RETRACTION IN MONTANA SALISH LATERAL CONSONANTS

by

RAMONA E. MCDOWELL

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Ramona E. McDowell
Name of Author *(please print)*

16/07/2004
Date (dd/mm/yyyy)

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Department of Linguistics
The University of British Columbia
Vancouver, BC Canada

Abstract

Although a number of researches have addressed the issue of consonant triggered vowel retraction in Salishan languages, these previous have always been undertaken from the standpoint of acoustic and/or phonological evidence. As documented in this literature (Bessell 1994, 1998; Doak 1992; Egesdal 1993; Czaykowska-Higgins 1990; Kuipers 1974; Mattina 1979; Reichard 1938; Shahin 2002; Van Eijk 1997; etc.), consonants functioning as retraction triggers fall into two classes: (i) post-velars (uvulars, pharyngeals and sometimes laryngeals), and (ii) a subset of coronal consonants, including retracted /r/, /s/, /z/ /z'/ /l/, /l'/, and /ɬ/. Despite the large number of segments in the category of retracted consonants, there has been significantly little investigation into the articulatory process of retraction on any coronal, but most notably, a lack of investigation into the lateral consonants.

The current study is an articulatory investigation into the status of retraction on the four lateral consonants in Montana Salish, which are comprised of a phonetically diverse array of segments: two approximants /l/ and /l̓/, and two obstruents, a fricative /ɬ/ and an ejective affricate /ƛ̓/. Through the use of ultrasound imaging of the tongue taken during real time speech, this study examines the physical properties of tongue retraction in each of the lateral segments. The articulatory information, taken in consideration with the acoustic signal, provides convergent evidence for the determination of retraction on these consonants. Ultrasound imaging also allows for investigation into the coarticulatory influences such retraction may have on adjacent vowels.

Understanding these two components of tongue retraction (the gestures involved and their corresponding coarticulatory effects) aims to contribute both to deepening our understanding of retraction within Salish languages, and to supplementing previous cross-linguistic work on the little studied lateral consonants. Beyond a well-needed articulatory description, this study helps evaluate the physiology of retraction within the phonological and acoustic based literature which distinguishes retraction as "uvularization" and "pharyngealization". The examined coarticulatory patterns provide insight into the interaction of local gestural resolution versus phonological retraction effects. Lastly, results from this study provide information useful in the phonological debate over the legitimacy of the term "lateral" as a class of sounds.

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Chapter 1 Conceptual goals

1.1 Introduction

Many investigations have addressed the issue of consonant-triggered vowel retraction in Salishan, among other languages. However, these have always been undertaken from the standpoint of acoustic and/or phonological evidence.* As documented in this literature (Bessell 1992, 1993, 1998; Doak 1992; and Egesdal 1993; Czaykowska-Higgins 1990; Kuipers 1974; Mattina 1979; Reichard 1938; Shahin 1997, 2002; Van Eijk 1997; and others), consonants functioning as retraction triggers can be commonly summed in two classes: (i) post-velars (uvulars, pharyngeals and sometimes laryngeals), and (ii) a subset of coronal consonants, including retracted /r/, /s/, /z/ /z'/ /l/, /l'/, and /ɫ/. Despite the inclusion of a large number of diverse segments into the category of retracted consonants, there has been significantly little investigation into the articulatory process of retraction. Several authors in various studies, primarily including N. Bessell, have examined the acoustic attributes of retracted consonants, but no articulatory work has been previously presented to establish how the tongue is physiologically involved in retraction for non-uvular and non-pharyngeal consonants. Furthermore, of the work that has been conducted, the narrowest focus considers the set of coronals in this category of phonologically retracted phonemes, and not for example, the lateral consonants, who by nature include an additional method of articulation which has potential to interact with tongue retraction.

The current study is an articulatory investigation into to status of tongue retraction on the four lateral consonants in Montana Salish. These are comprised of a phonetically diverse array of segments, two approximants /l/ and /l̓/, and two obstruents, a fricative /ɫ/ and an ejective affricate /ƛ̓/. Through the use of ultrasound imaging of the tongue taken during real time speech, this study is able to examine the physical use of tongue retraction in each of the lateral segments. Articulatory information is necessary to avoid relying on inferences that are based the circuitous acoustic signal, and which can only suggest what tongue movements are involved. The articulatory information, taken in consideration with the acoustic signal, provides direct evidence for the physical determination of retraction on these consonants. Furthermore, once the use of retraction or lack thereof has been determined, ultrasound imaging of the tongue allows for investigation into the coarticulatory influences such retraction may create on adjacent vowels.

Understanding these two components of tongue retraction (the movements and/or gestures involved and their corresponding coarticulatory effects) is an important contribution not only within Salish language literature, but also in the supplementation of previous typological work on the little studied lateral consonants. Montana Salish, and indeed the other Salish languages, are unusual among the worlds languages in their diverse array of lateral consonants in their phonemic inventory. Not only does this study provide a much-needed articulatory description of the tongue's involvement in lateral

* I am most grateful for the help and knowledge of each Montana Salish speaker who participated in this project. All credit and much gratitude goes to them.

consonant production, but it helps evaluate this physiological retraction within the phonological and acoustic based literature which distinguishes retraction as "uvularization" and "pharyngealization". Similarly, as evaluated through Browman and Goldstein's (1992) Articulatory Phonology, this study proposes gestural specification for the involved tongue movements. The examined coarticulatory patterns provide insight into the interaction of local gestural resolution versus phonological retraction effects in those Salish languages that exhibit phonological vowel harmony in conjunction with local consonant retraction. And lastly, results from this study provide information useful in the phonological debate over the legitimacy of the term "lateral" as a class of sounds and their corresponding features.

In order to fill in the background for research on these consonants, Chapter 1 includes an overview of the linguistic background of Montana Salish in Section 1.2, and a literature review of the relevant studies in Section 1.3. These are presented below. Chapter 2 presents an inventory description, with specific focus on phoneme pronunciation, distribution, and environmental restrictions, as well as a visually aided description of articulatory production. Chapter 2 also includes a detailed description of the methodology used in this study. Chapter 3 contains both articulatory and acoustic information for the plain uvular stop as the establishment of a model of tongue retraction from which the laterals are compared. Chapter 4 presents the articulatory investigation in determining whether or not the Montana Salish laterals are retracted. Once the physiological use of tongue retraction has been established, Chapter 5 presents a summary of the coarticulatory effects that these laterals have on adjacent vowels. And finally, Chapter 6 discusses the implications of these findings in terms of articulatory specification, typological contributions, lateral class unification, and the phonetic versus phonological function of lateral retraction in the (Montana) Bitterroot Salish language.

1.2 Montana Salish dialects

Montana Salish (MTS) is a cover term for the two dialects, Bitterroot Salish and Pend d'Oreille, of a Southern Interior Salish language which is spoken on the Flathead Indian Reservation in northwest Montana in the United States. These dialects are in the same continuum as Spokane and Kalispel (which are dialects spoken in the state of Washington). The Flathead reservation is home to three tribes, the Bitterroot Salish, who call themselves simply the Salish, the Pend d'Oreille, a historically neighboring tribe who speaks a similar dialect, and the Kootenai, a linguistically unrelated tribe.[1] The political tribal organization on the reservation is officially called the Confederated Salish and Kootenai Tribes of the Flathead Reservation. Because of pressures and force by the dominant English speaking community, Montana Salish, which again represents the Pend d'Oreille and Bitterroot Salish dialects, has only about 45 fluent speakers left. This number is quite debatable as a language census or survey has not been taken in the last 10-15 years and most of the first language speakers are very elderly with the exception of a few known younger speakers. Despite generations of intermarriage between all the

[1] "Montana" Salish is used only to differentiate between the individual tribes and the Salish language family as the Bitterroot Salish simply call themselves the "Salish".

local tribes, as well as many other ethnic groups of people, many elders are assured enough to distinguish which words are Bitterroot Salish and which are Pend d'Oreille or Spokane (neighboring language and tribe).[2] English is, however, the predominant language of daily life throughout the reservation. The primary speaker represented in this study is Bitterroot Salish.

The figure below, reproduced with permission from the Summer Institute for Linguistics Ethnologue website, locates the Salish tribes in the northwest corner of Montana.

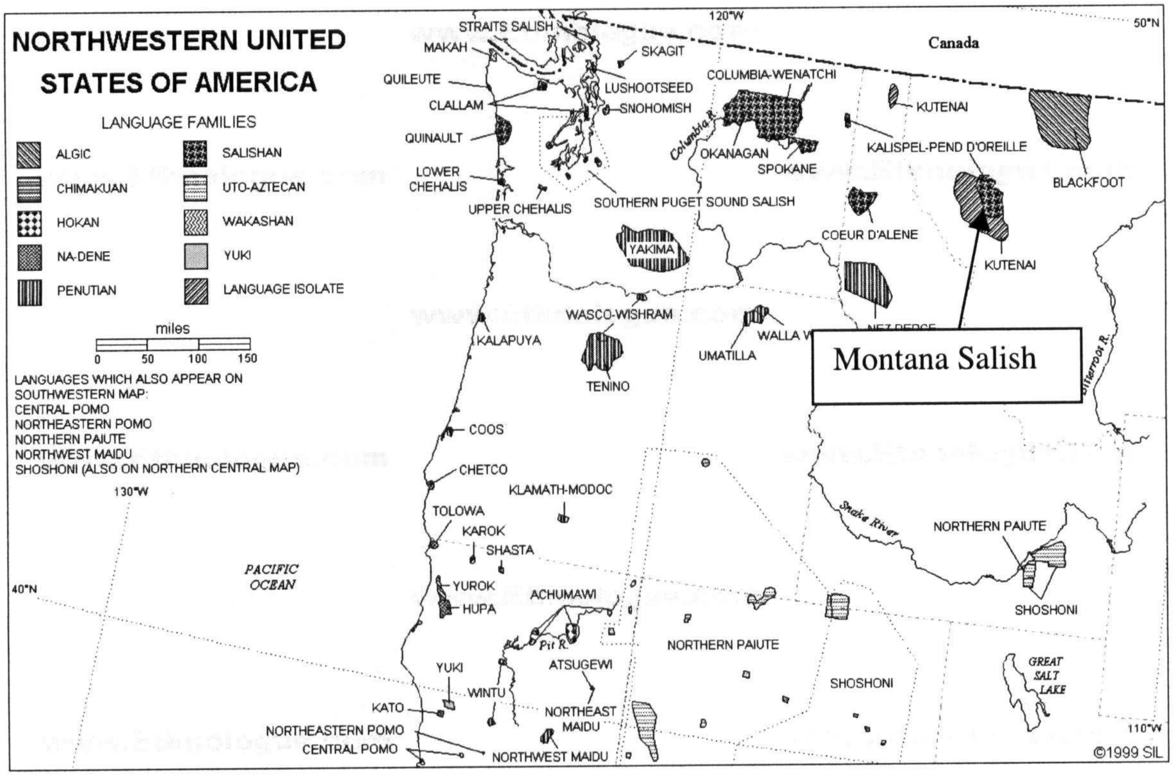

Figure 1. 1 Montana Salish Language Map

1.3 Retraction in Montana Salish: descriptive information and theoretical issues

The term "retraction" and its various cognates have been used to represent many different functions in previous literature (Bessell 1998a; Shahin 2002; etc.). Most commonly, previous literature concerning retraction generally distinguishes those consonants which are retracted, (i.e. those whose primary production is in the direction of the pharyngeal space) and those consonants which have a retracted counterpart.

For the purposes of the current investigation, articulatory retraction is defined as

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[2] There has been no systematic work which differentiates the Bitterroot Salish dialect from the Pend d'Oreille dialect. However, some of my speakers would mention that this is or is not "our" word, in reference to both Pend d'Oreille and Spokane. Thomason (p.c. 2004) cites truncation as differing between Montana Salish and Kalispel, but other specific differences have not been investigated.

any movement or gesture produced in the direction of the rear pharyngeal wall. Consonants, which are able to retract adjacent vowels, are considered "retracting" consonants, whereas consonants whose primary locus of tongue constriction is near the pharyngeal wall are labeled "retracted" consonants. For example, velars, which have sometimes been considered retracted consonants, are produced with complete tongue raising towards the palate. No backing gesture or movement is inherent in this production and therefore, these are not considered retracted for the purposes of this study. However, uvulars, which involve a directed movement of the tongue into the pharynx, both exhibit tongue retraction and are retracted segments. The acoustic lowering effects the uvulars produce on adjacent vowels enable these segments also to be considered retracting consonants. These vowels themselves are retracted.

Since the majority of retraction in the Salish languages results from uvulars and pharyngeals, these segments have been the focus of most previous investigation. However, some investigations into the coronal consonants have been undertaken. According to a summary compiled by Bessell (1994:33, 38, 1998a:128, 137), the following Interior Salish languages include laterals that participate in (regressive) phonological vowel retraction: Snchitsuʔumshtsn (Coeur d'Alene) r, r', Kalispel ḷ, ḷ̓, Montana Salish ḷ, ḷ̓.

Often the lateral approximant is described as having a "dark" counterpart, though no concrete connection is made to retraction. Vogt (1940:13) states concerning the lateral approximant in Kalispel "the voiced liquid is actualized as [l] or [lambda]. . . [lambda] is used after vowels, and is darker in timbre, tending towards English dark l ". Kuipers (1974:22) does not list the Shuswap /l/ as "retracted", however, he proposes that Proto-Salish *l and *r merged into /l/, whereby " *r 'darkened' a neighboring vowel", while *l did not. Thompson and Thompson (1992:54--55) describe the lateral resonants (/l/ and /l̓/) in Nɬeʔkepmxcin as "usually dark, produced with the tongue root drawn back". For the Lillooet lateral approximants, Van Eijk (1997:3) describes the retracted counterparts of the /l/ and /l̓/ phonemes as "velarization with concomitant tensing" which is compared to "dark" versus "light" English /l/ production. However, beyond these descriptions, there is little acoustic and no articulatory work done on these segments in regards to tongue retraction.

