An investigation of aspiration in nɬeʔkepmxcín

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1 Introduction

Aspiration is a common feature of phonological systems cross-linguistically. It is a characteristic linked closely with voicing and is typically measured as voice onset time (VOT; Lisker & Abramson, 1964). VOT is a measure used to categorize the voicing of stops by determining the time in milliseconds from the release burst of a stop consonant to the onset of the following vowel (as indicated by the first positive or negative movement of periodicity). Using a continuum of VOT alongside other phonetic parameters, stops can be broken down into four main categories: voiced aspirated, plain voiced (unaspirated), voiceless unaspirated, and voiceless aspirated. These four main categories of stops have been used to identify groupings of languages according to the number of stop categories per language: one-category languages like Blackfoot (ISO 639-3: bla), two-category languages like North American English (ISO 639-3: eng) and Cantonese (ISO 639-3: yue), three-category languages like Thai (ISO 639-3: tha) and Korean (ISO 639-3: kor), and four-category languages like Hindi (ISO 639-3: hin) and Marathi (ISO 639-3: mar; Genee & Li, 2023; Lisker & Abramson, 1964).[1]

Aspiration is a topic that has been under-researched in the study of Salish languages. Many language grammars offer only brief statements about aspiration, typically indicating only its presence or absence, with little or no data offered as evidence. For example, in SENĆOŦEN (Saanich, ISO 639-3: str), "obstruents are only rarely and weakly aspirated" (Montler, 1986) and in St̓át̓imcets (Lillooet, ISO 639-3: lil), "plain (non-glottalized) plosives are sometimes slightly aspirated" (van Eijk, 1997). In the Southern Interior Language Séliš (Kalispel-Spokane-Flathead, ISO 639-3: fla), there have been at least two descriptions of the VOT of voiceless stops (Cho & Ladefoged, 1999; Flemming et al., 2008). The VOT values from each study are provided in Table 1 and are consistent across the two publications. Unfortunately, the environments in which these stops were measured were limited to word-initial stops produced before non-high vowels or were not mentioned making it difficult to compare VOT in Séliš to other Salish languages.

Table 1: Average VOT in ms for voiceless stops in Séliš from Cho and Ladefoged (1999) and Flemming et al. (2008). Standard deviations when available are provided in parentheses.

Consonant	Cho & Ladefoged (1999)	Flemming et al. (2008)
/p/	22	24 (19)
/t/	24	22 (8)
/k/	48	37 (11)
/q/	55	54 (28)

* *nem kʷukʷstéyp* to c̓úʔsinek (Marty Aspinall), kʷaɬtəzétkʷu (Bernice Garcia), Gene Moses, and Bev Phillips without whom this project would not have been possible. kʷaɬtəzétkʷu wishes for it to be acknowledged that she is a Kamloops Indian Residential School speaker who is relearning her language and introduces herself as follows: *ʔes ʔúməcms kʷaɬtəzétkʷu təw ɬe c̓əɬétkʷu wéʔe ncitxʷ. ƛ̓uʔ wéʔec ʔex netíyxs scweʷw̓xmx, ƛ̓uʔ tékm xéʔe ne nɬeʔkepmx e tmixʷs.* "My traditional name is kʷaɬtəzétkʷu, my home is in Coldwater of 'Nicola' of Nlaka'pamux lands."

I am also very grateful to Lisa Matthewson, Ashley Farris-Trimble, John Alderete, and members of the nɬab and Secwepemctsín Working Group for their feedback on this work in its many iterations.

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[1] There are additional categories of stops that can be distinguished on the basis of glottalization. These are relevant to Salish languages but will not be discussed in this analysis.

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1.1 *Aspiration in nłeʔkepmxcín* The present analysis investigates the aspiration system of nłeʔkepmxcín (Thompson, ISO 639-3: thp), a Northern Interior Salish language spoken in south-central British Columbia. Based on the 2022 Report of the Status of B.C. First Nations Languages, there are 105 fluent speakers (most of whom are elderly), 312 semi-fluent speakers, and 517 active learners of the language (Gessner et al., 2022)[2]. Within nłeʔképmx territory, there are language learning initiatives for all ages including school, mentor-apprentice, and university programs, and language nests. One goal of this work is to help establish features of pronunciation that can be used by these learners in their language acquisition process.

nłeʔkepmxcín is documented as having 9 phonemic voiceless stops and no phonemic voicing. These stops are outlined in Table 2 (Thompson & Thompson, 1992: 3).

Table 2: The stop phoneme inventory of nłeʔkepmxcín as outlined by Thompson & Thompson (1992: 3).

