Title
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Publication Date
2013

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Introduction

One aspect of the maintenance of languages is the maintenance of the appropriate pronunciation. A language whose speakers use it only a minority of the time is often strongly affected by the phonetic patterns of the dominant language, particularly as speech habits natural to the 'new' language are carried over to the traditional one. Documenting the phonetic patterns of those speakers who were the last to have learned the language in question as their first language can provide an appropriate source of guidance to the pronunciation to adopt for later generations. In this paper we aim to present a good description of certain important aspects of the pronunciation of the stops of Tlingit. We hope that this data will be of value to those interested in the continuation of Tlingit as a spoken language. Of course, all languages change over time, and pronunciation will evolve in natural ways, so this information should be used in ways that accommodate natural changes. This data will also have value for comparative phonetic studies as illustrating details of a language whose phonetics has been previously little studied.

Tlingit ([ɬiŋít]) is a Na-Dene language (Krauss 1979) spoken in South-East Alaska and the Yukon. There are now few fluent speakers under the age of 60 (Dauenhauer and Dauenhauer 1995). The language has some dialect variation, with particular differences noted between Inland or Yukon Tlingit and Coastal or Alaskan varieties, and further differences between Northern, Central, and Southern varieties along the Coast. In this paper, all data is taken from what we are calling the Central dialect. Like its Athabaskan relatives, Tlingit has a quite complex consonant inventory, in particular having many affricates and fricatives. It also has a striking absence of plain labial consonants. More details on Tlingit phonetics are given in Maddieson, Bessell, and Smith (2001).

The basic stop inventory is outlined in Table 1 using standard phonetic symbols. There are stops at three places of articulation — alveolar, velar, and uvular, and with three manners of articulation — voiceless unaspirated, voiceless aspirated, and ejective. In addition to these nine stops there are also labialized velar and uvular stops in all three categories. The corresponding representations of these stops in Tlingit orthography are shown in Table 2. The voiceless unaspirated stops are written orthographically with the letters that would normally represent voiced stops, and the voiceless aspirated ones with the letters regularly used for voiceless stops in general. (This convention is also common in orthographies for Athabaskan languages.) Uvulars are written with the same letters used for velars but with an underline.

	Alveolar	Velar	Uvular
Voiceless Unaspirated	t	k	q
Voiceless Aspirated	t^h	k^h	q^h
Ejective	t'	k'	q'

Table 1: Inventory of non-labialized stops in Tlingit

	Alveolar	Velar	Uvular
Voiceless Unaspirated	d	g	$\underline{g}$
Voiceless Aspirated	t	k	$\underline{k}$
Ejective	t’	k’	$\underline{k}$’

Table 2: Tlingit orthography for stops

The Distribution of Tlingit Stops

The three series of stops contrast very straightforwardly in initial position, as in the triplet in Table 3.

Transcription	Orthography	Gloss
/qák^{w}/	*$\underline{g}$akw*	‘tree spine’
/q^{h}ák^{w}/	*$\underline{k}$akw*	‘basket’
/q’ák^{w}/	*$\underline{k}$’akw*	‘screech owl’

Table 3: A minimal triplet illustrating contrast between initial stop manners

The same three-way contrast also occurs in syllable-onset position in the middle of words. However, there are only two contrastive possibilities in word- or stem-final position, ejective and non-ejective. We will describe some aspects of the three-way distinction as it is produced in initial position, and then ask the main question that we wish to address in this paper, which is: what are these non-ejective stops in final position? We may entertain three obvious possible answers to this question:

A. They are the same as the aspirated stops in initial position.
B. They are the same as the unaspirated initial stops.
C. They are unlike either of the initial series, perhaps intermediate between the two.

The standard analysis accepted by previous writers is to treat them as aspirated, i.e., to accept possibility A above. This is clearly stated or quite expressly implied in one way or other by Boas (1917), Pinnow (1966), Leer (1978), and Dauenhauer and Dauenhauer (1991). The Tlingit orthography also treats them as aspirated in that the final non-ejective stops are written with the letters “*t, k, $\underline{k}$*” rather than “*d, g, $\underline{g}$*”.

The Definition of Aspiration

It may be useful at this point to clarify what we understand by aspiration. Aspiration is an interval after the release of a voiceless consonant during which noisy airflow is sustained. The vocal folds remain in the voiceless position — that is, slightly apart — after the articulatory movement in the mouth is over, and the flow of air through the space between the vocal folds, the glottis, creates the characteristic noise. The acoustic and articulatory patterns involved are illustrated in Figure 1, which shows an annotated spectrogram of the beginning part of the Tlingit word /t^haan/ 'sea lion' spoken by a male speaker. A time interval of about 450 milliseconds is shown in the figure. The approximate timing of the major articulatory phases involved is indicated by the boxes below the spectrogram. The precise moment at which the tongue makes contact with the alveolar ridge cannot be determined, but it is likely to be about 100 ms before the release, which is visible as the moment when the first acoustic signal is registered at the end of the 'tongue closure' box. The vocal folds come together into the voicing position a little after the 300 ms time point. The interval between the tongue release and the onset of voicing for the following vowel is filled with relatively high amplitude noise, with energy quite broadly distributed over the frequency range shown. On the spectrogram this is apparent as the heavy gray shading during this interval.