Some individual studies describe the other laterals in the related Southern Interior Salish languages in more detail. Vogt (1940:13) posits a non-glottalized /ƛ/ phoneme for Kalispel as a merger between [t] and [ɬ], and /ƛ̓/ as a "strongly glottalized stop". Kuipers (1974:22) also describes the /t̓/ in Shuswap phonetically either as [ƛ̓] or a dental stop [t̓]. Thompson and Thompson (1992:54--55) describe the /ƛ̓/ in Nɬeʔkepmxcin as a "glottalized dental stop with a lateral affricative ejective release". In Moses-Columbian Salish, Bessell (1998a:147 classifies the lateral fricative /ɬ/ as retracted by its "F2 perturbation, reflecting a back articulation for the consonant". (Note however, that there is no mention of any acoustic or phonetic properties which suggest that the lateral ejective affricate is retracted).

In Montana Salish, whose consonant inventory includes four lateral segments /l/, /l̓/, /ɬ/, and /ƛ̓/, there is specific mention of the status of /l/ and /l̓/ as a retracted consonants. These are attributed as the source of vowel retraction in otherwise unexplainable environments. According to Egesdal (1993:18) words like *ʔolín* 'stomach' and *ʔol̓ús* 'fire' are said to have lowered the initial /u/ to [ɔ] <o> because the

/l/ acts as a retracting trigger. However, other than the single statement "(back) /l/ and /l̓/ must also be included with the retracting, back consonants, at least historically", no investigation, either acoustic or articulatory, into the function of these two lateral approximants, has been attempted in Montana Salish (Egesdal 1993:18). Egesdal (1993:22) does, however, claim that the retracted /l/ is (or was) pharyngealized, not uvularized or velarized. In the Flemming et al. (1994) acoustic study, no mention of "retraction", "dark vs. light" timbre, or lowered adjacent vowels, is made concerning the Montana Salish laterals.

Furthermore, most phonological literature describing these retracted consonants differentiates the physical retracted tongue movement into either uvularization or pharyngealization (Shahin 2002). It is generally assumed that these correlate to distinct tongue dorsum and tongue root retraction, respectively, but little is said about the specifics of the articulators involved.

Previous literature has described the motivation for adjacent vowel lowering/transitioning through constraints on the articulators involved. Archangeli and Pulleyblank (1994), and Bessell (1998b) among many others, state that the high front position of an /i/ vowel is in direct contrast with the low, retracted gesture for the post-velar/retracted consonants. These two polar positions create an opposition reflected in both the first and second formants (Bessell 1998b). Through the use of ultrasound imaging of the tongue Gick and Wilson (2002, 2003) present an articulatory investigation into the dynamic function of conflicting tongue targets and their corresponding gestures. From their gestural examination of and acoustic pre- and post-vocalic effects of coronal /l/, /r/, and excrescent schwa in Nuu-chah-nulth (Wakashan), Beijing Chinese, Chilcotin (Athapaskan), Korean, and English, they conclude that there is a gestural conflict between the tongue root/tongue dorsum articulation of the trigger consonants, and the tongue body articulation of the vowels. Furthermore, they propose that languages physiologically have a choice of two characteristic types of strategies to reconcile this gestural conflict between opposing tongue root and tongue body articulatory targets. One option compromises the tongue body's spatial position by laxing/lowering the vowel; the other entails a temporal adjustment of the transitional articulatory gestures, this typically resulting in a schwa-like transition stage.

Gick and Wilson (2003) use this evidence to establish that certain types of transitory schwas during /l/ production are the result of the resolution of a gestural conflict of tongue root (TR) to tongue dorsum (TD) such that the tongue moves through both articulatory and acoustic space paralleling that of a "canonical" schwa. Furthermore, their investigation reveals that languages utilize the same gestural compromise strategies in exactly the opposite pre vocalic and post vocalic contexts. For example, Nuu-chah-nulth employs vowel laxing/lowering preceding back consonants and excrescent schwa following, while Chilcotin back consonant to vowel interactions are the reverse. Their sample of languages reveals most possible combinations of temporal to gestural compromise except one parallel response. That is, languages tended not to be "symmetrical" in their use of excrescent schwa in both pre- and post-consonantal context. However, one language, Skye Scots Gaelic, was found to demonstrate a laxing/lowering response in both CV and VC positions.

In an independent articulatory study investigating the post-velar (pharyngeal and uvular) -vowel interactions in Nuu-chah-nulth, Wilson (2003) found non-parallel vowel effects on adjacent vowels. He states "The uvular stop, /q/, usually lowers a following /i/ and /ii/, and often a preceding /i/ and /ii/ too. However, the labio-velarized /q^w/ has no lowering effect on a following /i/ or /ii/, there is [sometimes] a schwa off-glide from /i/ to /q/ and /i/ to /q^w/" (Wilson 2003:10). In addition, unlike the effects on the /i/ vowel, /q/ and /q^w/ have no lowering effect on /u/, /uu/, /a/, /aa/ pre or post consonantally, and the pharyngeal fricative gestural conflict is resolved through temporal compromise. In this language Wilson finds that different consonants in the same linear position in respect to a particular vowel utilize different methods of gestural conflict resolution, in this case the /q/ and the pharyngeal fricative resolve through vowel lowering and schwa-transition respectively.[3]

The following investigation into the function of retraction by the lateral consonants in Montana Salish is grounded in the above assessment of the coarticulatory processes. The framework provided for the examination of the Montana Salish lateral consonants is clearly presented in the Gick and Wilson (2002, 2003) gestural analysis and is modeled in the Wilson (2003) study. Presuming the position of the tongue for the Montana Salish laterals is in gestural conflict with at least some of the vowel positions, /i/ and /u/ being the most likely, the resolution should either be vowel laxing, or vowel transitioning. However, if the tongue position for the lateral consonants is not in gestural conflict with any vowels, then no spatial or temporal compromise is necessary and the acoustic signal of the vowels should be similar to the same vowel in other non-retracted environments. The precedents set through the Gick and Wilson, and Wilson investigations suggest that the effect of the laterals on adjacent vowels is not necessarily the same pre or post-vocalically, although only one resolution is applicable per environment, nor should each lateral necessarily pattern the same as the other laterals. This latter prediction is especially interesting because the characteristic of lateral class unification implies that these consonants should act similarly. That is, the physical tongue movement involved (whether retracted or not) should be similar for each Montana Salish lateral consonant, but the corresponding effect on the adjacent vowel is not necessarily parallel.

Acting concurrently with the above described coarticulatory interactions are the phonological processes of regressive and progressive harmony. These have been sufficiently described by Bessell 1992, 1993; Doak 1992; and Egesdal 1993; Czaykowska-Higgins 1990; Kuipers 1974; Mattina 1979; Reichard 1938; Shahin 1997, 2002; Van Eijk 1997; and etc. In these processes the retracted trigger segments act to lower a preceding or following vowel with immediate adjacency no longer being required. The outcome on to the vowels varies by language although the general processes is summed by Bessell (1998a:129) who states that "faucal articulation in Interior Salish lowers and slightly backs the quality of the adjacent vowel". This vowel movement is reflected in the acoustic signal by a lower F2 and a higher F1.

Of specific interest for the following study is the claim by Bessell (1994, 1998a) and Egesdal (1993), that the high front /i/ vowel does not participate in these phonological processes. That is, /i/ does not lower in either local or non-local environments. Egesdal (1993) does describe, however, that local i/_Q and i/Q_ result in variable, but lowered phonetic outputs of the /i/ vowel. He states "pharyngeals do not

[3] Note that Wilson (2003) suggests that this difference in resolution is due to the lack of glottal closure on the pharyngeal fricative versus the absolute closure on the plain uvular stop.

lower /i/ to [a]; instead there is a transitional onglide. . .That differs from the change of /i/ to [e] following uvulars. At most, there is a very slight onglide between uvulars and /i/: Q[ɛe], Qʷ[ɔe]" (Egesdal 1993:22). However, no concomitant description is made for the /i/ vowel's interaction with the lateral approximants, even though they are equally classified as retracting consonants in his description. The other vowels /e, u/ lower to [ɑ, ɔ] respectively.

While local phonetic effects on adjacent vowels can have the same final outcome as the effects imposed by regressive and progressive vowel harmony processes, the source of these affected vowels is distinctly different. It is probable that this phonological retraction was once initiated by local co-articulatory effects; however, in its current form it does not necessarily represent simple phonetic adjacency effects. The current study has been designed to eliminate as much confusion as possible in regards to the source of the CV/VC interaction. In this effort investigated sequences in Montana Salish have been carefully chosen to exclude all known consonantal retraction triggers except the particular lateral in question, in order to differentiate between CV/VC effects which are purely coarticulatory in nature, and those which might result from the phonological retraction harmony. Therefore, it is important to point out that the words and tokens examined in this study represent adjacent gestural conflict resolution effects only, and are not vowels which are known to exhibit phonological retraction harmony in the examined words.

In an attempt to differentiate between the acoustic effects resulting from phonetic V/_C and V/C_ coarticulation and phonological retraction harmony, Bessell (1998b) compares the acoustic output of such above described gestural conflicts to the phonological vowel lowering (harmony) in Moses-Columbian Salish and Coeur d'Alene. She finds that temporal distribution and formant cues assist in differentiation of phonological lowering effects from phonetic coarticulatory gestural resolution. Furthermore, in a claim disassociating the local gestural conflict resolution from the non-local faucal effects, Bessell (1998b:29-30) concludes that there is "no phonetic evidence for a relationship between faucal harmony and iterative coarticulatory retraction", and further hypothesizes that the vowel harmony likely stems from a relationship where "faucal features are maximally compatible with vocalic rather than consonantal structure. This may form part of the motivation for the association of faucal features with vowels, regardless of the lexical location of the feature".[4]

In light of these comments, one can see that determining whether retraction is a function of the consonants or the vowels (or roots etc.) is an important question. Although the data presented in this study do not compare consonant retraction versus vowel retraction, if no articulatory basis is found for the retracted effects on the adjacent vowels by the consonants, then either the retraction is truly sourced in the vowels, or the phonology is responsible for clarifying why the retracted effects are present. For example, if the /ɬ/ in Montana Salish is not phonetically retracted, but an adjacent vowel lowers (or transitions), then this suggests that the source of retraction must instead be attributed to the vowels.

Furthermore, according to Browman and Goldstein's (1992) model of Articulatory Phonology, each of these gestural motions and targets have phonological

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[4] Bessell uses the term "faucal" here to refer to the class of back consonants. This includes uvulars and pharyngeals.

meaning. This allows the individual tongue gestures such as TT, TD, and TR to represent phonological units (which therefore, are specified in the language's phonology) (see for example, Gick and Wilson 2003). If the retracted movements in Montana Salish can be systematically interpreted as representing distinct gestures, then this implies that the location of retraction in Montana Salish laterals is sourced in the phonology. However, if instead, it is found that the mechanism of retraction is variable, inconsistent, and explainable phonetically, then this would reflect a lack of specification for the tongue articulator. This specified movement, or lack there of, is a factor in determining of the retraction is phonological or phonetic.

Understanding the movements involved in lateral retraction is also relevant in consideration of the previous phonological literature which has presented uvularization and pharyngealization as the two types of retraction, which reflect the tongue dorsum and tongue root respectively. If tongue root retraction differs from tongue dorsum retraction, yet each still moves with the other as they are interconnected areas of the tongue, then gestural specification has to differentiate between these contradictory processes. A significant contribution of the present study using ultrasound technology is that it enables a clear look at the tongue during real time speech which assists in clarification as to which movements are phonologically specified gestures, and those which are the result of the tongue's physiological make up.

In light of the previous literature, this study investigates the physical properties of tongue retraction within the four laterals in the Montana Salish language, in the attempt to clarify their dynamic function as possible retracting agents. While previous conclusions have been based on the acoustic signal, an articulatory study of this magnitude will sufficiently clarify the function of physical tongue retraction for the lateral segments. This is done through direct investigation of the involved articulators and is not based solely on entire reliance on an indirect acoustic signal. Given that Salish literature predominantly describes only the lateral approximants as possibly retracted, and only once mentions lateral fricative and never the lateral ejective affricate as exhibiting retracting properties, and given that for Montana Salish, only the lateral approximants are proposed to have retracted counterparts, it is proposed that Montana Salish /l/ and /l̓/ will demonstrate retracted movements, while /ɬ/ and /ƛ̓/ will not. Accordingly, the two approximants should pattern closest to the other retracted consonants, especially the uvulars, in acoustic effects and articulatory movement, although to a lesser degree.

Once the articulatory examination of tongue movement has been successfully described for the lateral consonants, categorization of the function of these events as phonetic or phonological is possible. Classification of phonological status of tongue retraction for the lateral consonants includes insight into legitimacy of "lateral" as feasible phonological feature. The diverse array of laterals within a single language presents a unique arena to test this designation by investigating whether or not these lateral consonants pattern together in the use of tongue movement. Most importantly, this study supplies a detailed phonetic description of a little investigated language, which may in turn be incorporated into descriptive pedagogical materials for the Montana Salish tribe.

Chapter 2 Properties of the Montana Salish Sound System and Study Methodology

2.1 Introduction

The aim of this chapter is to introduce the Montana Salish sound system, and to present the methodology used in this study. The consonant inventory is presented first, and is followed by the phonemic vowel chart. Next, additional phonotactic and descriptive coarticulatory information is presented for the lateral, uvular, and pharyngeal consonants. The uvular and pharyngeal consonant information is included in order to establish the kinds of coarticulatory effects which are in place for known back consonants. Additional morphophonemic information is presented when necessary. Lastly the study methodology is presented in Section 2.5.