Place of articulation	**Orthography**	**IPA**
Labial	p	/p/
Dental	t	/t/
Post-dental	c̣	/ts/
Alveo-palatal	c	/tʃ/
Simple velar	k	/k/
Rounded velar	kʷ	/kʷ/
Simple post-velar (uvular)	q	/q/
Rounded post-velar (uvular)	qʷ	/qʷ/
Laryngeal (glottal)	ʔ	/ʔ/

Obstruents in nłeʔkepmxcín are described as lenis and voiceless (Thompson & Thompson, 1992: 3). The lenis nature of obstruents in the language means that in many voiced environments they can sound voiced to the English ear. An unpublished spectrographic analysis of a speaker of the Nicola Valley dialect conducted by Sharon Mayes and reported in personal communication to Laurence and M. Terry Thompson found no instrumental evidence of voicing of the language's obstruents (Thompson & Thompson, 1992: 4). Sounds like /z/, /ɣ/, and /ʕ/ that might be considered voiced obstruents in other languages are categorized as resonants (or sonorants) in nłeʔkepmxcín (Jimmie, 1994).

Within the inventory of plain voiceless stops in nłeʔkepmxcín, Thompson and Thompson (1992) outline a system of aspiration with four categories (Table 3). Within the proposed system, stops are categorized as "unaspirated before vowels and resonants, but often somewhat aspirated before a spirant and regularly before another stop. In syllable final position they are strongly aspirated" (Thompson & Thompson, 1992: 4).

Table 3: nłeʔkepmxcín aspiration system as outlined by Thompson & Thompson (1992)

Position	Description of Aspiration
_____V; _____resonant	Unaspirated
_____spirant	Somewhat aspirated
_____stop	Regularly aspirated
_____σ	Strongly aspirated

No data are provided as evidence for these categories, and clear definitions of the meanings of somewhat, regularly, and strongly are not provided[3]. This proposed system suggests that aspiration is allophonic with varying levels of aspiration based on the phonological environment. However, aspiration is not typically described as a linguistic feature with levels, rather it is a binary feature where sounds are either "aspirated"

[2] This count may not be fully reflective of the current population of nłeʔkepmxcín speakers or learners as during the survey period in 2021, communities in nłeʔképmx territory were affected by forest fires and severe flooding leading to a low number of reporting communities.

[3] Following data collection and analysis, a second interpretation of the proposed system was brought to my attention. In this alternative interpretation, Thompson and Thompson (1992) outline a three-category system where stops are often somewhat aspirated before spirants and regularly somewhat aspirated before stops. Based on the results shown in Figure 2 below, the results of this paper suggest that the four-category interpretation is more in line with the data.

or “unaspirated.”

Since this description of the nɬeʔkepmxcín aspiration system was outlined in the grammar, only one published work has presented evidence to further clarify the categorizations (Reid, 2023). In this preliminary study, a small sample of target stops from one fluent nɬeʔkepmxcín speaker was analyzed, and evidence was found that only word-final stops were aspirated in nɬeʔkepmxcín. However, the measured tokens were only targeted at word boundaries to the exclusion of stops in word-internal positions. This work serves as a continuation of that initial analysis.

A small amount of research has focused on aspiration in nɬeʔkepmxcín prosodic phrase boundaries. Koch (2010, 2015) examined how lengthening as a prosodic phrase boundary cue manifested as aspiration on the /t/ in the first-person plural clitic *-kt* in phrase-final position. Measurements of /t/ aspiration in phonological-phrase-final, intonation-phrase-final, and phrase-internal positions showed that /t/ had the longest release burst duration in intonation-phrase-final position (mean 218ms, SD 60ms), the shortest in phrase-internal position (mean 76ms, SD 42ms), and a release burst duration between those two in phonological-phrase-final position (mean 95ms, SD 42ms). Koch’s work provides support for aspiration being a feature of the language, but because it is focused on phrase positions, does not add further clarification to the system of aspiration outlined by Thompson and Thompson (1992). The primary goal of this research is thus to expand on the analysis of Reid (2023) and further describe the system of aspiration in nɬeʔkepmxcín and how it differs from the system proposed by Thomspon and Thompson (1992).

2 Method

Data collection for this project took place over a two-year period. The majority of the data was collected in Zoom elicitation sessions, but there were also some in-person elicitations. The targeted word list consisted of both mono- and multi-syllabic words selected from the published dictionary (Thompson & Thompson, 1996) containing labial, dental, velar, and uvular stops. In some cases, consultants provided words that were not on the word list but contained one of the sounds of interest, and these words were subsequently added to the word list and elicited from the other consultants. A sample of the word list is provided in Table 4.

Table 4: Sample of full word list. Target sound sequences are bolded and underlined

Target Environment	Example words	
_____V	***k****éyx* ‘hand’	*ntkʷ***p***éń̓i* ‘he/she becomes deaf’
_____resonants	***t****míxʷ* ‘land’	*spə***p***lánt* ‘skunk’
_____spirant	***kɬ****íyxems* ‘he/she stops doing something’	*sxáy***qs** ‘coho salmon’
_____stop	***pt****éyptn* ‘rug’	*sƛ̓í***qt** ‘sky’
_____σ	*ƛ̓ə***qʷ***ʔúm* ‘he/she sews something’	*sɣé***p** ‘tree’

The same word list was used in elicitations with three fluent speakers of nɬeʔkepmxcín: one female speaker from Lytton, one female speaker from Coldwater, and one male speaker from Shulus. Morphologically simple words were elicited in isolation by asking speakers to translate English words into nɬeʔkepmxcín. Morphologically complex words like *sq̓ʷoq̓ʷy̓éps* “his/her strawberries” were elicited by asking speakers to translate English sentences such as *These must be his strawberries* as in (1).