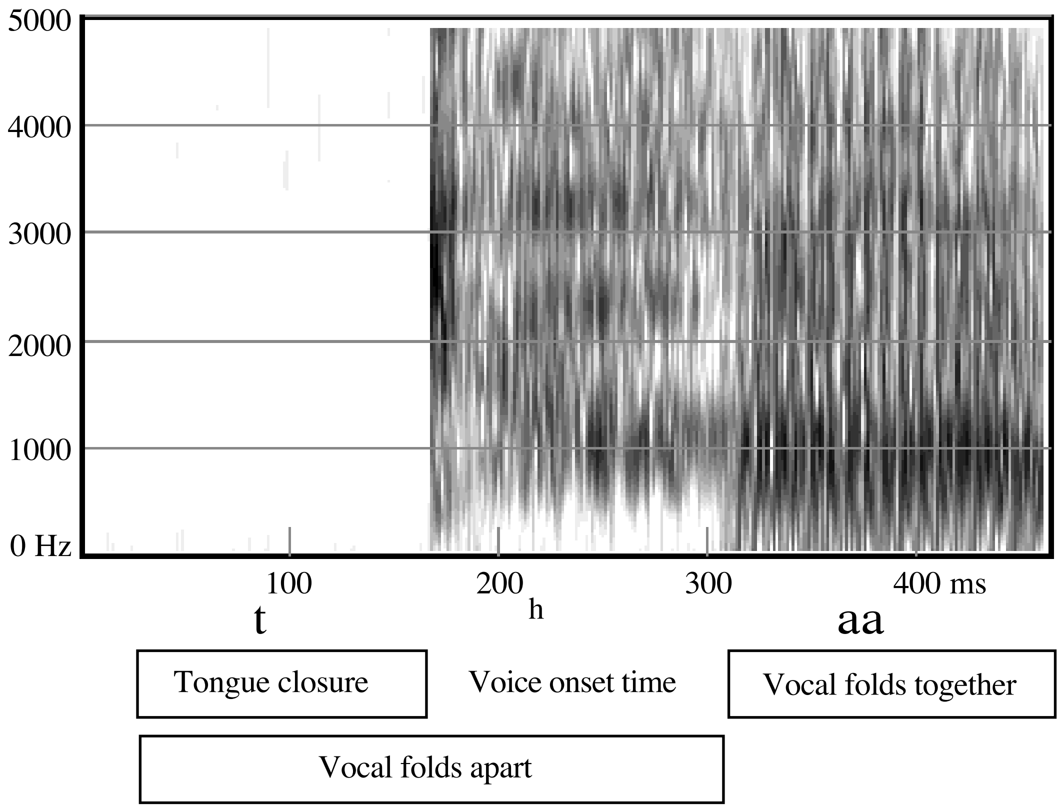

Figure 1: Acoustic and articulatory timing of aspiration in word-initial position

The interval between a stop release and the onset of voicing for a following segment is often referred to as the 'voice onset time,' abbreviated VOT. In Figure 1, the voice onset time is about 130 ms. It is sometimes suggested that an appropriate way to define a stop as aspirated is that there is a relatively long delay between release and voice onset. There are at least two reasons why this is not appropriate. First, this definition could only apply to stops which were in fact followed by a voiced segment, such as vowel. Hence, the definition itself would disallow word-final aspirated stops, or aspirated stops before another voiceless segment. Secondly, a delay in the onset of voicing can be due to a number of different causes. Of particular relevance is the fact that delayed voice onset can occur because the vocal folds remain fully closed for some time after the oral release of a stop. This is the case with the ejective stops of Tlingit, where the length of the interval between the release of the oral closure and the onset of a following vowel is about the same length as in word-initial aspirated stops. However, in the case of an ejective stop, the interval between the short burst of noise created by the oral stop release and the onset of voicing is filled with (near-)silence, rather than with the sustained noise that is characteristic of aspirated stops. This is illustrated in the annotated spectrogram in Figure 2, which shows the beginning of the word /t'aaw/ '(large) feather' spoken by a female speaker. Here, the release of the tongue contact for /t'/ occurs at about the 150 ms time-point, but the vocal folds maintain a complete closure for a considerable period after this release. Because no air is flowing out during this interval it is largely silent — that is, white on the spectrogram — rather than noisy. The onset of voicing, which occurs about 160 ms after the tongue contact is released, is due to relaxing a complete closure of the vocal folds, rather than to narrowing the glottis from the open position usually associated with voicelessness.