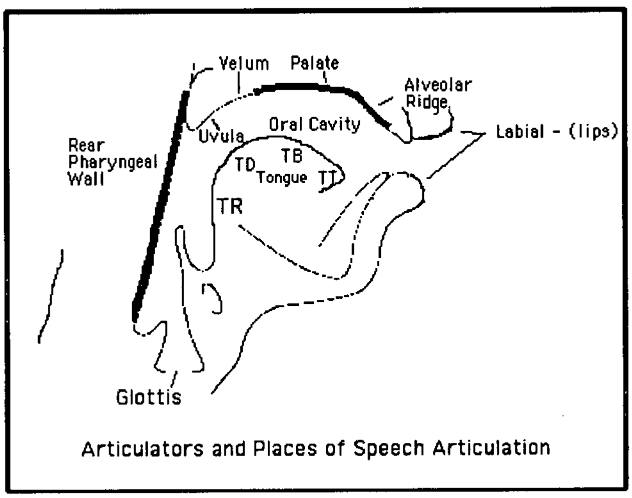
2.2 Inventory Description

The Montana Salish dialects have a rich sound inventory. They consist of 38 consonants, and 5 vowels. These are presented in Table 2.1 below. The consonants are organized in the table below according to their place and manner of articulation. A brief introduction to the vowel system is presented in the following diagram. In the ensuing chapters words and cited examples are written in the standard orthography used by the Montana Salish tribes. However, when more subphonemic detail is of interest, an additional IPA transcription is included. For both orthographic and IPA transcriptions of examined words, see Appendix A.

Place: / Manner:	Lab	Alveolar	Lateral	Alveo-Palatal	Palatal	Velar	Labialized Velar	Uvular	Labialized Uvular	Phar	Lab-Phar	Glottal
Voiceless Stops:												
plain	p	t				(k)	kʷ	q	qʷ			ʔ
ejective	p̓	t̓				(k̓)	k̓ʷ	q̓	q̓ʷ			
Affricates:												
voiceless		c		č								
ejective		c̓	ƛ̓	č̓								
Fricatives: voiceless		s	ɬ	š			xʷ	χ	χʷ			
Resonants:	Nasals											
plain	m	n	l		y		w			ʕ	ʕʷ	
glottalized	m̓	n̓	l̓		y̓		w̓			ʕ̓	ʕ̓ʷ	
Central Approximant:												h

Table 2. 1 Montana Salish Consonant Inventory

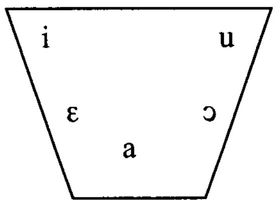
In order to help identify where these sounds are produced in the mouth, the Figure 2.1 below identifies several locations within the mouth that are used for Montana Salish speech. Note that the parts of the tongue are specifically marked as is the rear pharyngeal wall.



Articulators and Places of Speech Articulation

Figure 2. 1 Articulators and Places of Speech Articulation

Montana Salish has 5 vowels, /u/, /i/, /e/=[ɛ], /o/=[ɔ], and /a/.[1] These are shown in the chart below. Primary stress is marked with the (´) over the vowel. Stress always falls on the vowel (as opposed to a consonant), and never on prefix.



While not underlyingly distinctive, the remaining vowel which requires consideration in Montana Salish is schwa. This vowel is not written in the standard orthography, is never stressed, never occurs word initially, and its quality is extremely variable, as is its length and audibility. While acoustic measurements have not been collected for this vowel in this study, its impressionistic quality is inconsistent and varies by both speaker and context.[2] Flemming et al. (1994:13) describe this as a "transitional vowel of indeterminate quality".[3]

The importance of mentioning this vowel stems from the Gick and Wilson (2002, 2003) hypothesis, who show that a transitional schwa-like vowel is a byproduct of one method of resolving conflicting gestures. Not only does this apply to gestures in as much opposition as those used to produce a /q/ and an /i/, but also to those with less contrast in target position. In Montana Salish, a schwa, which is a byproduct from a transition between two conflicting gestures, is a distinct phenomenon from a full schwa as target articulation for the vowel nucleus.[4] However, both are phonetically apparent.

Moreover, the second motivation for discussion of schwa is in the clarification that these phonological characteristics help define schwa, the default vowel, as distinctly different from interspeech rest position (See section 2.4.7). Nuclear schwa distribution is, for the most part, predictable in occurrence based on environment and syllabic structure. Generally, any time a resonant consonant, such as /m, m̓, n, n̓, l, l̓, y, y̓, w, w̓, ʕ, ʕ', ʕʷ. ʕ'ʷ/, is preceded by another consonant, a schwa-like vowel is inserted (Flemming et al. 1994:13). Flemming et al. (1994:13) state "...sonorants may not follow obstruents in a cluster, they are always separated by a vowel. The vowel transcribed as [ə], a transitional vowel of indeterminate quality, only occurs between a sonorant and a

[1] Status of the <o> in Montana Salish is unclear. It is possible that there are phonetically two vowels, low back rounded [ɔ] and another mid back rounded vowel resulting from the no longer pronounced pharyngeal consonants. In addition, when adjacent to a rounded or labialized consonant, the <o> is closer to an [o] sound. Because of this variability, the /o/ vowel has not been examined in this study.

[2] In the current study, the nuclear schwa is transcribed as [ə], while the transitional schwa is unwritten, unless it is apparent in a CV/VC sequence already under investigation. Otherwise, standard orthographic transcription is used for all Montana Salish words. When necessary, a narrower IPA transcription is also added. When no [ə] transcription is present, e.g. *manínɬp,* then the consonants are all individually released without a vowel between them.

[3] Schwa does not occur word initially, but there are examples of it occurring word finally in three different contexts.

[4] For further information on the properties of nucleic schwa, the reader is referred to Shaw (1992 and 2004 to appear).

preceding consonant".[5] Similarly, when two resonants are immediately adjacent to each other like /m/ and /n/ in the word *áχʷomn* [áχʷomən] 'old-time scraping instrument', there is a brief transitional vowel which surfaces in between the two resonants.[6]

Section 2.2.1 Laterals and uvulars: distributional and descriptive information

In addition to the general introduction to the Montana Salish phonemic inventory, the laterals, in particular, deserve additional attention. These discussions are presented below and are followed by coarticulatory information for the uvular and pharyngeals. The latter two sets of consonants are included since the adjacent vowel interaction is what is expected of "typical" retracted consonants. This helps create a baseline from which the interaction with the lateral consonants can be compared.

Montana Salish lateral approximant /l/ occurs in all locations within a word: initially as in the woman's name *lamús*, medially as in *sqélixʷ* 'people', and finally as in *q̓ʷéʔel* 'something dried up'. However, occurrences of word final /l/ are numerically very few. There are also no restrictions on vowel environment. The consonant /l/ can occur with all vowels, following or preceding. Some Montana Salish additional examples of this are *eslalamísti* 'I'm moving around, restless' and *esčtaχélsi* 'he's hurting, suffering'. However, most pronunciations of /l/ include a small pre-stopped sound, followed by at least minimal frication of the lateral. This pre-stopped onset to the [l] is durationally very short, but auditorily quite distinct. Flemming et al. (1994:13) state "In most environments, the voiced and voiceless laterals are usually produced with a brief stop closure or some other gesture that produces a burst-like transient at the beginning of the lateral. However, this does not always occur".[7] This observation corroborates with Vogt (1940:13) who notes for the Kalispel dialect that the [l] is "pronounced with a supradental closure of short duration before the lateral release". When utilized, this pre-stopped movement is relevant for the articulatory analysis, as this contact with the roof of the mouth provides a consistent locus for the TT gesture. The authors also describe the voiced lateral as often fricated and sometimes devoicing (often only partly) in the word-final position and preceding voiceless consonants (Flemming et

[5] Additional clarification to these rules of schwa distribution is provided by Thomason (p.c. 2004) and will be included in Thomason, Sarah G. In preparation. A sketch of Montana Salish structure. Ann Arbor: University of Michigan, ms.

[6] However, when two of the same resonants are adjacent word finally (only mm, nn, yy, ww) they can be long without a transitory vowel of any kind between them as in the /mm/ sequence in *iesc̓ánmm*, 'I'm holding (one object) tight'. Resonant /m/ coalescence only occurs word finally, and depends upon whether the first /m/ morpheme contains an underlying vowel (Thomason, p.c. 2004). Flemming et al. state "in sequences of more than two sonorants, they need not all be separated by vowels; for example, in some utterances of [səˀnəmˀné] 'toilet' there may be two, but not three epenthetic vowels" (Flemming et al. 1994:13).

[7] The alternation in between the prestopped [l], and the non-prestopped [l] is in free variation. Also, because many times the tongue tip is not visible on the ultrasound image, there is no articulatory evidence to differentiate these two types of productions. Similarly, the glottalized /l̓/ and plain /l/ appear to have the same tongue motions but because the tongue tip is often not visible, this is a descriptive remark rather than one based on measurements or statistical comparisons.

al. 1994:14). These observations are consistent with the current speaker's data. These variations are [$^{\mathrm{d}}$l], [$^{\mathrm{d}}$ɮ], [$^{\mathrm{d}ɬ}$l], [l̥].[8]

In addition, because /l/ is often preceded by this stop-like onset, [ll] sequences are never long, but are always independently produced. This is similar, but independent from, another pattern whereby all consonants can be reduplicated, thus yielding sequences of identical segments. In this process, all stops, and affricates are individually released.

The /l̓/ can have all the voicing variations that are described above for the plain /l/ (partially or completely voiced or voiceless), and still include the pre-glottal closure. Flemming et al. (1994:16) state "glottalized sonorants. . .are preglottalized. . .Glottalized laterals are also pre-stopped". They also state "In final position and before voiceless consonants, the lateral is devoiced, as with non-glottalized laterals" (Flemming et al. 1994:17). In addition, sometimes the pre-glottal closure is incomplete and creaky voice results on the preceding vowel and/or a portion of the lateral.

The pre-glottalized /l̓/ is found preceding and following all vowels in Montana Salish. It is also found initially, medially, and finally as in *l'áχtmn* [l'áχtmən] 'I became friends with him', and *ltltkʷú* 'otters', *pl'íp* 'it drifted away' and *i nmál'* 'it's a warm liquid'. Next, sequential /l'/ is common as in *čn ʔessél'l'* 'twins'. The word *l̓lac* 'red raspberry' is sometimes pronounced with two glottalized /l/s as *l̓l̓ac*. Here, the first /l̓/ is pronounced independently (without any vowel-like transition).

Next, the lateral fricative is found both preceding and following all vowels. Some examples are *čn kʷéɬ* 'I feel nervous, scared', *snɬúcus* [sᵊnɬúcus] 'dough', and *ɬíčntuxʷ* [*ɬítsᵊntuxʷ*] '(you got) whipped, spanked'. It can also be word initial, medial, or final as in the words, *ɬécn* 'I smoothed it', *ččečeɬé* 'three people', and *míɬ* 'too'. Furthermore /ɬ/ can also be pronounced independently, with no intervening transitory vowel, as in the words *ɬtxtá* 'pepper' and *ɬtptúpn* [ɬtptúpᵊn] 'several little black widow spiders'. As with other Montana Salish consonants, in sequences, the lateral fricative can also be pronounced with length. Some examples are *čɬɬm̓oʔtétkʷ* 'a little steamboat', *qéyɬɬms* [qéyɬɬəms] 'he woke you folks up' and *ɬɬú* 'few, less'.

The lateral ejective affricate is found both before and after all vowels. However, it has limited contact with both /o/ and /u/ as there are only two roots with a /ƛ̓o/ sequence, *ƛ̓óqʷ* 'to crack knuckles' and *ƛ̓óχʷ* 'rattle; the sound of something rolling around'. There are similarly limited examples of /oƛ̓/ sequences; *χʷóƛ̓* 'crackling sound' and *q̓ʷóƛ̓/* 'run (plural)' are the only roots with an oƛ̓ combination.[9] All other examples are allomorphs of a /uƛ̓/ combination. Additionally, *p̓úƛ̓* as in *i čn p̓úƛ̓* 'I'm greasy' is the only root with a /uƛ̓/ sequence. There are many more /ƛ̓u/ combinations.

/ƛ̓/ is found at the beginning, middle, and end of words, and, as all other consonants, in reduplicative sequences. Some examples are, *ƛ̓áχt* 'fast', *esƛ̓ém̓scu* 'getting into trouble', *esčmíƛ̓* 'something that's spread on, (e.g. butter)' and *inɬƛ̓ƛ̓í* 'it's a sharp point'. There is no non-ejective counterpart for this lateral affricate except in reduplicated sequences like [*inɬƛƛ̓í*] 'it's a sharp point'. In these sequences, only the last lateral affricate is ejective.

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[8] For the current study, only fully voiced and non-fricated /l/ data was used in order to provide a control within lateral production.

[9] It is not clear whether these two roots have an underlying /o/ since they are perpetually adjacent to possible retraction triggers.

Since the following articulatory examinations are partly motivated by the retraction effects that a consonant may produce on the adjacent vowel, it is important to describe what effect this might be. In this task, the vowel interactions with the known retracted consonants, or those whose primary production involves the uvula or pharynx, are described. Generally this interaction involves a lowering or schwa-like transition for the high vowels, but minimal or no change in the low vowels. In Montana Salish, the only consonants which have been proposed to interact in such a way with the adjacent vowels, are the uvulars and pharyngeals. The known co-occurrence restrictions and relevant vowel interactions are described below. An immediate dissimilarity is obvious between the above environmental limitations for the lateral segments and those co-occurrence restrictions for the known retracted consonants. Overall, the laterals are found both preceding and following all vowels in the Montana Salish inventory. However, pharyngeals, for example, are not. This is because /e/ always lowers to [ɑ] when adjacent to a pharyngeal. Similarly, limitations on /u/ adjacent to a pharyngeal or uvular are because /u/ almost always lowers to [ɔ]. In order to fully evaluate these environmental dissimilarities in comparison with the laterals, the co-occurrence limitations for the uvulars and pharyngeals are presented below.

The consonants /q/ and /q̓/ are commonly found with all vowels except /u/. There are only two isolated examples of [qu] combinations, although various root final /q/ grouping with the suffix *=úlex^{w}*, 'earth, land' occurs 5 times. The other root final /q/ combination occurs with the *=úps* 'bottom, tail' suffix.[10] According to Thomason (p.c. 2004), when an /q/ and /w/ are adjacent to each other, they are phonetically distinguished by an inserted schwa, such that the sequence /qwi/ would be realized as [qəwi] not [q^{w}i]. Similarly, a non-labialized /q/ followed by the vowel /u/ does not necessarily result in labialization of the /q/. Instead, these sequences can be pronounced as [qəu] where schwa is never stressed, but the full [u] vowel may be.