(1) c̓é nke xʔe ʔe sq̓ʷoq̓ʷy̓éps.
c̓-[ʔ]e=nke=xʔe e=s-q̓ʷoq̓ʷy̓ép-s
EMPH-COP=INFER=DEM DET=NMLZ-strawberry-3POSS
‘These must be his strawberries.’ (BP | 2023-02-22)

Stop targets were categorized based on Thompson and Thompson’s (1992) original four categories assuming that the phonetic environments did not extend across syllable boundaries. Research on the syllable structures of Salish languages is limited and there has been no established syllable template to date for nɬeʔkepmxcín specifically. For the purposes of this analysis, I assumed a relatively simple syllable shape with no more than two segments allowed in an onset or a coda. I also assumed adherence to the sonority sequencing and maximum onset principles (Clements, 1990). Previous research on syllables in Salish languages has suggested similar syllable shapes across the family (Bates et al., 2015; Czaykowska-Higgins & Willett, 1997; Marinakis, 2004; Marlo, 2004). Using my syllable assumptions, a stop preceding a vowel, resonant, spirant, or stop in the same syllable was labeled as pre-vowel, pre-resonant, pre-spirant, or pre-stop respectively. Stops occurring as the last segment in a syllable were labeled as syllable-final. For example, in a word like *tukʷtúkʷt* "shelter," the first /kʷ/ was labeled as syllable final and the second /kʷ/ was labeled as pre-stop (see Figure 1).

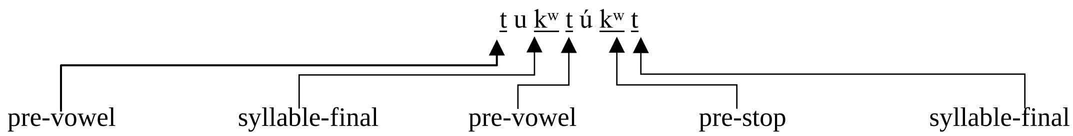

Figure 1: Stop classifications for the nłeʔkepmxcín word *tukʷtúkʷt* "shelter"

2.1 *Audio processing and analysis* All Zoom recordings were converted from MP4 to WAV files to allow the audio files to be measured with Praat (Boersma & Weenink, 2022). In-person recordings were saved as WAV files after each session, so no file conversion was required. Target words were extracted from the long audio files and target stops were annotated from the onset of the release burst to either the onset of the following sound or to the visible and audible end of the release burst for stops in word-final position (this measure has also been referred to as voice offset time or VOFT; Abramson & Whalen, 2017).

3 Results

Before reporting the results, it is first necessary to determine whether stops before vowels and stops before resonants can be considered one category. A t-test comparing these two environments showed no significant differences in release burst duration ($t(448) = 0.12$, $p = 0.91$). As such, this category will be referred to throughout the remainder of the paper as pre-sonorant.

In total, 855 plain voiceless stops were measured with 451 stops before sonorants, 77 stops before spirants, 67 stops before stops, and 260 stops in syllable-final position. A breakdown of the place of articulation of these stops based on their position within the target words is provided in Table 5.

Table 5: Number of tokens for each proposed Thompson and Thompson (1992) environment and place of articulation

Target Environment	/p/	/t/	/k/	/q/	Total
_____sonorant	141	120	122	68	451
_____spirant	30	8	32	7	77
_____stop	27	10	18	12	67
_____σ	68	97	47	48	260

3.1 *Results by Thompson & Thompson's (1992) categorization* Average release burst durations for each of the four targeted environments at first appear to pattern closely to the categories outlined by Thompson and Thompson (1992). Table 6 shows the mean release burst duration for each category and place of articulation.

Table 6: Average release burst duration in ms for each proposed Thompson and Thompson (1992) environment and place of articulation. Standard deviations are provided in parentheses.

Target Environment	/p/	/t/	/k/	/q/	Overall
_____sonorant	15 (9)	22 (15)	38 (20)	35 (22)	26 (19)
_____spirant	15 (6)	59 (35)	40 (23)	54 (26)	34 (26)
_____stop	46 (34)	48 (18)	98 (27)	90 (22)	68 (37)
_____σ	98 (54)	122 (70)	114 (54)	113 (67)	113 (63)

A multiple linear regression model was used to test if the Thompson and Thompson aspiration category, speaker, or place of articulation significantly predicted the duration of release burst for plain voiceless stops (see (2)).