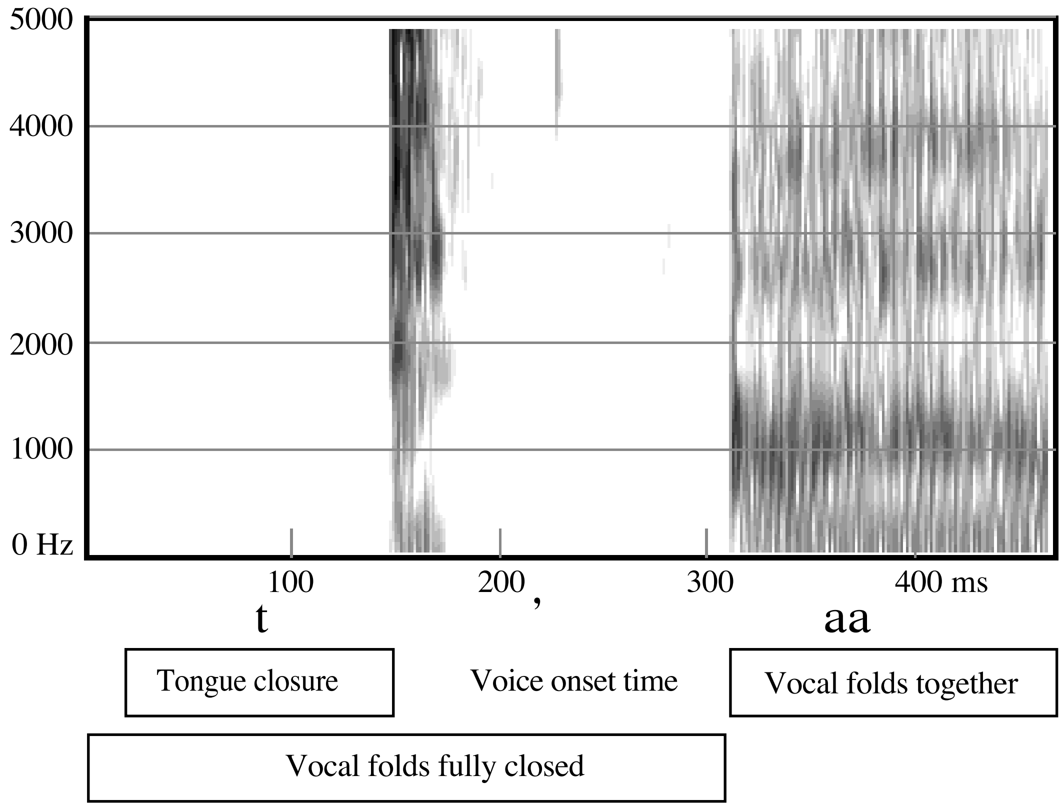

Figure 2: Acoustic and articulatory timing of an ejective stop in word-initial position

Across a substantial number of tokens, the mean value of the VOT for both the aspirated and the ejective stops in initial position is over 100 ms, as is shown in Figure 3. The VOT is considerably longer (four or five times) for both these categories of stops compared to the VOT for the voiceless unaspirated stops in the same position. The means in the figure represent 25 tokens in each category, taken from two (occasionally three) repetitions by four speakers of words with initial stops at all three places of articulation. The words were spoken in isolation as part of a recorded wordlist, and so are always utterance initial.

Since the ejective stops share with the voiceless aspirated stops the property of having a long period of VOT, this property alone is clearly not sufficient to characterize aspirated stops. Another description of aspirated stops as being followed by 'a puff of air' is also unhelpful, since a puff of air will be expelled following any released stop. What is crucial about the identification of aspirated stops as aspirated is that their release is followed by a sustained period of noisy airflow, rather than only a short noise period (as for unaspirated stops) or a sustained (near-)silence (as for ejective stops).

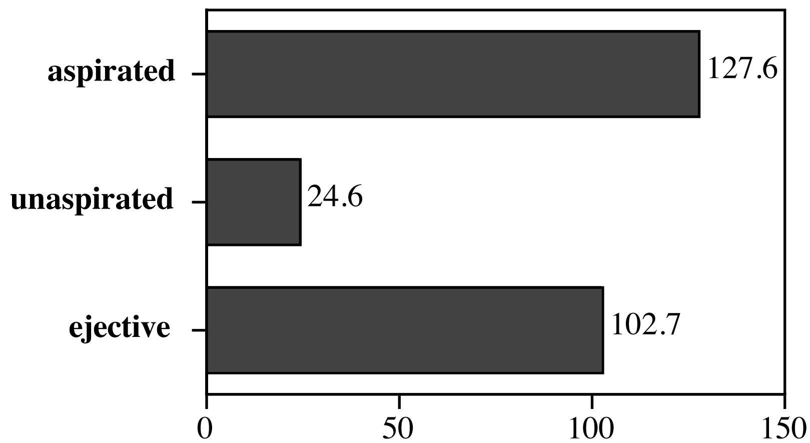

Figure 3: Mean durations of VOT in word-initial stops in Tlingit (in milliseconds)

We are now ready to consider whether it is appropriate to regard the final voiceless stops in Tlingit as exemplifying the aspirated or the unaspirated category, or if they are different enough from both of the voiceless stop categories that appear in initial position to be considered a different class from either. Both phonological and phonetic evidence will be taken into account.

Vowel-Initial Suffixes

There is a good phonological argument in favor of treating the final non-ejective stops as belonging to the unaspirated category: they are clearly not aspirated when they are followed by one of the relatively few vowel-initial suffixes. One such suffix is the genitive suffix whose base form can be considered to be /-i/ with polar tone. This suffix occurs in the phrase [aχ χaatí] 'my fish,' orthographic *ax̲ x̲aadí*, which is illustrated by the spectrogram in Figure 4. The stem-final stop release occurs a little after the 800 ms time-point in this figure, and the onset of voicing for the following vowel occurs only about 20 milliseconds later.