Since uvular consonants, including the two fricatives, are back consonants, they can lower the quality of the adjacent vowel as demonstrated in the word *nisq̓^{w}ót* 'And that's when they bought this [land] across the river and into the mountains' where the lexical suffix =ut for 'far off place' has lowered. A similar example is *lq^{w}q̓^{w}ótm* 'it can be done' where the lexical suffix *=útm* 'possible' has lowered in the environment of the uvular. Here the /u/ is pronounced somewhat between an [o] and an [ɔ] sound as it is affected by the labialization of the uvular as well as the retracted status of the uvular. Some additional words which demonstrate the effect from the adjacent uvular are *[χ^{w}ópt]* from the root *χ^{w}úpt* 'lazy', [sc̓əmq^{e}ín] from *sc̓mqín* 'brain' and the uvular-/i/ sequence in the sentence *čn esc̓áχi* [ɛsts'áχ^{ə}i] 'I'm frying something'. However, the uvular-/i/ transition is not always audible to the same degree. There is a large variation in the amount of transition depending on the word. For example, the word *estaqí* 'waving at someone', has a much less audible transition between the uvular stop and the following /i/ while *sc̓mqín* 'brain' has a very distinct transition.[11]

Not only do within-speaker repetitions often vary in amount of transition in the uvular-vowel/ vowel-uvular sequences, but also it is likely that the amount of transition,

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[10] Numerical occurrence comes from the dictionary files of Thomason (2000).

[11] Thomason (p.c. 2004) cites penultimate vowel stress from Mengarini (1877-1879) for *estaqi*. Pronunciation from the speaker in this study was difficult to determine, but seemed to be final vowel stress.

if any, between the vowel and consonant depends can vary depending on syllabification. That is, when the retraced consonant is in the coda position, its effect on the preceding vowel is of a slightly different quality than when the consonant is in the onset position. For example, in the word *siχ^{w}eyχ^{w}ó si.χ^{w}ey.χ^{w}ó* 'badger', the first /χ^{w}/ is only produced as the onset of the second syllable, and there is minimal acoustic effect on the initial /i/. However, the /i/ transition before the coda /q/ as in *piq* is a minimal but noticeable onglide.

More dramatic vowel interactions are associated with the pharyngeals. For example, pharyngeals generally occur freely with /a/, and /i/ either preceding or following, as in *ncʕíls̆* 'You went up the river' from the root *cʕ* 'upstream', *esʕác* 'it's tied' from the root *ʕác* 'tie', *yíʕ'^{w}* 'it moved' from *ʕ'^{w}íɬ*, the root for 'whole', and *c'íʕ'^{w}*, the root for 'squeal'. However, there are some numerical limitations on these environments. While, /i/ is often found following the labialized pharyngeal it is does not precede it except in one example *líʕ^{w}mstn*, [líʕ^{w}mst^{ə}n] 'I rang the bells accidentally' from the root *líw* meaning 'bell'. Furthermore, while there are /áʕ/ and /ʕá/ sequences, there are no stressed or unstressed /aʕ^{w}/ or /ʕ^{w}a/ sequences. The only two examples of /áʕ'^{w}/ combinations are found as allomorphs of the roots *háw'* 'loose' and *cáw*, 'bathe, wash'.

The /u/ vowel is somewhat limited in occurrence preceding and following the various pharyngeals, as it often lowers to [ɔ] when adjacent to a pharyngeal, but is by no means prohibited completely. There is only one example of an /u/ preceding the plain pharyngeal and it is not in the underlying root (e.g. *háʕuʔ* 'it came loose' from the root *háw'*, 'loose'). Similarly, the only /uʕ/ or /uʕ^{w}/ (stressed or unstressed) sequences are found in variations of the root *cúʕ^{w}*, 'print'. There are only two roots with /u/ preceding a labialized pharyngeal, *cúʕ^{w}*, 'print', and *xwúʕ^{w}*, 'vagina', and only two examples with /u/ immediately following a plain labialized pharyngeal, *esʕ^{w}úm*, 'it's mashed together' from the root *ʕ^{w}úm*, 'rub' and *čn k̓^{w}ɬcuʕ^{w}ús* 'I made a print of my face', where *cúʕ^{w}* is the root, but /=ús/ is the lexical suffix for 'face'. There are no /ʕ'^{w}u/ or /uʕ'^{w}/ combinations (stressed or unstressed).

Nor does the vowel /o/ occur with any non-labialized pharyngeals but only with rounded pharyngeals as in *yoyóʕ^{w}t* for 'strong', *lʕ'^{w}ó* 'put in', and a metathesis of the vowel and pharyngeal in the phrase *nsʕ'^{w}óp* 'it is draining' from the root *sóʕ'^{w}*, 'to become low'. More restricted, /e/ does not surface adjacent to any pharyngeal, labialized or plain, as /e/=[ɛ] always lowers to [ɑ] in the adjacent position.

Note that pronunciation of the pharyngeal greatly varies. Sometimes the pharyngeal itself is lost completely, but the remaining coarticulatory effect is realized as a long vowel (e.g. *i xaa* 'it's cool'). Or, the pharyngeal may be underlying as in *ʕ^{w}ós* 'lost', but it is not pronounced, only the effect on the vowel is, as in [oós] or [óos]. In many cases, what was once a pharyngeal historically, or which still occurs as a pharyngeal in the neighboring Salishan languages, is no longer pronounced in present day Montana Salish speech. However, often the vowel effects (such as lowering) remain and have become lexicalized independent of the pharyngeal's surface occurrence. In these cases, the resulting surface pronunciation is with additional length on the vowel, and/or lowering.

A previous summary of vowel interaction with pharyngeals is noted in Flemming et al. (1994:19) who state, "Rounded pharyngeals only appear before round vowels or word-finally, and unrounded pharyngeals only appear adjacent to the low, unrounded vowel /a/". According to Egesdal (1993:9) "/e/ and /u/ never directly precede a uvular or pharyngeal. Surface [u] may be contiguous to a uvular, as a result of /w/ vocalizing". However, as demonstrated by data above, S.G. Thomason (2000) has elicited pharyngeals in more diverse environments since these papers were published. Regardless, any cases of /u/ immediately adjacent to pharyngeals are interesting. An analysis of retracted tongue root ought to predict that these instances would surface as /o/ not /u/. It is therefore not entirely clear why these surface as /u/.

The interactions with uvulars and pharyngeals are important to interpret here in light of the lack of restrictions for the lateral consonants. The retracted back consonants (uvulars and pharyngeals) impose more dramatic coarticulatory effects such that some vowels do not ever surface adjacent to them. However, the laterals impose no such restrictions, regardless of their coarticulatory influences. Because the laterals have no distributional restrictions, it implies that the laterals will exhibit less of a retracted movement, if any, as compared with the uvulars and pharyngeals. In other words, these distribution facts imply that there will be less dramatic adjacent vowel effects than the other back consonants.

Two additional Montana Salish phonological generalizations, which are relevant for the examined /ƛ̓/ sequences presented in the following chapter, concern consonantal release as opposed to glottalization or ejection. All consonants can occur in clusters. However, when any stop or affricate is immediately next to another stop or affricate consonant in a cluster, then each sound is separately articulated. That is, each consonant is pronounced and released (without any vowel or vowel-like sound between the consonants). In addition, all consonants can be reduplicated, thus yielding sequences of identical segments. In this process, all stops, affricates, and the lateral approximant, are released. However, when glottalized oral stops and affricates are adjacent to another ejective, only the last ejective in the sequence is pronounced. That is, all ejectives are deglottalized except the last one in the sequence. This does not apply to glottalized resonants (Thomason, p.c. 2004).

The last comment concerns the remaining consonantal inventory and the establishment of "neutral" and "non-neutral" segments. In order to acoustically and articulatorily pair vowels which are influenced by back consonants, with those not under the same retracting influence, categorization of the inventory items was made. Recall the effects on the vowel inventory as listed in the sections on uvulars and pharyngeals above. Since no vowels in the context of the remaining inventory items are known to lax/lower, all consonants whose primary place of articulation is at the velum or farther front in the mouth, are considered "neutral". This is not to ignore the obvious coarticulatory effects that all consonants have, regardless of place or manner, but simply to differentiate between these effects and those retracted tongue root effects which have the potential to retract the adjacent vowel. In addition, to eliminate large coarticulatory effects, vowels adjacent to glides are not counted in the neutral category. Complete methodology for the comparison of these vowels, both articulatorily and acoustically, is presented in the following section.

2.3 Introduction and Motivation for Experiments

As demonstrated by the variable vowel pronunciation discussed previously, interaction with retracted consonants has a large effect on adjacent vowels. Previous literature, as discussed in Chapter 1, has shown that these effects are noted across multiple Salish (and non-Salish) languages. However, all studies prior to this have relied on acoustic analysis such that when claims about lateral segments were made, they were indirect regarding the actual function of the lateral. Acoustic measurements can reflect certain tongue behavior, but these are indirect inferences and cannot be considered conclusive as there are numerous factors that can influence the acoustic signal which are not sourced in the oral tract. A specific illustration of the lack of clarity in the interpretation of the acoustic signal is shown in Egesdal (1993). He posits two historically distinct retracted and non-retracted lateral approximants in Montana Salish in order to explain the variability in adjacent vowel lowering that is not otherwise accounted for by the standard post-velar consonants. He then goes on to say that the amount to which these two historical /l/'s have merged is unclear in current speakers (Egesdal 1994:18). It is clear that Egesdal has used the variability in the acoustic signal to motivate the positing of two distinct phonemes (which may or may not have merged). This was done in response to conflicting interpretations of the acoustic signal. A direct look at the articulators involved will avoid the convolution of the acoustic signal, and be able to make more conclusive claims on tongue movement.

It is clear from previous literature that there is potential for /l/ in Montana Salish to have a retracted component, but to what extent is yet to be clarified. The following chapter is an in-depth examination of possible tongue retraction of the lateral consonants in Montana Salish. The investigation will determine which laterals are retracted, and what the dynamics of the retraction movement are. How these tongue movements affect the adjacent vowels is discussed in the following chapter. Specifically, investigation into the use of tongue dorsum versus tongue root movement will reveal whether all lateral retraction is dynamically the same, or whether there is differentiation.

As previously mentioned, according to findings by Gick and Wilson (2003), adjacent vowel laxing can be explained as the byproduct of a gestural conflict between the tongue root and tongue dorsum. If the tongue root is retracted for a back consonant, such as a uvular, but the tongue dorsum needs to be high and front for an /i/ vowel, the physical system has the option of either compromising the tongue body's spatial position by laxing/lowering the vowel, or compromising temporally, which then results in a schwa-like transition stage; that is, "the resulting transition moves the tongue through an articulatory and acoustic space almost identical to that of a canonical schwa" (Gick and Wilson 2003:13). This choice is evident in the acoustic signal. Furthermore, in order to clearly differentiate why the lateral consonants might cause any kind of gestural conflict, clarification of their movement and position in the oral tract must be made. That is, if the lateral consonants exhibit a retracted movement, then it would necessarily affect the high vowels, either through spatial or temporal resolution. If there is no retracted movement, then there is no motivation for retraction effects on adjacent vowels (if indeed there are any). An articulatory analysis of the lateral to vowel interactions in Montana Salish will convincingly determine whether the lateral consonants themselves are retracted.

Three separate methods of analysis are used in order to fully investigate the retraction in laterals (or lack thereof) and the overall TR/TD gestural conflict in Montana Salish. These are: tongue position measurements, overlaid tracings of tongue positions, and the acoustic signal. Specific methodology for these is discussed below in section 2.4. These processes facilitate the establishment of retracted and non-retracted baseline of comparison for lateral consonant positioning and acoustic interactions. The following sections detail the methodology of these comparisons.

2.4 Methodology

Section 2.4.1 Participants

The author collected data during a four-week field session in the fall of 2003 with three elderly female, Montana Salish speakers. Sessions were recorded on site at the Confederated Salish and Kootenai Tribal reservation. All speakers are of the Bitterroot dialect of Salish, which is to be distinguished from the related "Pend d'Oreille", or "Kalispel" dialects. The primary speaker (DF) was ~ 74 at the time of recording. DF's father was Spokane. She often commented that certain words were "ours" and other words were either Pend d'Oreille or Spokane. She, and the other speakers, use English as a daily language though each is fluent in Montana Salish.

Because only one speaker (DF) provided visually clear ultrasound data, she has become the case-study speaker for this study. Neither acoustic nor articulatory data from the second or third speaker was interpreted within this study. However, descriptive and perceptual observations are still taken from all three speaker's recordings when valuable.[12]

Section 2.4.2 Apparatus and Organization

Real-time ultrasound recordings were made of all three speakers using a Sonosite 180 Plus portable ultrasound machine with Sonosite 180 plus C15/4-2 MHz MCX set at the obstetrics setting, penetration, with a non-reported internal scan rate, linked to a Sony (mini-dv) Handycam Vision DCR-TRV900 (NTSC) digital video recorder (Figure 2.2b). The camera recorded at 30 frames per second. The transducer was held steady by a microphone stand set upon a table before which the consultant sat (Figure 2.2a). An Audio Technica lapel microphone was attached to another stand in front, but level with the consultant's mouth, and simultaneously captured the audio signal (digitized at 44,000Hz).