(2) Duration ~ TT_code + speaker + POA_code + speaker * TT_code + POA_code * TT_code

Forward difference coding was used for both aspiration category and place of articulation. With these variables the proposed differences change from one level to the next; forward difference coding allowed for this type of comparison. Helmert coding was used for the speaker variable and allowed for a comparison of the Lytton dialect speaker to the non-Lytton speakers and the two non-Lytton speakers to each other.

Table 7: Test of categorical variables on release burst duration

	EST	*SE*	*t*	*p*
(intercept)	61.2	2.5	24.9	< 0.001
pre-sonorant vs pre-spirant	-15.5	6.7	-2.3	< 0.05
pre-spirant vs pre-stop	-32.3	9.2	-3.5	< 0.001
pre-stop vs syll-final	-28.5	7.2	-3.9	< 0.001
labial vs dental	-17.2	5.6	-3.1	< 0.01
dental vs velar	-12.9	5.8	-2.2	< 0.05
velar vs uvular	0.7	5.8	0.1	0.90
pre-stop – syll-final : Lytton – non- Lytton	-40.8	11.9	-3.4	< 0.001

Results of the fitted regression model (see Table 7) showed that each Thompson and Thompson (1992) category was significantly different from the next. Figure 2 shows that stops before sonorants were significantly shorter than stops before spirants which were significantly shorter than stops before stops which were in turn significantly shorter than syllable-final stops.

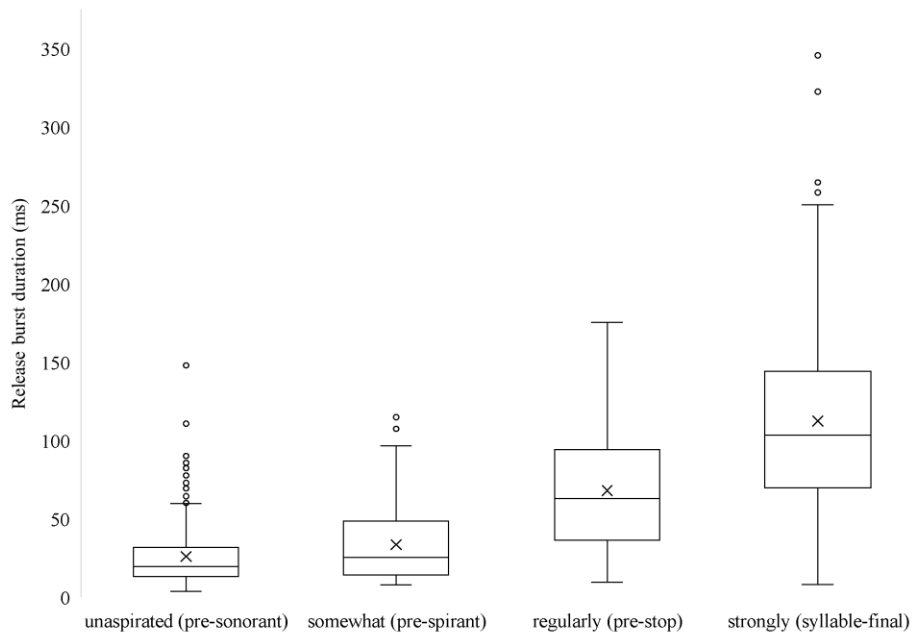

Figure 2: Release burst duration for each Thompson and Thompson (1992) category

For place of articulation (Figure 3), dental stops had significantly longer release bursts than both labial and velar stops, but velar and uvular stops were not significantly different. This follows patterns seen in previous literature that stops produced further back in the mouth like /k/ or /q/ will have a longer duration of release burst compared to stops produced further forward in the mouth like /p/ (Cho & Ladefoged, 1999). This difference is related to the volume of the cavity behind the point of restriction. When the cavity behind the point of restriction is smaller, there is a greater amount of pressure built up behind the obstruction which takes longer to fully release. Release burst duration was not significantly different for speakers which suggests that there were not dialectal differences in the way that aspiration is used in nłeʔkepmxcín.