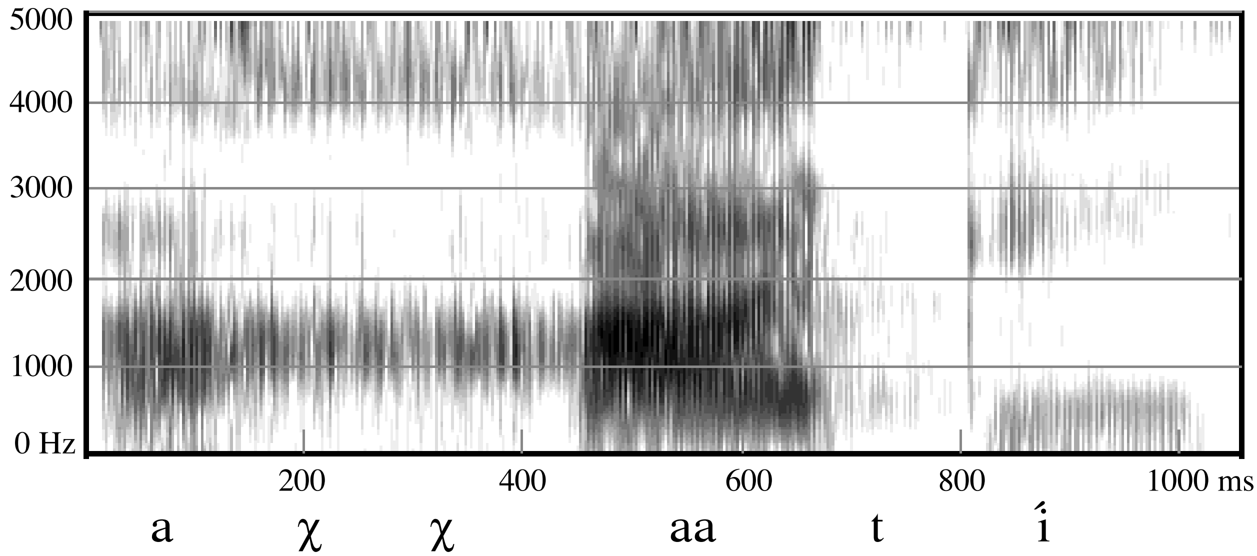

Figure 4: Spectrogram of the phrase /aχ χaatí/ (orthographic *ax xaadí*) ‘my fish’

A consequence of orthographically representing the final non-ejective stops as aspirated, as in the word *xaat* ‘fish’ is that the spelling of the stem must be changed when it is suffixed, as in the possessed form shown here, *ax xaadí* ‘my fish.’ The pattern in such cases was noted by Boas (1917) who explicitly chose to analyze it as a process involving replacing final aspirated stops with their unaspirated counterparts (actually, in his terminology, as replacing surds with sonants). That is, for Boas the stem-final stop consonant contrast was between ejective and aspirated stops when it occurred in coda position, but between ejective and unaspirated stops when the stem-final stops shifted to onset position. This analysis is accepted by all later writers. In particular, this is the case in the morphological analysis of Story (1963). Although she opts to write stem-final non-ejective stops with the symbols she uses for unaspirated stops, she clearly states that this is simply for the convenience of maintaining a constant transcriptional shape for the stems, which she considers to be phonologically alternating.

Cross-linguistically an alternation which introduces aspiration in coda position is somewhat surprising, since in many of the languages with aspiration contrasts in onset position, aspiration is disallowed in coda position (e.g., Thai, Korean, Cantonese, Navajo, Hupa, Tanana, and other Athabaskan languages). A simpler and more easily motivated phonology would posit no phonological alternation between stem-final non-ejective stops in coda and onset positions. We suggest that this is in fact the case, and that these stops are always unaspirated. The shape of the stem is faithfully preserved in all forms. Preliminary phonetic support for this claim is provided by the spectrogram of the unsuffixed form of the word for ‘fish’ (orthographic *xaat*) in Figure 5. The final stop in this word is similar in all major aspects to the intervocalic stop shown in Figure 4. In particular its release, at about the 680 ms time-point is followed by only a short noisy interval, suggesting that the appropriate transcription is indeed /χaat/ not /χaat^h/.

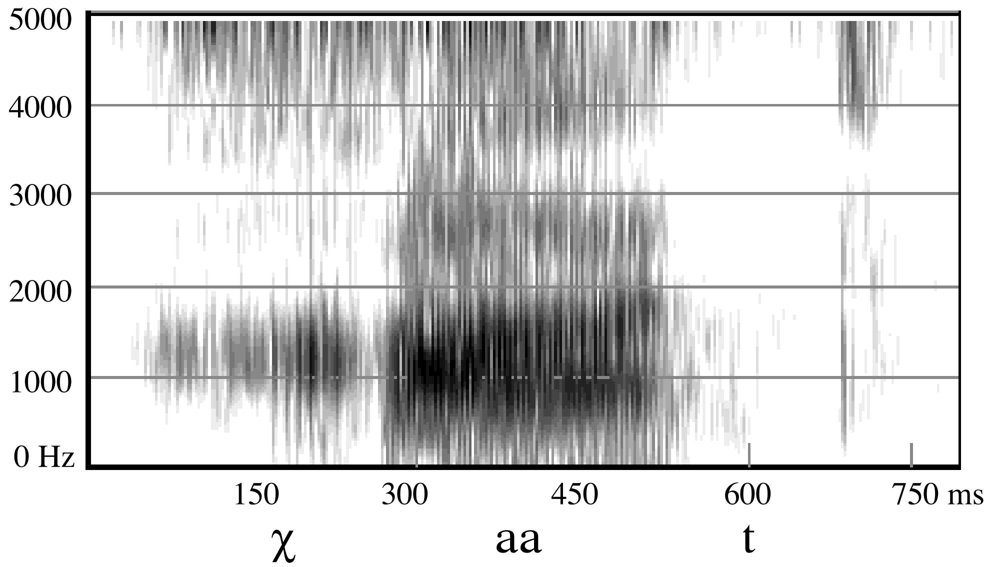

Figure 5: Spectrogram of the word /χaat/ (orthographic *x̲aat*) ‘fish’ spoken by the same speaker as Figure 4

Are Final Voiceless Stops Aspirated?

In order to compare initial aspirated stops and utterance-final non-ejective stops more systematically, a set of measurements was made of the amplitude of the noise following release in the words given in Table 4. We would expect aspirated stops to have a higher amplitude for a longer period of time following their release than would be observed in unaspirated stops. Data from four speakers, three female and one male, was examined. To eliminate possible effects of vowel quality and word length only monosyllabic words with the long vowel /aa/ were used. Uvular stops were excluded from this analysis, because they often have the complicating factor of a substantial duration of affrication following their releases. Therefore only alveolar and velar stops are shown. Typically two repetitions of two words from each of the speakers were measured, but there are fewer tokens of initial /k^h/ than of the other cases. The data measured includes a total of 33 final cases and 25 initial ones.