The ultrasound was placed directly in front of the speaker during recording in

[12] Because all three speakers worked together on this project, even though only data from only DF was clear enough to be used, I am including their information as well: Speaker 2 (SH) was ~72 at the time of recording and had both one parent and husband who spoke Spokane. She is, however, self-described as competent between noting the origins of true Bitterroot Salish vocabulary, and other related dialects. Speaker 3 (MF) is ~80 years old, but is much less assertive in her Montana Salish speech because she has not spoken it in years. She also suffered slight hearing loss and lack of front teeth, which affected her speech.

order to establish a location of focus and eliminate as much head movement as possible. Because the speakers could watch their tongue while speaking, they were potentially able to self-correct if they noticed their head position was slipping. However, none of the speakers actually did this. Rather, perhaps because of an overload of information, the speakers consistently closed their eyes when speaking in Montana Salish, but opened them in the pauses while I was prompting them for the next set of tokens.[13] This balanced out possibility of visual feedback correction. Regardless, because of the point of focus, speakers were much more able to maintain a steady amount of pressure on the transducer and therefore produce a clearer image.[14]

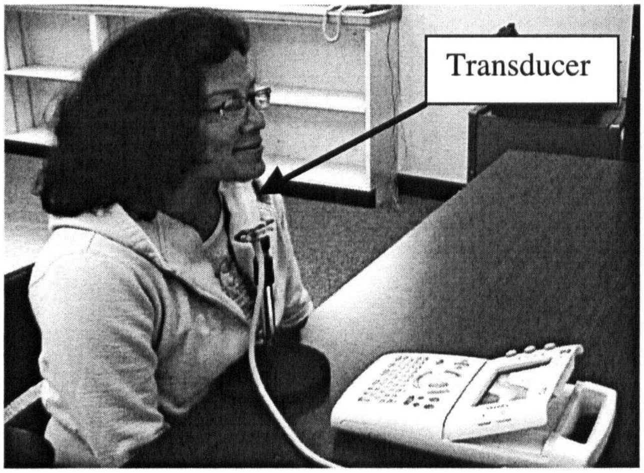

Figure 2.2a Placement of Ultrasound

Figure 2. 2b Portable Ultrasound

An attempt was made to measure the transducer to head angle but there was still enough uncontrollable head movement that only a general angle could be established. All pictures viewed represent a mid-sagittal cross-section of the tongue within the mouth such that the consultant's head is not vertical in the images. Instead, this angle is approximately 25 degrees off from true-vertical so that the a line drawn from the center of the tongue image to in-between the tongue tip and tongue dorsum is close to a true-vertical reading (See Image 2.2). Some isolated clips of the coronal cross-sections of the tongue were taken for select consonants (laterals and uvulars) by turning the transducer 90 degrees. When collecting the cross-sectional data, transducer stability and head movement was only minimally controlled for, thus the data cannot be analyzed in any manner other than descriptively.

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[13] Because the speakers did not actually focus on the real-time ultrasound images, there is little likelihood of the data being skewed by visual feedback.

[14] Maureen Stone (p.c. 2004) has suggested that for future data collection, a fixed point upon the wall or anywhere directly at eye level about 6 feet in front of the speaker is the best option for stabilizing head movement. Gick (p.c. 2004) also suggests that resting the back of the head against a wall or any other hard surface will reduce head movement.

Section 2.4.3 Analysis Materials

Analysis of collected data was conducted using numerous hardware and software. Initial transfer of the mini-dv recordings to a Macintosh computer and, finally, to DVD was done through use of Macintosh Final Cut. Subsequent acoustic analysis utilized Praat 4.0.22 while statistics were compiled using both Microsoft Excel and Statview 5.0.1. Apple Quicktime and Macintosh Final Cut were used for articulatory analysis of the ultrasound images, and Adobe Premiere provided the same function when on a PC. Image J version 10.2 was used to measure the articulatory data.

Section 2.4.4 Procedure for Elicitation and Token Organization

First, a word list of Montana Salish words exemplifying the targeted CV/VC interactions was created by referencing previous language data collected by Dr. S.G. Thomason in her Montana Salish Dictionary project and also previous language data collected by McDowell. Word lists were reviewed with all three speakers as a group in an audio session prior to ultrasound recording. The group review made sure that each speaker knew the targeted words, and was comfortable with their use and definition. If the words were not familiar, they were eliminated.

The word list was constructed to illustrate all possible stressed CV/VC combinations of /q/, /l/, /l'/, /ƛ̓/, /ɬ/, with /a/, /e/, /i/, and /u/.[15] Note, first, that combinations with /o/, semi-vowels, and glides are not analyzed and second, that limitation of particular sequences resulted from gaps in the language where the desired CV/VC sequence did not exist or simply could not be found without another possible retraction trigger in the word.[16] For a full list of elicited words, see Appendix A.

Words were collected individually in isolated repetition sets numbering 3 at a minimum, and sometimes several more. The polysynthetic nature of Montana Salish meant that some words were collected in a declarative sentence (different stress patterns for a phrase and sentence were noted when necessary). For the few elicitations in multi-word/multi-particle sentences, tokens were eliminated if the desired vowel was not stressed, if syllabification changed across word boundaries, or if the immediately adjacent word contained a retracted consonant. Stress in the repetition cycle was also noted for its effect on formant frequency. That is, in a set of three repetitions, the last utterance was often lowest in intensity, though still stressed (more than a non-stressed vowel). However, because of a concern for a sufficiently robust sample size, all three repetitions were still used unless the difference was sufficiently of concern.

Acoustic data collected simultaneously with the ultrasound images are in "citation form". That is, the author prompted the speaker with either the previously reviewed Salish word or the English translation of the reviewed word. However, acoustic data collected during the initial overview of the words with the speakers could be considered from a "natural" context as the desired words often arose in a kind of

[15] Because stress placement does not rely only phonetic or phonological properties of a word and is partially predictable by lexical specification of morphemes as 'strong' or 'weak' it is considered contrastive (Thomason, p.c. 2004).

[16] The vowel /o/ is not analyzed because of its additional conflicting status. It is not always clear whether it is /o/ underlying, or it is a lowered /u/ under influence from a retracted consonant.

discussion over the speaker's familiarity with the words. This context varied from sentences to isolated utterances etc. and was not taken into account for the acoustic statistics unless a dramatic stress shift or other dominant change occurred. Both sets of acoustic data were used in the data analysis. For example, the i/_ɫ sequence in *miɫ čta ɫu Mali* 'Mary is too skinny' has an /i/ vowel which is reduced to a slightly lower vowel during fast speech, where as *miɫ* in isolated production is with a true [i] vowel. See Chapter 4 section 5 for acoustic validation for this distinction.

Next, individual words were chosen to demonstrate the targeted consonant-vowel combination as stressed, within the same syllable. This includes the first vowel following a consonant cluster of the CCCV type (etc.,). Since there is no word initial stress (except in mono-syllabic words), all CV/VC contexts were either word medial, or word final position such that unless the vowel is monosyllabic, it is never stressed in word initial position (e.g. *x̌eʔéč* 'the sun, or something/someone, peeks out' and *i čn púx̌* 'I'm greasy').

Furthermore, in the selection of the elicited words, morphology and syllable structure are constrained as much as possible, though this is dictated primarily by coda and onset position. First, CV/VC sequences which span a morphological boundary are accepted in the selection of tokens as long as the CV sequence is onset-vowel and the VC sequence is vowel-coda. Therefore the /qi/ sequence a word like *estaqí* 'he/she's waving at someone', (ACT-wave- INTR.CONT.) would be acceptable even though the /q/ is from the root (*taq 'wave'*) while the /i/ is the continuative suffix. Similarly, because syllabification (likely) results in the /q/ acting as an onset for the following /i/ vowel, this word would be used.

Unfortunately, sometimes situations occurred where the coda/onset function of an intervocalic consonant is unclear, and the VCV context is the only possible environment available. When this was true, the word in question was examined separately in the analysis but used anyway. For example, in the word *smúl̓mn* [smúl̓ᵊmᵊn] 'war lance, spear' because there is a slight vocalic like sound between the /l̓/ and the /m/, the /l̓/ could conceivable act as the onset rather than as the coda in the /ul̓/ sequence. Similarly ambiguity arises in vcv́ sequences like *talíp* 'loose', where the consonant of focus is either a coda, an onset, or both, to the adjacent vowels.[17] Next, the majority of words examined exhibit a CV/VC interaction that occurs in the morphological root, but when this was not available, CV/VC combinations found in a lexical or grammatical suffix were utilized.

Lastly, and most importantly, words with any possible non-adjacent retracting trigger anywhere within the word (or on an immediately adjacent word regardless of intervening vowels) were eliminated. This includes any of the four laterals, the uvulars, or the pharyngeal consonants (but not the low vowels).[18] In addition, words with historically known retracted segments were rejected such as those with known underlying (but not surfacing) pharyngeals etc.[19] For example, cross-reference with

[17] No template of syllable structure is promoted by any of the criteria used in word selection for this project.
[18] In order to eliminate all chances for long distance phonetic or phonological effects from retracted consonants, words with any back consonant are eliminated. For example, *qʷo qʷéylis* "Johnny cheated me' would not be used because in theory, the uvular *could* effect the /l/ even though a vowel and a glide are situated in between the consonants.
[19] Thomason (p.c. 2004) notes that there are possible effects of glottalization on vowels. Thomason cites Mengarini (1877-79) who writes <ko> for words which are [k̓ʷ]u but <ku> for [kʷ]u. In consideration of

cognates in Spokane, Colville-Okanagan, and Kalispel as documented in the Montana Salish dictionary (2000) enabled this criterion to be enforced. Because of the frequency of these back consonants and the other strict definitions for which words might be eliminated, some VC/CV combinations could not be obtained. Other words in the word list are the sole known examples in the language after all the criteria have been applied. Conditions for inclusion or exclusion in the examined words are listed in the table below.

Table 2. 2 Word Selection Criteria

Words Used	Acceptable Environment
RTR Consonant anywhere in word	No
RTR Consonant in adjacent word less than 1 syllable away (for phrases only)	No
RTR Consonant historically present	No
CV/VC across morphological boundary	Yes
Coda-vowel sequence/ vowel-onset sequence	No
Stressed vowel	Yes

In addition to the focused elicitation, supplemental elicitation from the three Montana Salish speakers was used to collect phrases and words which demonstrate all additional phonemic inventory items. Beyond the targeted CV environments, examples of all items in the inventory (32 consonants, 5 vowels, and 4 semi-vowels/glides) were recorded on ultrasound imaging.

A complete word list for tokens utilized in this study is found in Appendix A. The list is separated into words used in both acoustic and articulatory analysis, and words that are only used in the articulatory analysis.

Section 2.4.5 Procedure for Acoustic Analysis

Acoustic analysis was done through cross-vowel comparison of the first, second, and third vowel formants. Formant transitions were measured and compared between "neutral" vs. "non-neutral" vowel environments, that is, between environments with the specified consonant, and those without any possible retracting consonant. For acoustic comparison, in addition to the elimination of known retracted consonants (and laterals), a "neutral" vowel environment was considered the context of consonants produced at the velum or farther forward in the mouth. In order to eliminate large transitory effects resulting from vowel-glide sequences, the stipulation of a "neutral" vowel also excluded adjacency with all glides (/y, ẏ, w, ẇ/).[20]

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this possible retracting effect on the adjacent vowel, it is possible that the predominant effect on the /u/ in *esk̓ʷuʔl̓l̓i* and *k̓ʷúʔl̓* is not from the lateral, but from the preceding /k̓ʷ/. Similarly, if effect from the /k̓ʷ/ carried over to the lateral, it would help explain why the lateral position in these two words is more defined then the lateral in *pl̓íp* and *smúl̓mn.* Nevertheless, since these /u/ vowels were not evaluated auditorily, they do not skew the acoustic results for the /l̓/.

[20] Henceforth, all reference to neutral vowels refers to this definition and is not meant to imply that other segments do not exhibit acoustic effects on an adjacent vowel.

Approximate correlations made from the measured formant values were as follows. Tongue body height is encapsulated through the first formant frequency such that the higher the tongue body, the lower the F1. Tongue body backing is reflected through F2 whereby the farther back the tongue body moves, the lower the F2 falls. And lastly, tongue root retraction is captured by changes in F3 such that the more tongue root constriction, the lower the third formant frequency Kent and Read (1992). However, interpretation of F3 is more complicated since there is also a pressure maximum near the uvula. It seems possible then that F3 formant values could rise in this location, thereby convoluting the interpretation of the F3 signal. In order to understand the possible interpretations of the F3 readings in terms of TR or TD retraction or advancement, F3 is discussed in more detail below.

The figures below illustrate a simple tube diagram of the vocal tract. Here pressure (P) and velocity (V) maximums correspond to different areas and constrictions in the vocal tract. Constriction at a V maximum lowers F3, while constriction at a P maximum raises the third formant. For example, in theory, F3 is lowered by movement of the tongue back in the TR area, but raised by movement of the tongue toward the uvular. However, beyond all the additional factors like lip rounding (which lowers all formants), the exact location of the P or V maximum is difficult to correlate with specific consonants. This is because consonants, and indeed all sounds, are not necessarily produced at exact pressure maximums or minimums. Montana Salish uvulars (see Chapter 3) seem to be produced in the upper pharyngeal, posterior uvular area and thus the F3 values reflecting this may not reflect the exact center of a pressure maximum. Therefore, F3 can be considered a more convoluted, and less straightforward formant than either F1 or F2. Kent and Read state, "the curve for F3 has negative [lowering] regions corresponding to constrictions as the lips, the palate, and the pharynx" (Kent and Read 1992:27). However, the diagrams below, as modeled from Borden et al. (1994:97), put the pressure and velocities at slightly more specific places within the vocal tract.[21] These many-to-one effects on the acoustic formants underlie the importance of a direct investigation into the articulatory production. F3 information is valuable when incorporated along with the articulatory imaging which illustrates the direction of tongue movement.

[21] For constriction locations for F1 and F2 see Bessell (1991).

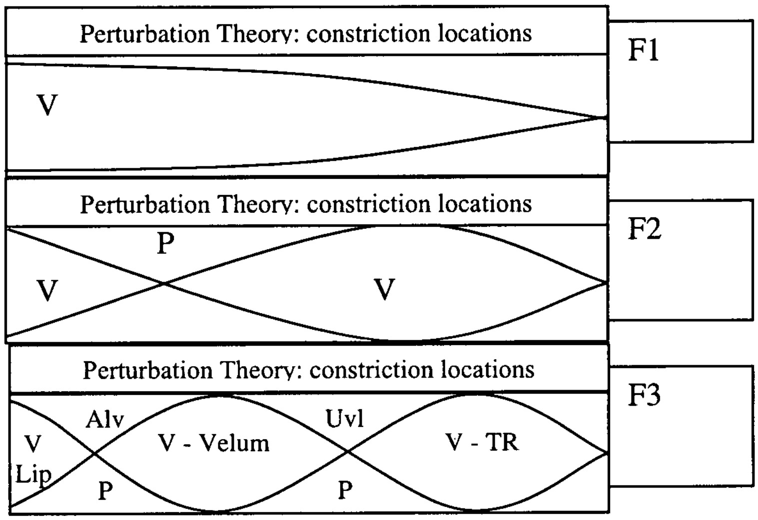


Image 2.1 Vocal Tract Tube Model

F3 is not the only signal which is interpreted through the many-to-one acoustic-articulatory relationship. As illustrated here, it is fact of the acoustic signal that extension in one area or compression in another area will change the resulting formant values. This is particularly relevant to F2 and F3 as there are multiple locations of velocity and pressure maximums and minimums, but is equally applicable to F1. While interpretation of the signal is in terms of TB height, TB backing, and TR retraction, there are always additional factors both internal and external to the oral tract which can influence the final formant outcome. This is fundamentally why a direct look at the articulators is necessary now that the means is available.