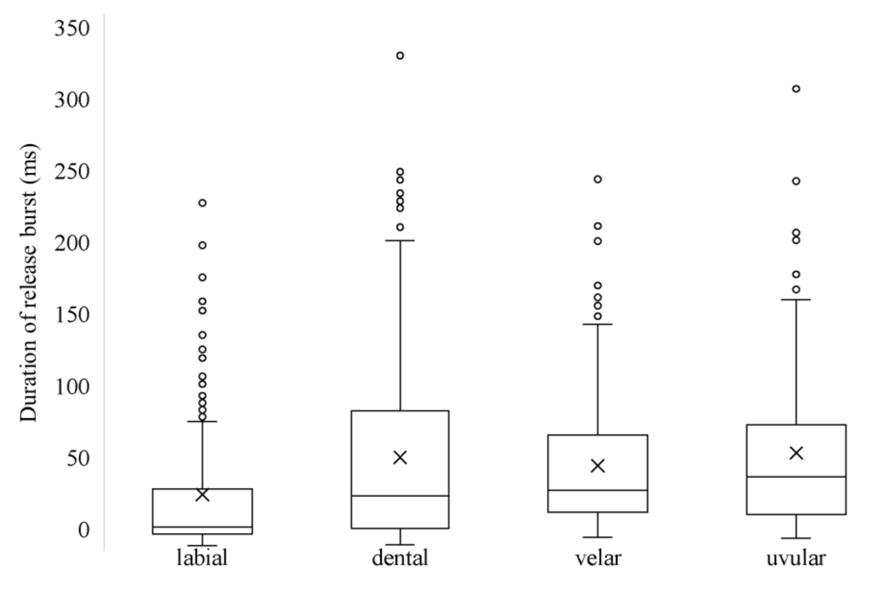

Figure 3: Release burst duration for each place of articulation

There was a significant interaction found for speaker and proposed Thompson and Thompson (1992, Table 7). As seen in Figure 4, all three speakers had longer release burst duration for the syllable-final stops. However, the Lytton speaker (BP) had a much greater duration for syllable-final stops. It is unclear whether this difference should be attributed to dialect of speaker specific characteristics and research with additional speakers of these dialects is needed to help identify dialect differences.

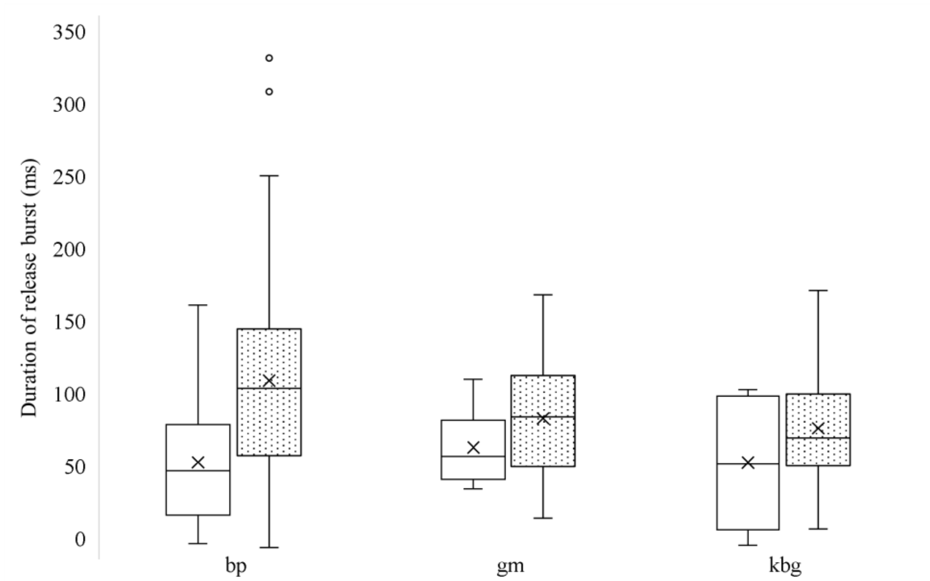

Figure 4: Release burst duration for the pre-stop (white) compared to the syllable-final (dotted) categories for all three speakers

3.2 *Considering word position* Looking at the above results alone, it does appear that the original categorization proposed by Thompson and Thompson (1992) can in part capture the way that aspiration patterns in the language. However, these categorizations are an oversimplification of how aspiration on plain voiceless stops appears in nłeʔkepmxcín. The problem with the original categorization is that it only considered the immediately following segment within a syllable and did not consider effects of word-position. For example, stops before sonorants can occur word-initially or word-medially, stops before stops and stops before spirants can appear word-initially, word-medially, and word-finally, and syllable final stops can occur in word-medial and word-final positions. I thus compared release bursts in different word positions for each Thompson and Thompson (1992) category. An updated sample of the word list that reflects these word positions is provided in Table 8.

Table 8: Sample of full word list separated by Thompson and Thompson (1992) proposed category and word position. Targeted sound sequences and bolded and underlined.

Target Environment	Initial	Medial	Final
_____sonorant	***k****ázeʔ* ‘lie’	*spé****k****eʔ* ‘gloves’	
_____spirant	***t****xíʔxeʔt* ‘narrow’	*spté****kʷ****łem* ‘tell creation story’	*sx̣áy****q****s* ‘coho salmon’
_____stop	***p****téyptn* ‘rug’	*ptéy****p****tn* ‘rug’	*sƛ̓í****q****t* ‘sky’
_____σ		*cá****q****cəqt* ‘spruce grouse’	*łké****p*** ‘pot/pan’

A breakdown of the average release burst duration for each of the target environments by word position is provided in Table 9.