	Transcription	Orthography	Gloss	Speakers
Initial /tʰ/	tʰaan	*taan*	‘sea lion’	F1, M1, F2, F3
	tʰaat	*taat*	‘night’	F1, M1, F2, F3
Initial /kʰ/	kʰaak’	*kaak’*	‘forehead’	M1, F2, F3
	kʰaa	*kaa*	‘measuring stick’	F2
	kʰáax’	*káax’*	‘chicken, grouse’	F1
Final /t/	tʰaat	*taat*	‘night’	F1, M1, F2, F3
	χaat	*x̲aat*	‘roots’	F1, M1, F2, F3
Final /k/	saak	*saak*	‘eulachon’	F1, M1, F2, F3
	ɬ’aak	*l’aak*	‘dress’	F1, F2, F3
	jaak	*yaak*	‘mussels’	M1

Table 4: Words measured for comparison of initial and final stops

An amplitude curve and the way that measurements were made is illustrated by Figure 6. The amplitude of a speech sound is the amount of acoustic energy it has. A speech waveform, as at the bottom of this figure, displays the pressure variation in the signal both positive and negative as a series of instantaneous amplitude values. But the measure that corresponds to the total energy of a signal is a measure of the absolute value of the amplitude, usually called the RMS (root mean square) amplitude. To relate to sensations of loudness in the signal, this needs to be calculated over a certain window of time. For this analysis, a window 10 ms long was selected, which was moved along in 1 ms steps, so that values are reported at 1 ms intervals for overlapping time slices. The resulting amplitude curve — on a greatly enlarged scale — is shown in a lighter shade above the waveform. The highest amplitude occurs during the vowel, with lesser peaks after the two stop releases, whose times are marked by vertical gray lines. Note that because of the length of the analysis window, the amplitude curve appears slightly delayed with respect to the speech waveform.

In Figure 6 the amplitude remains quite high between the release of the closure of the initial stop and the onset of the following vowel, that is, during the aspiration interval for /tʰ/. In final position, although there is a short peak with nearly the same maximum, the amplitude drops off rapidly. A systematic analysis was performed in order to quantify such differences. The amplitude values were averaged over an interval of 80 ms beginning 20 ms after each stop release. The first 20 ms were not included in order to exclude the high amplitude of the release burst itself. The next 80 ms was measured so as to include most of the aspiration, whose duration is over 100 ms, as shown by Figure 3.

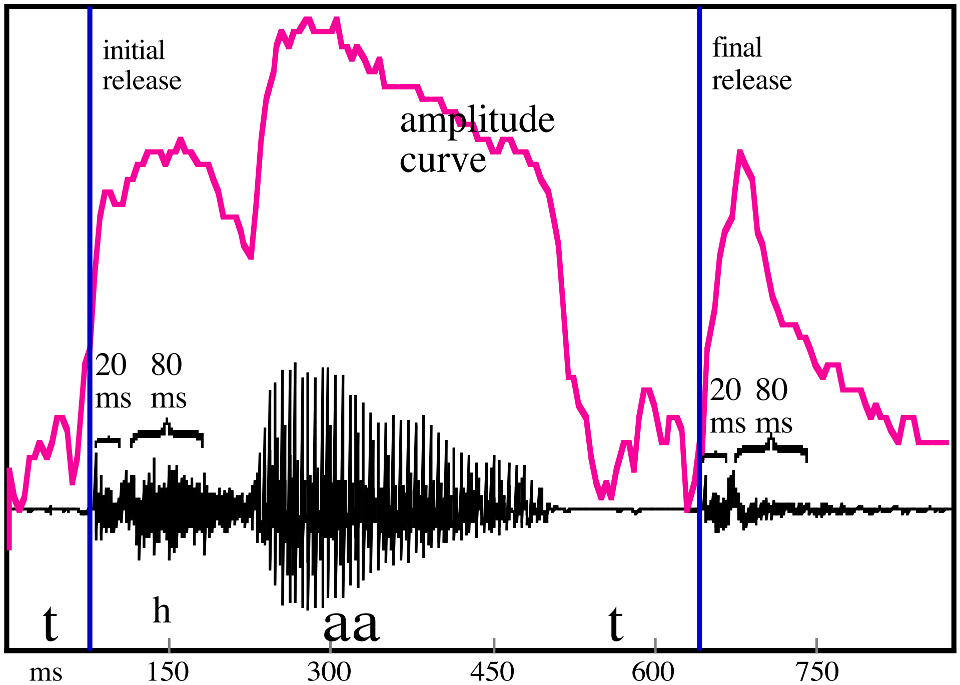

Figure 6: Waveform and amplitude curve for /t^haat/ 'night'

Amplitude is measured on the logarithmic scale of decibels (dB), and a difference of 6 dB corresponds roughly to an impression of double the loudness to a listener. In aggregate, in the data measured the mean amplitude over the 80 ms interval after initial stops was 25.0 dB, but the mean amplitude after final stops was only 15.8 dB. That is, it was well under half as loud on average. In statistical terms we may say that the initial and final amplitude values are significantly different (in a two-way analysis of variance with position and speaker as main effects, $F\ (1,50) = 14.26$, $p < .0001$ for position). The results are shown for each individual speaker in Figure 7. Although the levels for different speakers are also significantly different, in each case the noise amplitude after final non-ejective stop releases is at least 7 dB lower than after initial aspirated stops.

