patterns. The clearest individual differences are between those talkers who seem to make a contrast (p01, p03, p09, and p13), and those who do not. But, those four talkers are equally split across gender, and while three of them (p01, p03, and p09) are speakers of the Dapzal dialect, that means there are three other Dapzal speakers (p04, p10, and p11) who are not making any affricate contrast at all. With only three talkers each from the Lamka and Lamzang dialect, the question of whether there is a consistent dialect difference remains to be addressed in future work.

There do not seem to be consistent effects of vowel context, either. Figure 7 shows the slopes of each affricate production from each talker split according to vowel context. Across some of the talkers there does seem to be a trend in which high vowels have flatter (closer to zero) slopes (e.g. p01, p03), whereas other talkers show no variation at all (e.g. p04, p10, p11). Furthermore, there does not seem to be any consistent trend as far as the difference in slope between affricates across vowel context: that is, it is not the case that, for example, <ch> consistently has a steeper (more negative) slope in some vowel contexts but not others. For these reasons, the most reasonable preliminary conclusion from the current data seems to be that no effect of vowel context is apparent. More data in a future study may shed light on this, however.

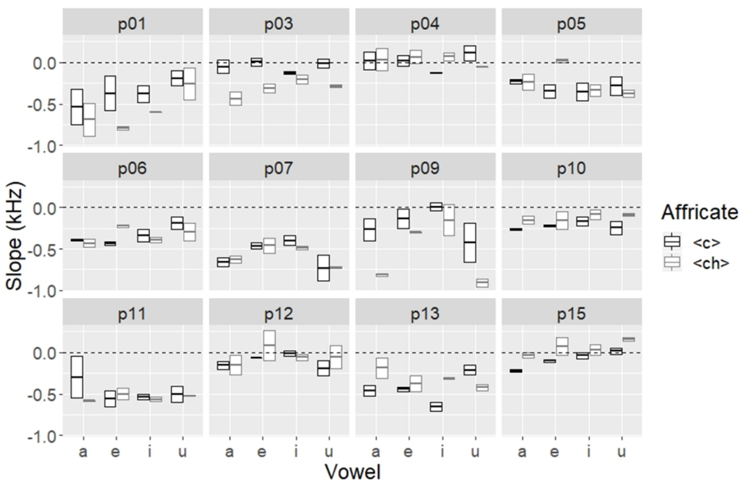

Figure 7. Distributions of spectral slope by talker, vowel context, and affricate orthographic variant

5. Discussion

The current study was undertaken to address four questions. As Kuki-Chin languages are underrepresented in the VOT literature, the first objective was to present VOT data for Paite and to establish the VOT distribution for Paite stops. While VOT values for each stop type exhibit some variation, the three stop types inhabit distinct portions of the VOT continuum: voiced stops are characterized by long negative VOT values, voiceless unaspirated stops by short positive VOTs, and aspirated stops by long positive VOTs (see Figures 1, 2). Significant differences in VOT across places of articulation were also found. In alignment with previous cross-linguistic findings, velar stops in Paite are produced with longer VOT values than labial or coronal stops. No robust differences between labial and coronal stops emerged, and differences across voiced stop categories were not significant.

The third and fourth research questions were more targeted, focusing specifically on the realization of the aspirated velar stop and the affricates. In particular, given that previous scholars have reported variable realization of these sounds in Paite, one question addressed herein was whether the aspirated velar stop /k^h/ is still realized as [k^h] or whether it is now realized as a fricative [x], and whether any variation observed is conditioned by vowel context, speaker gender, or dialect. With regards to the affricate(s), the question was whether or not the orthographic variants <c> and <ch> have merged, and whether there is any observed variation across speaker gender or dialect.

The findings actually reflect the same range of variation reported by previous scholars. The aspirated /k^h/ is produced as [k^h] by at least some of the speakers some of the time, in keeping with claims made by Devi (2010) and Khan (2000). As reported for some other Northern Chin languages, however, à la Button (2011), the velar fricative [x] production noted by Nianglianmoi (2016) and Singh (2006) is also well-attested in the current data set. The fricative variant is particularly well-represented for speakers of the Lamzang dialect. As noted above, these data may reflect a change in progress involving lenition of PKC /*k^h/ to /x/. This change would not be unexpected, as it has occurred in other Northern Chin languages (Button 2011).

Similar variability is reflected in the affricate data. Just as the aspirated sibilant affricate has been lost from some Peripheral Chin languages (Lotven et al. 2020, Van Bik 2009) and has been retained as either /ts/ vs. /ts^h/ or /ts/ vs. /tʃ/ contrast in some Central Chin languages (Lotven et al. 2020), all three possibilities are realized in the

Paite data reported herein. Eight speakers show near-complete merger between orthographic <c> and <ch>. The contrast between /ts/ and /ts^{h}/ is all but lost for these talkers. Four talkers maintain some kind of a contrast. The centroid trajectories shown in Fig. 5 suggest that for p01, p03, and p09 the contrast is between /ts/ and /ts^{h}/: these talkers show clear durational differences between the two affricates, and <ch> productions show the decreasing centroid trajectory that would be expected for aspirated segments. For speaker p13, meanwhile, /ts/ contrasts with something more /tʃ/; both <c> and <ch> have decreasing trajectories, but <ch> is produced with an overall lower frequency. Within this small sample of 12 talkers, then, all of the patterns reported in previous work are instantiated. These findings are likely indicative of a change in progress, but future work will be needed to confirm that the change is indeed progressing and to probe which factors influence the variation that is evident in the community.

The current work has provided instrumental acoustic analysis of speech produced by twelve native speakers of Paite. In addition to expanding the existing literature on VOT values in 3-category languages, it has probed questions of particular relevance to Paite. Specifically, it investigated the realization of the affricates and the voiceless aspirated velar stop, which have been described variably in previous work. The results align with all of the previous scholarship: variation is indeed attested in both the affricates and /k^{h}/. Future work involving more speakers, and conversational (rather than laboratory) data, will aid in developing a better understanding of both how robust the observed variation is and the role played by factors like gender, age, and dialect.

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