Table 9: Average release burst duration in ms for each proposed Thompson and Thompson (1992) environment and word position. Standard deviations are provided in parentheses.

Target Environment	Initial	Medial	Final
_____sonorant	27 (19)	25 (19)	
_____spirant	43 (30)	38 (32)	29 (22)
_____stop	37 (18)	47 (21)	95 (28)
_____σ		50 (33)	125 (61)

A multiple linear regression model was used to test if Thompson and Thompson (1992) aspiration category, word position (initial, medial, or final), or speaker significantly predicted the duration of release burst for plain voiceless stops (see (3)). Place of articulation was not included in this model. As with the model described in Section 3.1, forward difference coding was used for aspiration category and Helmert coding was used for the speaker and word-position variables.

(3) Duration ~ TT_code + speaker + position + TT_code * Position + speaker * Position

Results of the fitted regression model (see Table 10) showed that when incorporating word position as a variable, the effect of Thompson and Thompson (1992) aspiration category was weaker than for the model presented in Section 3.1 suggesting that the effects of word position subsumed the effects of the following segment. Figure 5 shows that stops in word-initial and word-medial positions had overlapping ranges of release burst duration. However, in word-final position (stops following the final syllable nucleus of a word), stops had significantly larger release bursts. Figure 6 further shows how word-final position was the aspiration environment that made pre-stop and syllable-final stops in particular differ from the other previously discussed environments.

Table 10: Test of categorical variables and significant interactions between variables on release burst duration when considering word position

	EST	*SE*	*t*	*p*
(intercept)	43.4	2.1	20.9	< 0.001
Pre-spirant vs pre-stop	-22.3	8.8	-2.7	< 0.01
Lytton vs non-lytton speakers	11.7	2.5	4.7	< 0.001
Final vs non-final position	19.2	5.9	3.3	< 0.01

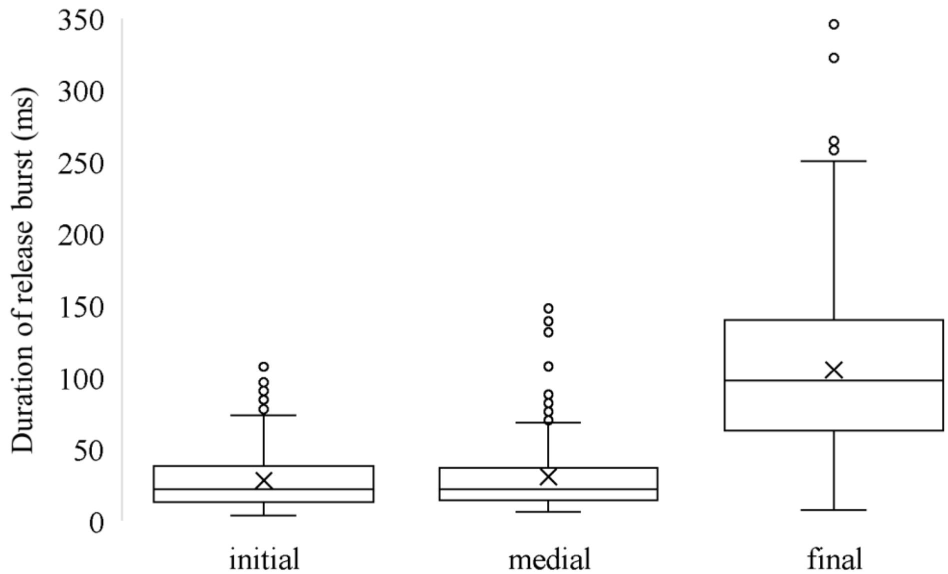

Figure 5: Release burst duration for stops across word positions

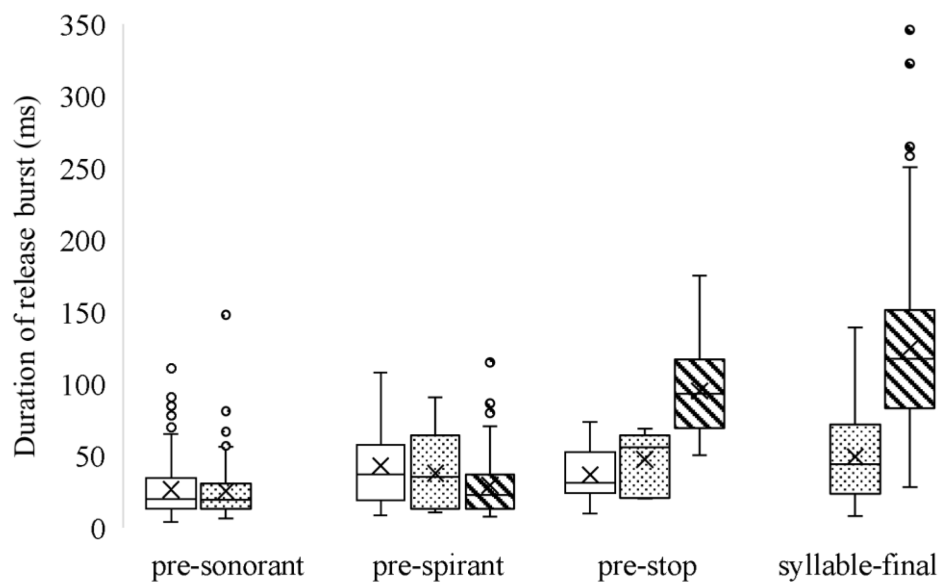

Figure 6: Release burst duration for word-initial (white), word-medial (dotted), and word-final (lined) stops by the original Thompson and Thompson (1992) aspiration categories