Continuing with the acoustic measurement procedure, F1, F2 and F3 are measured at 5%, 50% and 95% into each vowel neighboring the targeted consonant for all words. This was completed in Praat 4.0.49 (1992) using the scripting and text-grid functions. All measurements are compared against the formant value of the neutral vowel at that particular time. For example, in the words, *piq* 'white' and *ciq* 'dig', all formant values for /i/ are measured noting that the first measurement 5% into the vowel will most likely reflect the preceding consonants effect, and less of the following consonants effect. Midway should show influences from the consonant on either side, but 95% into the vowel will show more of the following consonants effects. Similarly, the reverse is applicable to a V/C_ context. If all three measurements demonstrate retained lowering effects from the adjacent retracted consonant, then the vowel could be considered to be lowered, as well as transitioned. These are compared to averaged /i/ values for a neutral /i/ at the same point in time (5%, 50%, 95%). The neutral vowel values always represent the average of all neutral /V/ measurements as in such words as *t̕apím* ' she/he shot something'. In addition, as exemplified by Wilson's (2003) Nuu-chah-nulth articulatory and acoustic results, it is necessary to separate vowel results by pre- and post- consonantal position.

Section 2.4.6 Articulatory Procedure

The procedure for the articulatory, ultrasound analysis was as follows. Still frame clips were extracted from the video, and real distance was calculated in centimeters (to the tenth of a centimeter) as marked by the fixed control points (represented by circular white dots) imprinted on the recorded ultrasound image. Real distance was calculated through a pixel to cm conversion in the Image J program. Measurements were then compared both internally and also externally against measurements from other the laterals and vowels. These measurements quantify the amount of tongue root retraction (or lack thereof) in each VC/CV environment. In addition to comparing the position of the specified consonant, a comparison was sometimes made between this adjacent "retracted" vowel position and the "neutral" vowel position (e.g. i/q_ vs. i/p_). This enables a conclusive claim as to whether the vowel adjacent to the specified consonant did or did not completely reach its gestural target.

When the selected consonants demonstrated a distinct end to their movement, such as that done by the lateral ejective affricate, measurements were taken both at time of the tongue (tip) constriction, and then at the peak back movement of the release. For consonants that did not have a clear end to their movement, tongue position data was recorded midway through the consonant.

The mechanics of the articulatory measurements are described subsequently: Figure 2.3 below, copied with permission from the Laval X-ray database (Munhall et al. 1995), illustrates the location of the epiglottis relative to the tongue root. The epiglottis is a fixed position and is therefore, the ideal location which can be a steady base point from which other measurements can be made.

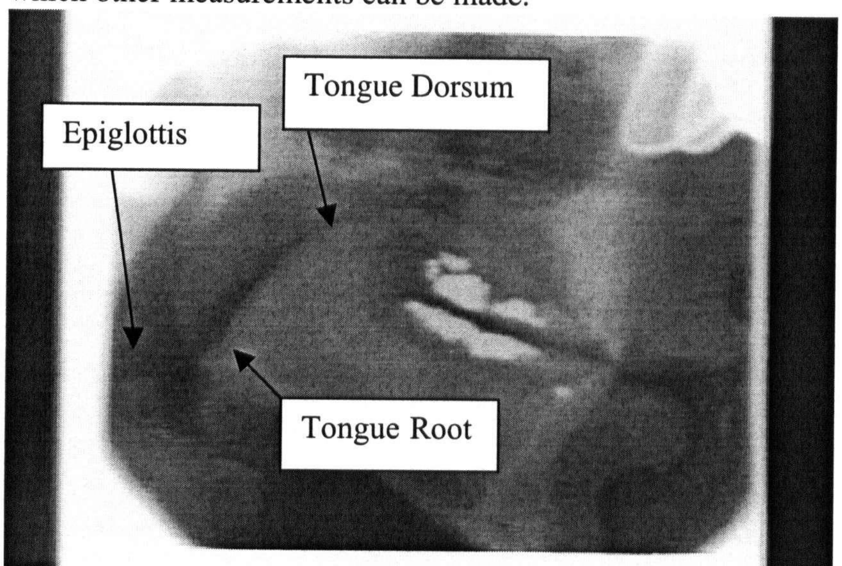


Figure 2. 3 X-ray image of a male English speaker.
(Munhall, Tohkura, Vatikiotis-Bateson 1995)

However, the epiglottis position is not visible within the scope of the ultrasound image. Additionally, the shadow of the hyoid bone is often observable in the ultrasound image, and frequently blocks the image of the tongue root. An illustration of the width of the ultrasound's midsagittal image is shown in Image 2.2. One can see that hyoid bone, which blocks the sound wave signal, is in the visual scope of the ultrasound image.

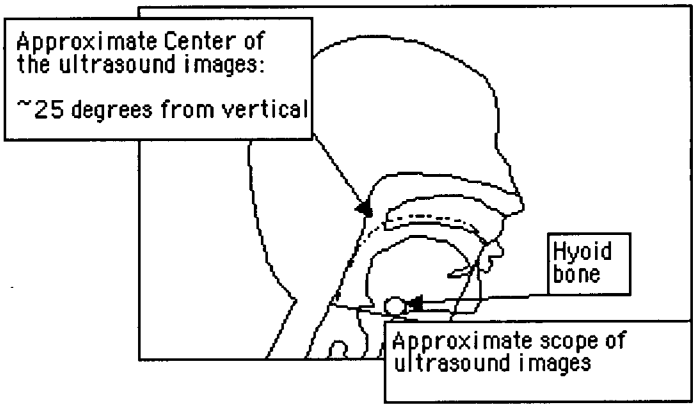


Image 2.2 Angle of Ultrasound View

(Image adapted from Stone 1997)

Furthermore, since there was minimal ability to control for head movement during field collection, all measurements and data need to be relative to the tongue itself, rather than the transducer. That is, the only static point visible on the ultrasound image is one that is internally relative to the tongue. As neither the epiglottis, nor any other static point, is visible as long as head contact is maintained with the transducer, then the tongue root position becomes the steadiest landmark available. This locus became the base point from which the other measurements were made. Specifically since this locus is tongue internal, it allows for measurements to be taken even though the tilt of the head may vary.[22] It is imperative to compare all images with the real time video in order to make sure that the same part of the tongue was visible in all frames.

Figure 2.4 shows the location of the hyoid bone shadow in the collected ultrasound data and displays where the initial tongue root measurement was taken. This area of shadow is extremely variable by speaker and transducer angle. Note that all ultrasound images are presented with the tongue tip facing the right, and the tongue root facing the left.

[22] However, note that this speaker's head tilt has proven to be exceedingly minimal, even over multiple sessions and multiple days.

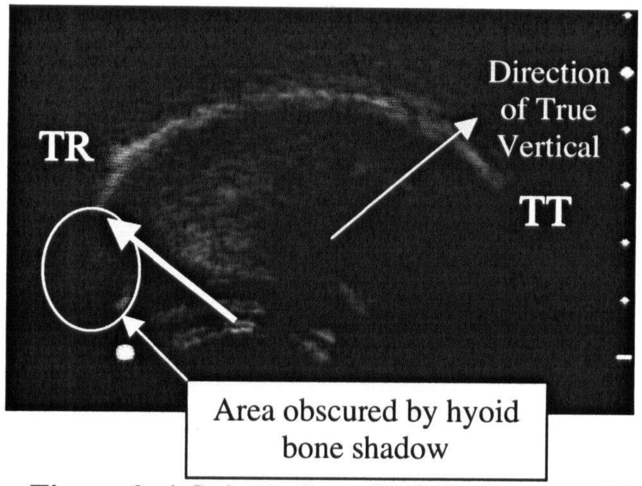


Figure 2. 4 Orientation of MTS ultrasound images

The locus of the initial baseline measurement (#1) bears explanation: A completely tongue internal measurement, is based exclusively on the measurer's judgment of where the TR is, and which spot represents the same position as the last image that was measured.[23] However, a completely tongue external measuring method bears no relation whatsoever to where the tongue actually is on the ultrasound image. That is, the visible area of the TR varies in each captured image (because of speaker head tilt, hyoid bone shadow intrusion, and other still unexplained clips on the image). This limits the possible method of measurement to the more reliable approach and when visible cues are taken into account, this is what the closest point on the transducer arc represents (Figure 2.5). (The measurer keeps a crucial visual note of where the same part of the tongue is in each different image). Further support for the chosen process is possible because the particular speaker used in this study had exceedingly little head tilt.

[23] In addition, note that the "TR" measurement does not represent the true actual physical base of the tongue where it connects to the larynx. If measurements were taken here, they would not reflect the tongue's movement. Furthermore, the numbers in the following section represent the change in tongue movement, not the actual size or shape of the tongue.

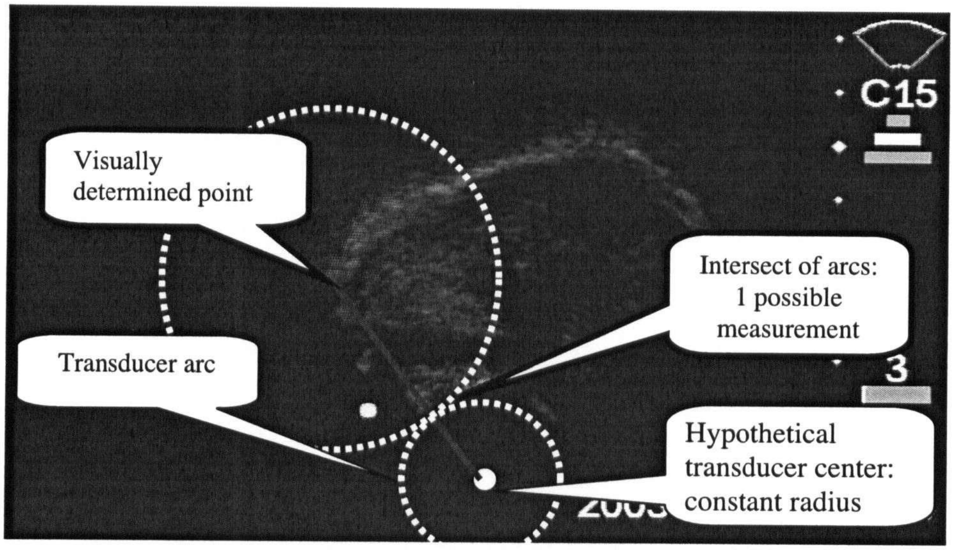


Figure 2. 5 Intersect of Measurement Location

Figure 2.6 below illustrates the process and location of each ultrasound measurement.

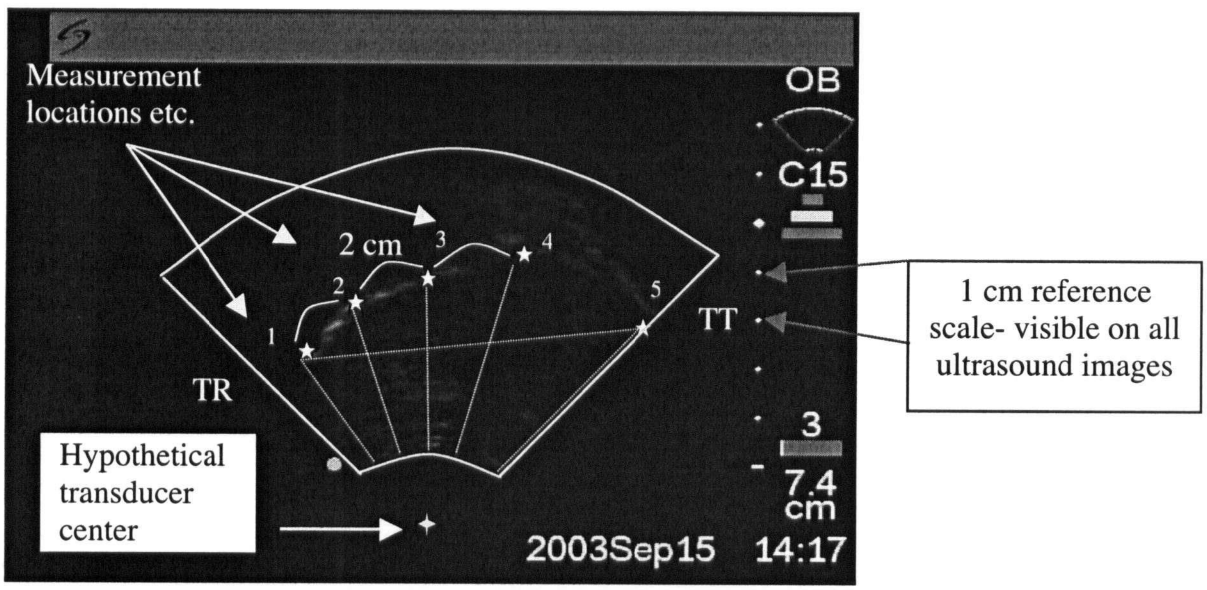


Figure 2. 6 Location of Tongue Measurements

Measurements (in cm) were taken along the outline of the tongue beginning at the visible base-point TR position (1) to the closest point on the transducer arc, then at three points in between TT and TR, each 2 cm apart initiating from the TR position (2, 3, 4), then from TT (5) to closest point on the transducer arc, and finally from the TT (5) position to the TR position (1). Established procedure (Stone 1997) is that these measurements are taken from the underside of the white lines visible on the ultrasound image. As mentioned before, because of possible head tilt, only measurements based on an internal marker within the tongue image allow for inter-speaker comparison. In this system, a larger number between the TR (1) and the base-point measurement on the transducer arc, represents more tongue root retraction, as the whole tongue mass is shifting back. Therefore, a lower number for measurements 1 and 2 represents a more advanced tongue position. Measurements 2-4 approximate the general area of the upper TR, uvular, and TB positions. Numerical values for measurements 3-5 represent the position for the TD, TB, and TT, but do not equate exactly to more or less tongue retraction. These measurements are only analyzed as a complete set demonstrating the entire tongue position (i.e. as a measurement set including 1-5).