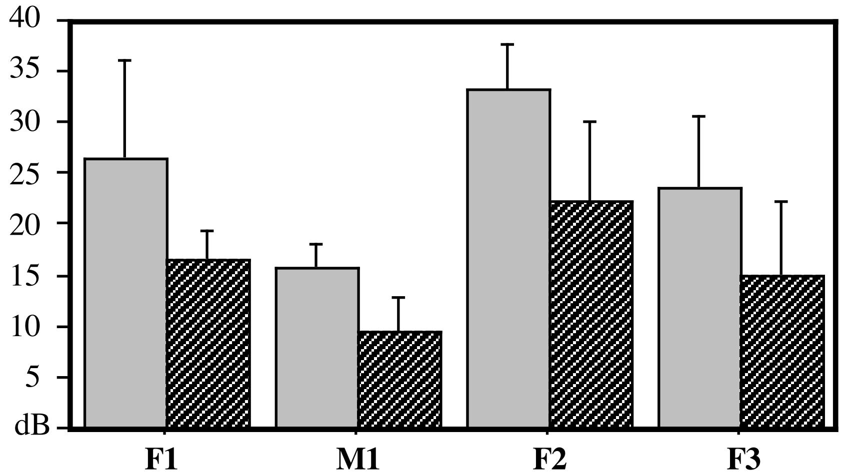

Figure 7: Mean amplitude averaged over an 80 ms window after voiceless stop releases in initial (stippled) and final (hatched) positions (alveolars and velars only)

Suggested Interpretation

Both the phonological and phonetic evidence presented above suggest that the final non-ejective stops are in fact unaspirated. Phonologically, this means that there is no alternation between an unaspirated form in onset position (preceding a suffix) and an aspirated form in coda position. Such an alternation would be surprising in view of the general disfavoring of aspiration in final position noted in many of the world's languages. Phonetically, the rapid reduction in amplitude following the release of final stops confirms that they are unaspirated. The RMS amplitude does rise briefly to a fairly high level immediately at the release of a final stop, but this peak is of very short duration, and corresponds to the audible release of the stop closure.

We suspect that the description of these Tlingit final stops as aspirated arises from a property of the phonetic grammar of the language which specifies that the release of utterance-final stops must always be audible. This is in quite marked contrast to English, where the final stop in a word such as *hat* is often pronounced without an audible explosion. It is likely that the invariable presence of an audible release struck English (and German) speaking linguists as making the final stop releases in Tlingit saliently stronger than those they were familiar with. However, as was emphasized earlier, the presence of an audible release is not the same as aspiration, which involves a sustained period of outward airflow.

The tendency to interpret final released non-ejective stops as aspirated may have been reinforced by an effect which can be noted on some occasions when such stops occur in words spoken in isolation. When an utterance is finished, a speaker usually opens the vocal folds wide into the position used for normal respiration. This posture is considerably wider than that for voiceless segments in speech. When respiration follows closely on the heels of an audible stop release, the release may be followed by some noise due to exhalation. This noise is of much lower amplitude than true aspiration noise, generated when the vocal folds are held in the voiceless position.

What About Word-Final Stops Not Utterance-Final?

The amplitude measurements presented above were for stops in utterance-final position. In this position, an audible release occurs without exception. To investigate how general the requirement for an audible release is in Tlingit, we also examined word-final stops that were not utterance-final. That is, we examined non-ejective stops occurring at the end of a word in the middle of a phrase, preceding another word. Because the data collection protocol had not originally been designed with this comparison in mind, suitable recordings were available only from one female speaker, identified by the code F2. In the phrases selected for this analysis, the second word always began with a voiceless stop or affricate, since a release of the first consonant can be unambiguously seen in such sequences. An example of the phrase /tɬeet q^háa/ (*dleit káa*) ‘white person’ (literally ‘snow person’) is shown in Figure 8 (note that the lateral component of the initial /tɬ/ segment in this particular utterance was pronounced as an approximant, not a fricative). In this example, the release of the /t/ at the end of the first word is clearly visible shortly after the 300 ms time mark, followed by a separate closure for the uvular stop /q^h/ about 50 ms later.