There were three interactions involving word position in the model (see Table 11). One interaction was for pre-spirant compared to pre-stop stops in non-word-final and word-final positions. As seen in Figure 7, in non-word-final positions pre-spirant and pre-stop release bursts were similar. In word-final positions, the pre-stop environment had larger release burst durations.

Table 11: Interactions found in linear regression

	EST	*SE*	*t*	*p*
(intercept)	43.4	2.1	20.9	< 0.001
pre-stop – pre-spirant : Final – non-final	-60.3	14.0	-4.3	< 0.001
Lytton – non-Lytton : final – non-final	28.3	5.2	5.4	< 0.001
Lytton – non-Lytton : initial – medial	13.6	6.2	2.2	< 0.05

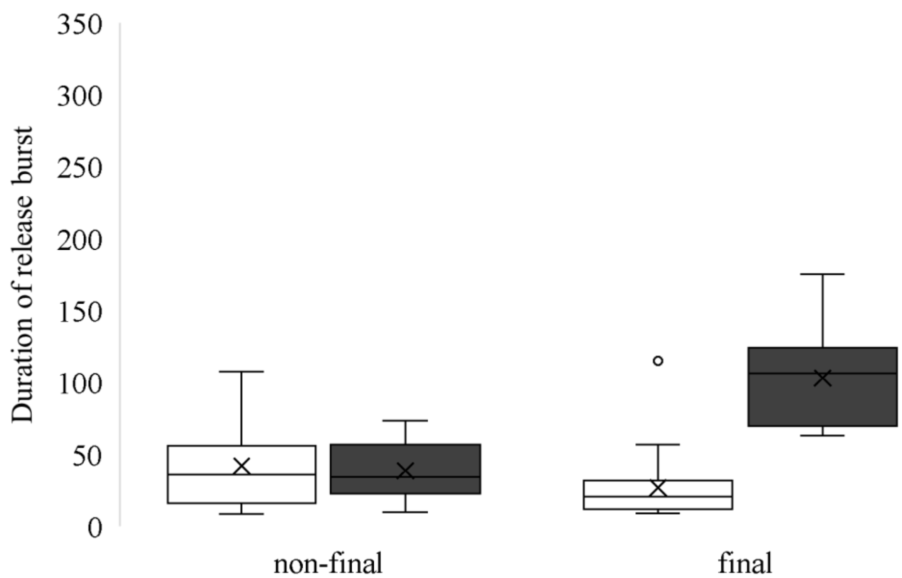

Figure 7: Release burst duration for stops in pre-spirant (white) and pre-stop (grey) environments by word position

The other two interactions involved word position and speaker. In both interactions the Lytton speaker showed different release burst durations compared to the non-Lytton speakers. These interactions are plotted in Figures 8 and 9. In both plots, it is clear that the Lytton speaker had more variability in release burst duration than the two non-Lytton speakers. For the comparison of final and non-final positions, the speakers had similar durations for stops in non-final positions but the Lytton speaker had longer release burst durations in final position. For the comparison of initial and medial word positions, the mean release burst duration was similar between the Lytton and non-Lytton speakers for medial position, but in initial position the Lytton speaker had a longer average release burst duration compared to the non-Lytton speakers. Average release burst durations for each comparison and dialect are provided in Table 12.

Table 12. Average release burst duration in ms for voiceless stops by word position. Standard deviation is provided in parentheses.

	Initial	Medial	Final
Lytton	32 (22)	31 (27)	116 (71)
Non-Lytton	23 (14)	31 (22)	87 (44)