Using MRI data, Gick et al. (2002) divide the vocal tract into upper and lower pharyngeal, uvular, and oral regions. Furthering this distinction, Figure 2.7 below illustrates the parts of the tongue in relation to speech as shown using ultrasound imaging. Notice that the uvular region has been separated into an upper and lower area in order to distinguish the Montana Salish pharyngeal-uvular (posterior uvular) production from "true" uvulars. However, even this distinction does not sanction clear boundaries from one area of articulation to another.

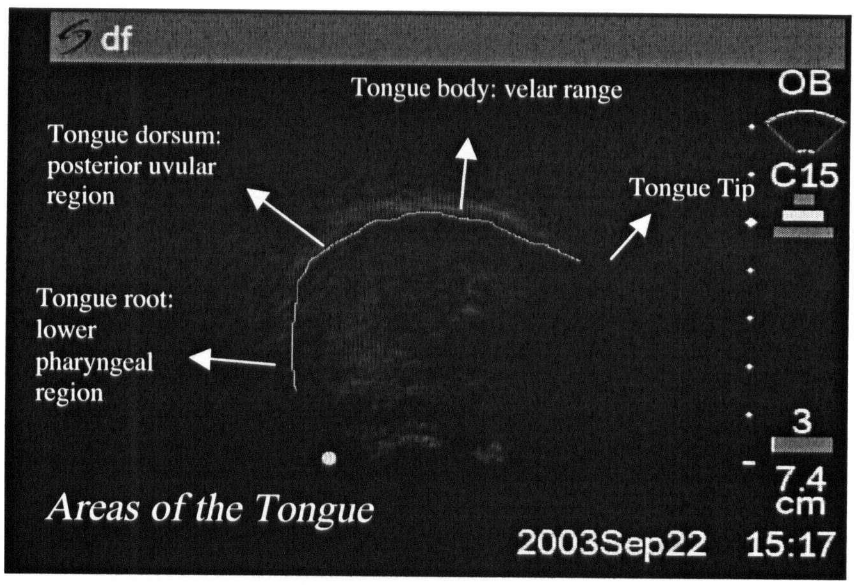


Figure 2. 7 Areas of the Tongue

The organization of articulatory analysis merits further elaboration. The subsequent chapters explore the following attributes of dynamic gestural movement. First, position of the tongue gestural target for the lateral consonants is considered. Relevant statistics for tongue positioning are presented. Average positioning is compiled per environment and exemplified primarily with tongue tracings. These tracings allow for an illustrative comparison of consonant and vowel positions in different environments. Tracings of the tongue illustrate retracted and non-retracted counterparts for the vowels and consonants in question. All tracings, and corresponding plotted tongue positions based on the averaged measurements, are compared to interspeech rest position (see section 2.4.7).

Next, the articulatory analysis includes a description of the dynamic movements of the tongue. This is illustrated in a frame-by-frame level of analysis either through sequential images of the tongue, or with tongue tracings. This enables a conclusive portrayal of tongue retraction (or lack of retraction) for each consonant. Averages for initial and final position are again compared statistically and represented graphically. This supplements the static measurements of the tongue through qualitative description of the tongue shape, movement, and direction.

Lastly, articulatory analysis also includes a comparison of coronal cross-section data. For this imaging, the transducer was turned 90% from the mid-sagittal position and placed under the midpoint of the chin. The angle of measurement varied more than the mid-sagittal data because only a few consonants along the coronal cross-sectional view were recorded, and this cross sectional sampling was collected under less controlled conditions. Therefore, no measurements are made from this view. However, tongue tracings, which demonstrate the dynamic movement of the tongue, are used.

Section 2.4.7 Interspeech Rest Position

Once the procedure for measurement was established, comparison was made between tongue positions in different vowel contexts. In addition to visual determination, the objective method of quantifying whether the amount of retracted tongue movement qualified the token as "retracted" involves evaluating the particular consonant context in comparison to /i/, /e/ ([ɛ]), "interspeech rest position", and /a/. These four target tongue positions create a scalar baseline for advanced tongue root (/i/), no TR advancement or retraction (rest position), and retracted tongue root (/a/). Rest position was averaged from a variety of tokens (that is, with varying consonants and vowels word finally and initially) and taken from the brief pause in between repetitions of words. If the pause was too short, and the 'rest' position skipped, then these tokens were ignored. As the minimal variability in the rest position images demonstrates (Figure 2.8) this is a targeted position that is regularly reached in between inter speech tokens.[24] Measurements were taken the same as with the other vowels and consonants from all the specified points along the tongue.

In this subsequent attempt to establish a entirely neutral baseline of comparison for whether a segment can be defined as "retracted" tongue measurements for inter speech rest position were taken and plotted against the vowels in the graph below. According to Gick et al. (2004c), inter utterance rest position is a language specific articulatory target. Gick (p.c. 2004) suggests that this position may represent a medial position within the language inventory (not necessarily the medial position within the vocal tract) such that the tongue positioning might reside in the middle between retracted and non-retracted vowels as well as consonants. In order to spatially examine the effects on tongue position, a baseline position of the neutral vowels is collected based on the 5 measurement points along the tongue. These plot the vowel space at the midpoint of production, thus corresponding to the acoustic measurement of 50% into vowel production. This referential comparison of vowels to interspeech rest position is presented below.

[24] For more information in interspeech rest position, the reader is referred to Gick et al. (submitted).

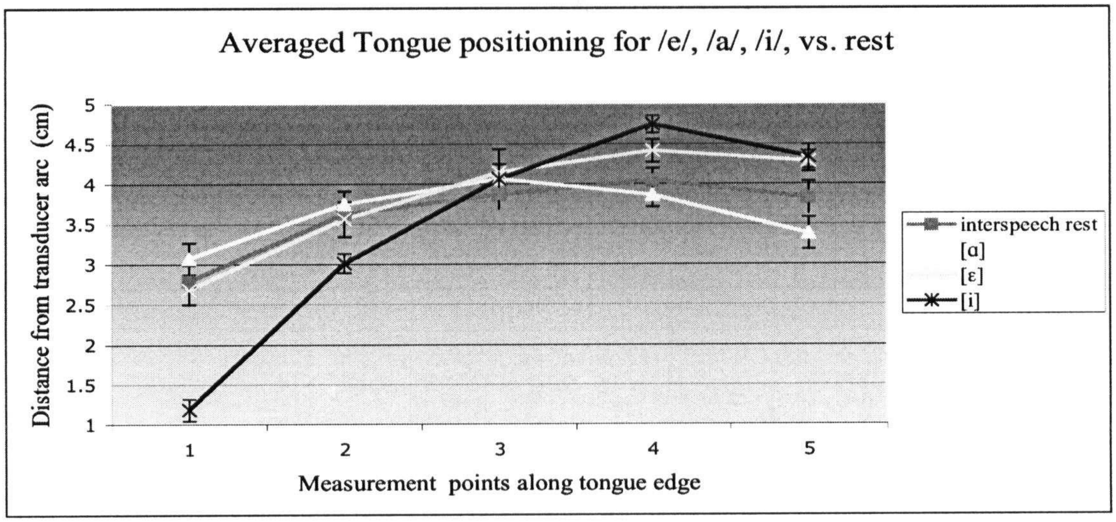


Figure 2.8 Interspeech rest position as plotted against /i/, /e/, and /a/

Note, fore mostly, that at the tongue root measurements of #1 and #2, rest exhibits a medial position between the low and non-low vowels. As predicted, tongue root position during inter utterance rest does lie between the low vowel /a/ [ɑ] and the mid and high vowels /e/ [ɛ] and /i/ [i], and is thereby consistent with function as an objective medial baseline. Interpretation of the graph is such that at measurements #1-2 a number smaller than that of interspeech rest is not "retracted" but a larger number along the Y-axis represents more TR retraction. Note that the tongue dorsum measurement (#3) acts as the approximate fulcrum, such that rest measurements 4-5 (representing tongue body and tongue tip) are now lowered more than that /i/ and /e/ [ɛ] vowels, but are not as low as the /a/ vowel. The area represented by measurements #4 and #5, while not the focus of the current investigation, is used in overall description of the tongue position. In addition, it must be clarified that interspeech rest is independent from the canonical schwa vowel in Montana Salish. Interspeech rest as proposed by Gick et al. (2004c) maintains an independent language articulatory setting which is a distinct and consistent gestural target and is produced with a degree of accuracy equivalent to that of vowel targets. Now that interspeech rest has been established as a point of reference for retraction within Montana Salish, objective evaluating the retraction of the laterals is possible.

Chapter 3 Retraction by the Uvular Stop: establishing a benchmark of comparison

3.1 Introduction to organization of results

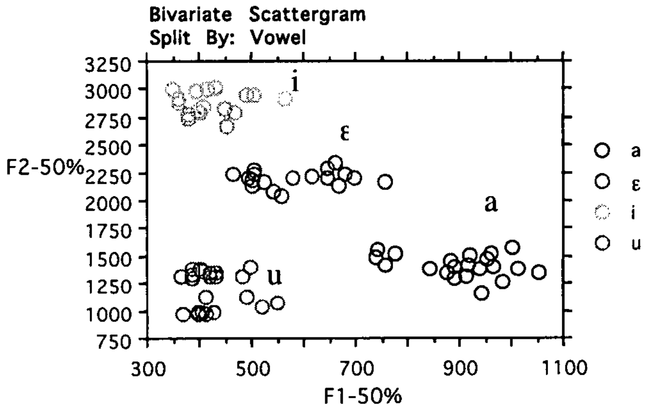
The processes and methods discussed in Chapter 2 facilitate the establishment of retracted and non-retracted baseline of comparison for lateral consonant positioning. The results sections are organized in the following manner. First, in Section 3.2, a summary of the primary speaker's vowel space is presented in order to assist in the interpretation of the acoustic results. In addition to the auditory signal, vowel tongue positioning is compared to interspeech rest position. Articulatory positioning of interspeech rest is presented as a speech internal tongue position which represents the outlined boundary between retracted and non-retracted vowel positions. Next, in Section 3.3, an acoustic and articulatory analysis of the uvular stop is presented. The Montana Salish uvular stop is included as representative of an uncontroversial retracted consonant. This, then, allows it to become the reference of tongue retraction via acoustic effects on adjacent vowels, the tongue position within the oral tract, and the overall dynamic tongue retraction movement. In Chapter 4, the tongue movement of the laterals is examined using both this, and interspeech rest positioning as a reference.

3.2 Vowel Space

The following graph and table provide referential data for the vowel space of the speaker from whom all the ultrasound information was collected. Recall that all measurements are taken in non-retracting environments (i.e. no uvulars, laterals, or pharyngeals in the word context). Also note that too few /o/ vowels in non-retracting environments were available for analysis and are therefore not included below.

The following vowel averages in Figure 3.1 for the speaker used in this study are consistent with those averages as listed in the Flemming et al. (1994) acoustic survey which was collected from 3 female Montana Salish speakers (one of which is the same consultant as in the present study). Flemming et al.'s listed formant values for F1 and F2 range considerably. For /i/ F1 extended from near 275Hz to 500 Hz while F2 ranged from near 2500 Hz to 3200 Hz with means being 372 Hz and 2645 Hz respectively. F1 for /e/ stretches from approximately 400-650 Hz: F2 for /e/ between 2100 Hz and 2900 Hz with the means at 535 Hz and 2181 Hz. F1 for /u/ was between 300 Hz and 550 Hz with several outliers and F2 was between 1150 Hz and 1800 Hz. The averages for F1 and F2 for /u/ were at 407 Hz and 1168 Hz. Formant frequencies for /o/ ranged from 450 Hz to 725 Hz for F1 and 1200 Hz to 1600 Hz, again with several outliers. Average frequencies were 601 Hz (F1) and 1170 Hz (F2). Lastly, Flemming et al. (1994) found /a/ to range between near 600 Hz and 1100 Hz for the first formant, and then from 1600 Hz to 2200 Hz for the second formant, with means listed at 854 Hz and 1603 Hz.

Formant averages collected by Flemming et al.(1994) are consistent the formant values collected for the present study listed in Figure 3.1 below. Note that these represent the formant average at the midpoint of each vowel in order to best avoid coarticulatory influences of the adjacent segments.



Descriptive Statistics
Split By: Vowel

	Mean	Std. Dev.	Std. Error	Count
F1-50%, a	901.143	89.376	19.503	21
F1-50%, e	584.833	86.854	20.472	18
F1-50%, i	420.056	57.847	13.635	18
F1-50%, u	425.818	50.133	10.688	22
F2-50%, a	1418.476	102.231	22.309	21
F2-50%, e	2202.444	71.570	16.869	18
F2-50%, i	2880.118	103.158	25.020	17
F2-50%, u	1207.045	170.384	36.326	22
F3-50%, a	3236.450	186.090	41.611	20
F3-50%, e	3352.500	132.760	31.292	18
F3-50%, i	3411.412	118.437	28.725	17
F3-50%, u	3279.550	88.091	19.698	20

Figure 3. 1 Vowel Formant Averages

Once average vowel formant ranges have been established, pairings against the same vowel adjacent to the possible retracted lateral segments can be examined. The differences in formants reflect the coarticulatory effects of the adjacent lateral.