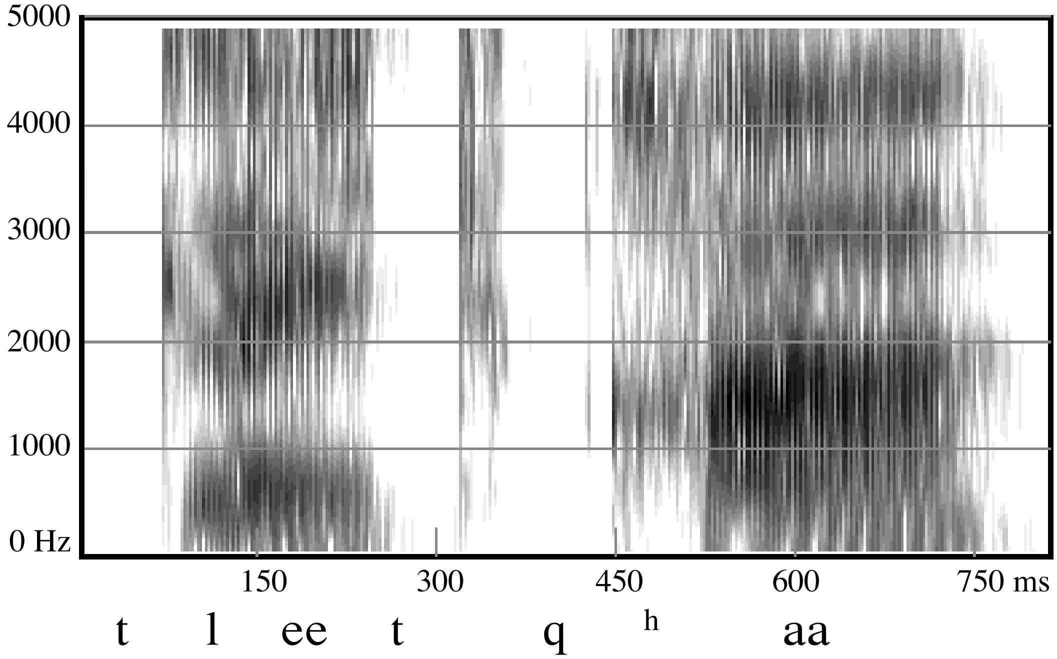

Figure 8: Final stop followed by non-homorganic stop

In all the examples examined, when the word-final and word-initial consonants are at different places of articulation, as in Figure 8, the first consonant always has an audible release before the silent period for the voiceless stop closure at the beginning of the second word. Thus the two closures never overlap in time and the silent periods for the two stops are separated by the release noise, making it easy for a listener to tell that there are two distinct stops being pronounced. In particular, the release noise provides information about the place of articulation of the first stop, which would otherwise be more difficult to extract from the signal.

In order to determine whether these word-final, phrase-internal voiceless stops are more like the aspirated or unaspirated stops that occur in syllable onsets in their timing, the durations of the releases of the word-final stops were measured and compared with the durations of voice onset times for word-medial aspirated stops in words such as /qaat^{h}aa/ ‘steel trap’ for the same speaker. The release duration is the interval from the beginning of the release burst for the first stop until the onset of the closure for the second (as deduced from the acoustic displays). Comparing the word-final stops with the word-medial aspirated stops, rather than the word-initial, may be more appropriate because in English, and likely in many other languages, consonants in utterance-initial position are longer than consonants later in an utterance. Mean results are given in summary form in Figure 9.

The mean release duration of the word-final stops is notably longer than the voice onset time for utterance-initial voiceless unaspirated stops reported in Figure 3. It also depends considerably on the place of articulation, being longer for consonants articulated further back in the mouth. The release duration of the word-final stops was shorter than word-medial aspiration for /t/ and /k/, and longer for /q/. As mentioned above, the release of /q/ is often accompanied by a substantial amount of affrication, which accounts for the longer release duration at this place of articulation. On the other hand, word-medial aspiration duration, measured as the Voice Onset Time, was relatively uniform across different places of articulation; hence a single mean is shown.

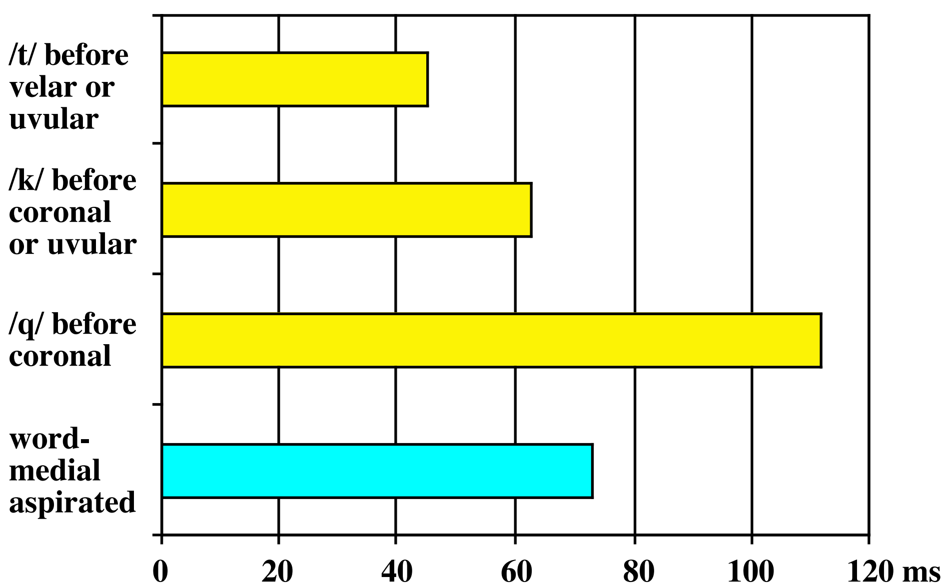

Figure 9: Duration of release for phrase-internal word-final stops and aspiration for word-medial aspirated stops

Because the number of tokens varied for different combinations of consonants, a more detailed breakdown of the results is given in Table 5. The data is not extensive, but it is sufficient to suggest that while the place of articulation of the first consonant is important, the place of the following consonant has no major impact on the length of the release interval. Table 5 confirms the relative stability of VOT measures for medial aspirated stops at different places. The difference in place sensitivity between release duration and aspiration duration can be taken as a further reason not to identify the final stops as belonging to the aspirated category.

Word-final stops	**Followed by**	**Number of tokens**	**Mean duration of release (ms)**
/t/	velar	24	45
	uvular	7	46
/k/	coronal	5	62
	uvular	1	68
/q/	coronal	3	112
Word-medial aspirated stops			**Mean duration of aspiration (ms)**
/t^{h}/		8	71
/k^{h}/		14	72
/q^{h}/		6	77

Table 5: Duration measures and number of tokens for word-final phrase-medial voiceless stops and word-medial aspirated stops

When a word-final stop is at the same place of articulation as a following word-initial stop or affricate in a phrase, creating what is known as a homorganic sequence of consonants, there is a quite different pattern to observe. In this case, an audible release of the first stop is not required. For example, in the /t t/ sequence from the phrase /tɬeet taak wusit^{h}án/ 'it is snowing', shown in Figure 10, the first /t/ is not separately released. Instead, the two stops are produced with a single long, geminate-like, closure.