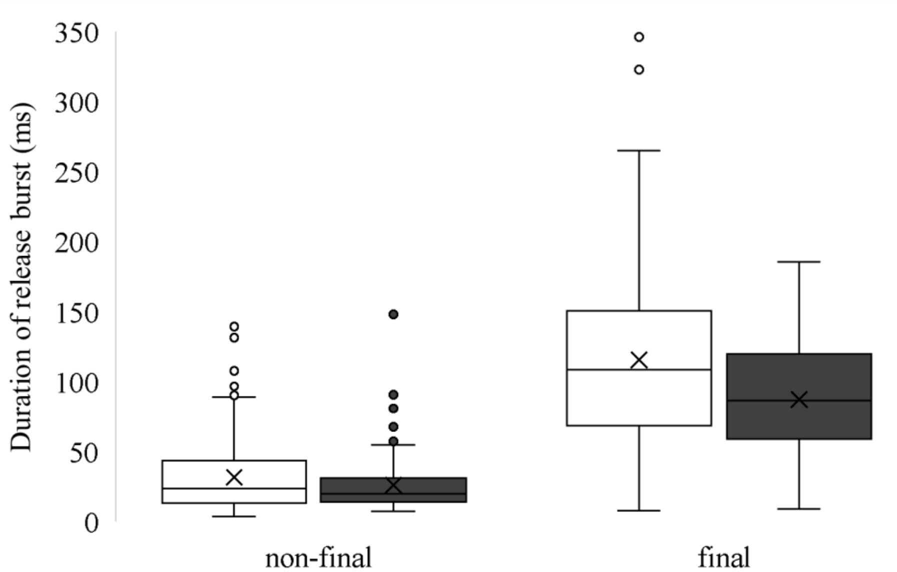

Figure 4: Release burst duration for Lytton (white) and non-Lytton (grey) speakers based on stops in final and non-final word positions

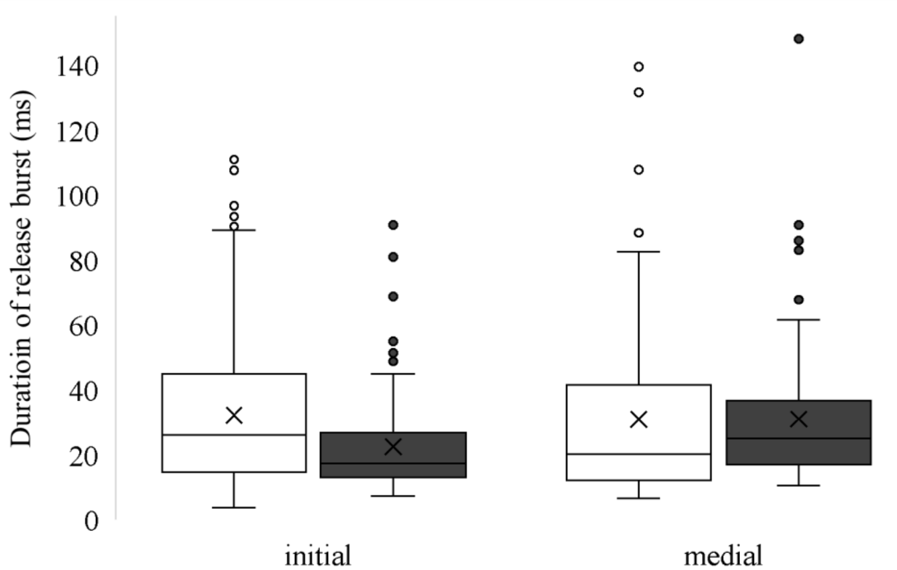

Figure 5: Release burst duration for Lytton (white) and non-Lytton (grey) speakers based on initial and medial word positions

4 Discussion

The purpose of this study was to attempt to verify the system of aspiration for nłeʔkepmxcín voiceless stops. In the above analysis, I have shown that the four-level system originally outlined by Thompson and Thompson (1992) did not fully account for the way that three fluent speakers of nłeʔkepmxcín used aspiration. Most notably, this original system did not account for the effect of word position that I have shown was driving the differences in release burst duration. This was clearly true for truly word-final stops such as the /p/ in the word *sɣép* 'tree' and stops that preceded word-final stops such as the /q/ in the word *sƛ̓íqt* 'sky.' Interestingly, stops that preceded word-final spirants did not aspirate. The lack of aspiration on these pre-spirant stops in a word-final position could be explained if aspiration is liked to a word- or phrase-final lengthening like that proposed by Koch (Koch, 2010, 2015). If aspiration is linked to phrase-final lengthening, in a stop-spirant word-final coda, the lengthening could focus only on the spirant which is already continuant whereas in singleton stop codas and stop-stop codas, lengthening could spread more evenly across the non-continuant segments. Future research will need to measure these spirants and look at the production of aspiration in fluent speech to help answer these questions.

This analysis serves as a first stop in documenting the modern sound system of nłeʔkepmxcín. I have shown throughout this paper that the system of aspiration outlined by Thompson and Thompson (1992) while on the right track, did not accurately document the way that aspiration is used by speakers of the language. This highlights the need to look at more than just one level of the phonological word when identifying phonetic and phonological patterns. By focusing on the syllable alone, Thompson and Thompson (1992) unintentionally misrepresented where aspirated voiceless stops are produced in the sound system. By looking at the word level rather than just the syllable level, I have shown that aspiration is specifically a word-final process. Further work will be needed to validate and expand on the results presented in the analyses of this paper, but this is an important step in ensuring that the relevant properties of the sound system are documented for language learners.

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