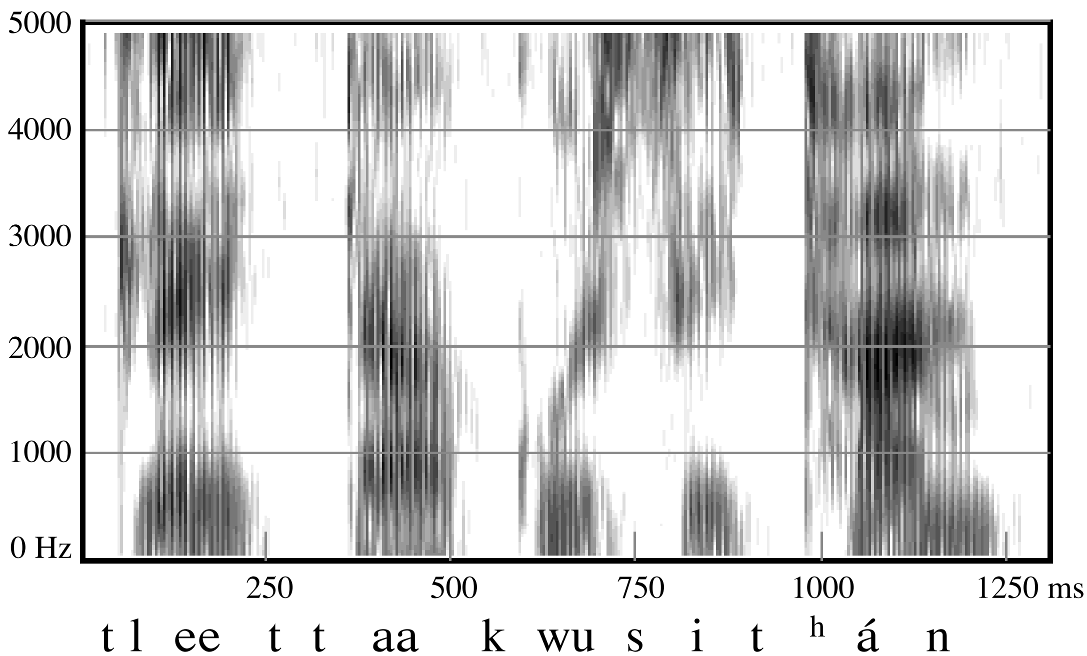

Figure 10: Sequence of stops [t t] at the same place of articulation

To examine how often a release was present or absent in such cases, a set of phrases in which a word-final /t/ or /k/ occurred before a word-initial consonant at the same place of articulation was examined from the tape available for speaker F2. No tokens were available of a uvular stop followed by a uvular. The number of tokens found and the number of these sequences in which no release of the first consonant could be heard, or seen in a spectrogram, is given in Table 6. Overall, the word-final consonant was not released in almost two-thirds of the homorganic sequences examined.

Word-final stop	**Followed by**	**Number of tokens**	**Number of tokens with no release**	**Percentage of tokens with no release**
/t/	[t], [tʰ], or [tʃʰ]	19	13	68%
/k/	[k] or [kʷʰ]	7	4	57%

Table 6: Number of tokens for word-final voiceless stops followed by a word-initial stop at the same place of articulation

Since the place of articulation is the same in these sequences, the release of the first stop does not provide any non-redundant information to the listener, provided there is a long closure duration to signal the presence of two segments. Thus the release is not perceptually functional in the same way that it is in the sequences with different places of articulation. We may also consider that the freedom to suppress a release in such contexts supports the interpretation of the final non-ejective stops as unaspirated. This is because the absence of a release would be quite odd if these stops were distinctively specified as aspirated, as aspiration cannot be manifested unless a release is present.

In a follow-up study we hope to analyze the quality and amplitude of the release duration noise which occurs in phrase-medial position, and to look at a wider range of consonant sequences, with data from a larger number of speakers.

Summary

We have shown that Tlingit follows the pattern found in Athabaskan languages of having a contrast between unaspirated and aspirated voiceless stops in initial position but in having only the unaspirated series in final position. Both phonological patterning and detailed phonetic analysis support the conclusion that word-final non-ejective stops should not be considered as aspirated. Utterance-final unaspirated stops are produced with an audible release, but measurements show that this release is not comparable to aspiration. The release noise is shorter and has lower amplitude than the noise of aspiration. Furthermore, a release is found in almost all word-final stops in phrase-internal positions; the cases where it is not produced being just those contexts where the release would contribute little to perception — that is, when the stop is followed by another stop or affricate at the same place of articulation. This pattern suggests that rather than being an essential property (as aspiration noise is for aspirated stops), the release is instead a consequence of speakers maximizing the perceptual distinctiveness of place of articulation cues in word-final stops. One aspect of speaking Tlingit correctly is to respect the distribution of such cues in the appropriate places.

The Tlingit orthography is helpful in showing that only one type of non-ejective stop occurs in final position, but misleading as to the correspondence between the final stops and the contrasting stops that occur in initial position. But so long as speakers are aware of the appropriate pronunciations, as laid out in the 'phonetic grammar' of the language, this is not likely to be a problem.

Acknowledgements

The data reported here were collected in August 1996 in Juneau through the good offices of Richard and Nora Dauenhauer and the Sealaska Heritage Foundation. We are extremely grateful to the Dauenhauers and all the speakers of Tlingit who graciously shared their knowledge with us. We also owe a great deal to our collaborator Nicola Bessell who originated the idea of a research trip to study Tlingit phonetics in more detail. Major support for this project was provided by the National Science Foundation through grant SBR-9319705 to Peter Ladefoged and Ian Maddieson for research on the phonetic structures of endangered languages.

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REPORT 15

SURVEY OF CALIFORNIA AND OTHER INDIAN LANGUAGES

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Table of Contents