3.3 General Gestural Conflict resolution for Montana Salish Uvular stop

A sketch of the uvular articulation is presented in order to situate the articulatory investigation of the four lateral consonants. Since previous research has distinguished "uvularization" from "pharyngealization" in terms of tongue retraction, one must articulatorily define what this entails (Bessell 1998a; Doak 1992; Egesdal 1993; Johnson 1975; Shahin 2002; etc.,). Shahin (2002) describes Arabic uvulars as co-occurring with pharyngealization such that the uvular movement cannot occur without the pharyngeal movement (Shahin 2002:24). For Coeur d'Alene, Doak (1992:12) states "In the pharyngeal resonants, this [pharyngeal] constriction is primary... In the uvulars and r, pharyngeal constriction is produced by tongue root retraction coinciding with other articulation, in these cases produced by the tongue blade or body". This implies that uvular production includes both tongue dorsum and tongue root retraction. If true for Montana Salish, then similar retracted acoustic effects produced by the laterals would imply a similar tongue shape and movement.

Interpretation of the lateral consonants tongue movement is therefore paired against the uvular results presented below. The plain uvular stop is used to represent the class of uvulars in terms of physical movement and corresponding effects on the vowel's acoustic signal. That is, since in Salish languages, /q/ is a prototypical retracted consonant, it is used as a baseline of comparison which gives a frame of reference in relation to direction of retraction. Investigation into the uvular as compared with the lateral consonants allows the claim designating uvular space as X. Laterals retract to this space, which is in Y relation to the uvular space and the pharyngeal space within the oral tract. The target retracted consonants interact with vowels in Z relation. Analysis of the plain uvular stop consonant as the least marked segment of the uvular class is used as a representative for the class of uvulars. The plain uvular is chosen because a labialized sound will affect the acoustic results and make for a different interaction with the vowels beyond the simple uvular interaction. Similarly, an ejective sound will allow too much movement to take place during the glottal closure so that the conflict resolution is possibly masked (acoustically).

Figure 3.2 below illustrates the locus of prototypical uvular constriction for Montana Salish plain uvular stops. Notice the large TR presence in both the uvular and pharyngeal region. This TR presence illustrates that these uvular stops are consistently produced in the upper pharyngeal/posterior uvular locus of the oral tract and can considered uvular-pharyngeal in production.

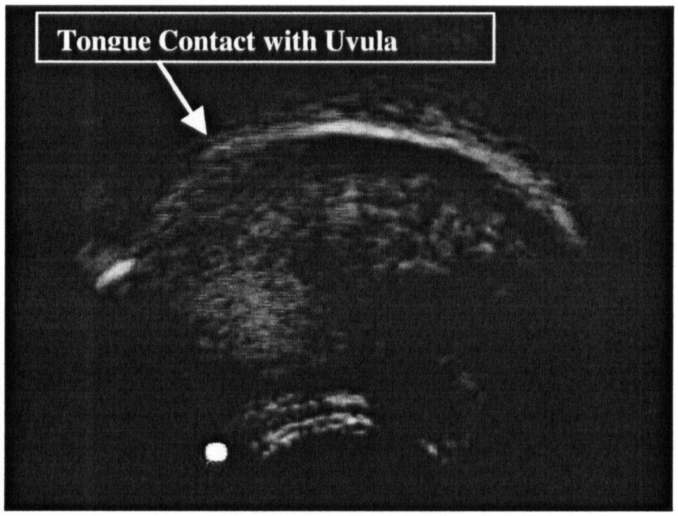


Figure 3. 2 Position of uvular contact

It is clear through the ultrasound imaging that the uvulars, as a class are produced in the far back uvular-pharyngeal range and no fronting occurs. Egesdal (1993) claims that uvulars change /i/ to [e] with at most, a slight onglide of Q[$^{\varepsilon}$e], Q^{w} [^{ɔ}e]. He also reports that some speakers instead produce a higher vowel [e+] or [i-]. However, he then erroneously explains this by saying it is likely that the uvular consonants (as a whole) are fronted toward velars (Egesdal 1993:22). The articulatory evidence shows that uvulars do not front, but that instead, the amount of vowel transition is variable. Additionally, acoustic data presented below does not show [i] lowering entirely to [εe] or any other ultimately laxed/lowered vowel.

Since the uvular is really an upper pharyngeal/posterior uvular, as shown in the figure above, then it has the potential to lower the immediately adjacent /u/. That is, if the uvulars were true uvulars, then there is no articulatory reason for the (uvular/back) /u/, to lower, unless, the /u/ itself is somewhat more anterior.

In order to attempt explanation of this lowering phenomena in MTS, the /q/ and /u/ were examined in comparison to the /q/ and /u/ in Nuu-chah-nulth. Montana Salish /q/ almost always lowers a following /u/ to [ɔ], but Nuu-chah-nulth /u/ does not lower when adjacent to a /q/ (Wilson, 2002).[1] One initial hypothesis is that the MTS /q/ is

[1] All Nuu-chah-nulth data and information is credited to Wilson (2002).

produced farther back in the mouth and therefore, the immediately following /u/ position creates a gestural conflict, resulting in gestural compromise. Similarly, NCN /q/ would be slightly more anterior (or the /u/ would be more posterior) and the /u/ would not be in conflict. Comparisons of the two are illustrated below.

The two figures below are approximate overlaid tracings of a Nuu-chah-nulth /k/ and q/ii_ overlaid with a Montana Salish /kʷ/ and q/i_ respectively. They are a visual attempt to represent the different uvular production in these two languages as seen in the ultrasound films. While the two sets of ultrasound data were recorded from two different speakers in different locations and times, and with differing setups (thus possibly a different probe or head angle etc.), a visual comparison between the /u/s and /q/s is worthwhile. However, no measurements can be made.

Ladefoged and Maddieson (1996) describe uvular production as the backing of the tongue dorsum into the uvular region, which resides just above the pharynx. However, in Figures 3.3 and 3.4, notice that while the MTS and NCN velars appear to have a similar production location the two languages uvulars are (consistently) produced quite differently. The MTS /q/ is predominantly retracted in the tongue dorsum area, and has significantly less tongue root retraction than the NCN uvular has. The NCN uvular has both a large TR backing and raising as well as the predicted TD retraction. The tongue fills more of the back of the mouth for the NCN uvular stop, than for the MTS uvular. This production difference undoubtedly has different corresponding acoustic effects as the gestural resolution is resolved. However, general uvular production is described as involving the posterior uvular/upper pharyngeal region by both the TD and TR.[2]

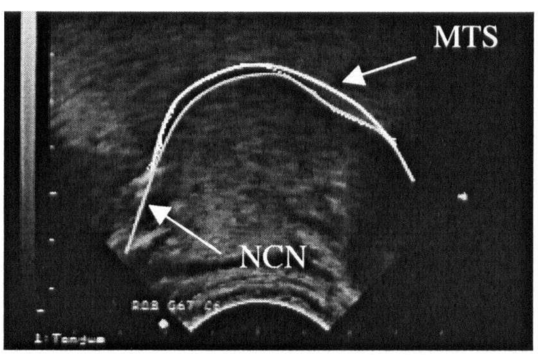


Figure 3. 3 MTS /kʷ/ vs. NCN /k/

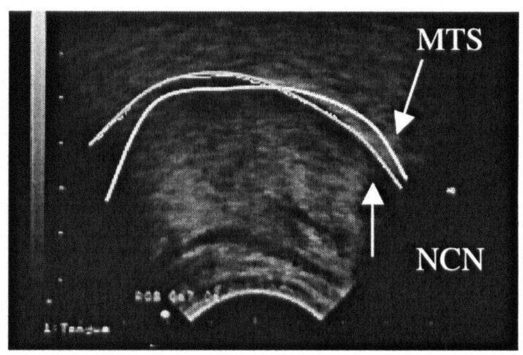


Figure 3.4 MTS q/i_ vs. NCN q/ii_

A more relevant set of comparisons is displayed in figure 3.5 below. These tongue tracings represent three different /u/ vowels. The light blue line is the NCN /u/ after a uvular. The white line is the MTS /u/ in a non-uvular context, and the dark blue line is a MTS /u/ immediately following a /q/. Notice the large difference in MTS /u/ productions depending on environment. The MTS /u/ following a uvular has a lower tongue body and more retracted tongue root and dorsum than the non-uvular context /u/. When the /u/ is viewed in comparison to the above MTS uvular production, the difference in TR positioning is obvious. It is this conflict which the results in the

[2] The Montana Salish frames in Figures 3.2-3.4 come from *cikʷkʷkʷkʷ*, *piq*, and *nq'wusn*. The Nuu-chah-nulth words are *quul*, *ciikiiqa*, and *ciiqciiqa*.

modification of the /u/ position and thus the acoustically lowered vowel. The tracing representing the NCN u/q_ does not show as large an amount of retraction and backing, but no NCN non-uvular context /u/ was available for comparison. However, the /q/ and /u/ in NCN visually seem to be as distinct from each other as the MTS /q/ and /u/, therefore it is not clear why the NCN /u/ does not also lower.

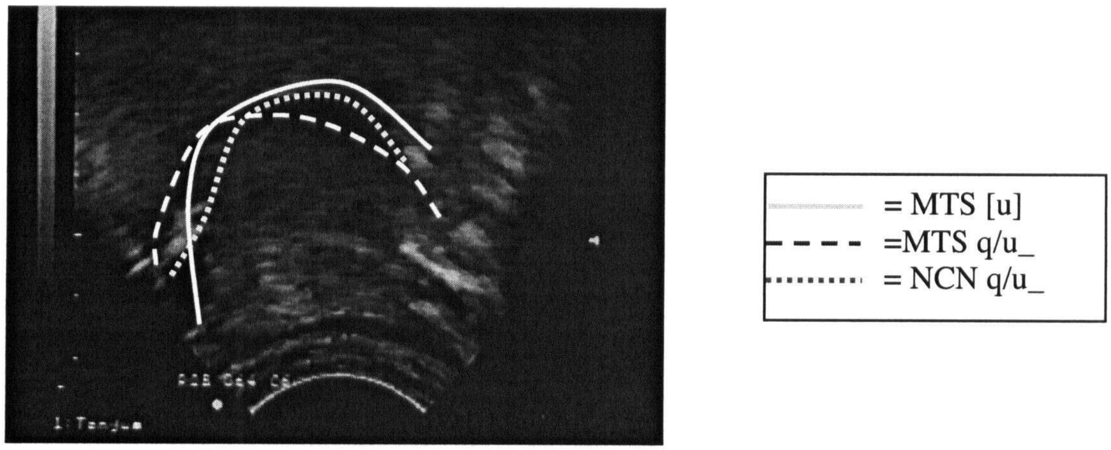
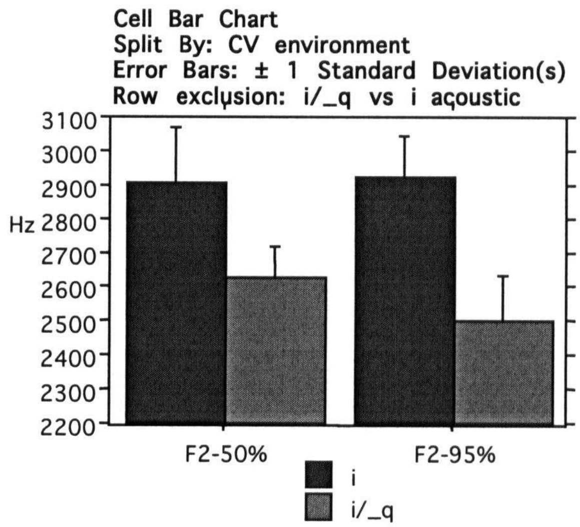
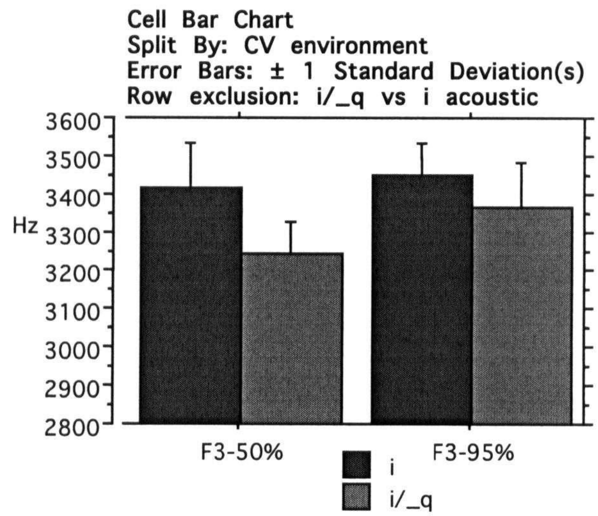


Figure 3. 5 Cross Linguistic Comparison of /u/ vowels

Next, in order to determine the acoustic effect which this retracted consonant has on adjacent vowels, an acoustic comparison between the high front vowel /i/ and an /i/ preceding a uvular stop is presented below. Statistical information for each formant with significant pairings at 50% (midpoint), and 95% (offset) is listed in the figures and table below.[3] Differences in F1 were not significant and are therefore, excluded. The deviations from the mean for i/_q are consistent with the perceived auditory variation of the vowel within multiple repetitions of the same tokens. Notice that by midway through the vowel, F2 and F3 are already much lower for the /i/ in the retracted context as compared with the neutral /i/ values. The statistically significant differences are listed in the tables below.

[3] Significant level is set for $p > 05\%$.





Fisher's PLSD for F2-50%

	Mean Diff.	Crit. Diff.	P-Value	
i, i/_q	295.276	86.506	<.0001	S

	Count	Mean	Std. Dev.	Std. Err.
i	17	2919.11	157.228	38.133
i/_q	19	2623.84	93.453	21.440

Means Table for F2-50%
Effect: CV environment
Row exclusion: i/_q vs i

Fisher's PLSD for F2-95%

	Mean Diff.	Crit. Diff.	P-Value	
i, i/_q	430.486	84.831	<.0001	S

	Count	Mean	Std. Dev.	Std. Err.
i	17	2931.11	119.923	29.086
i/_q	19	2500.63	129.407	29.688

Means Table for F2-95%
Effect: CV environment
Row exclusion: i/_q vs i

Fisher's PLSD for F3-50%

	Mean Diff.	Crit. Diff.	P-Value	
i, i/_q	185.372	67.217	<.0001	S

	Count	Mean	Std. Dev.	Std. Err.
i	17	3427.52	111.515	27.046
i/_q	19	3242.15	86.524	19.850

Means Table for F3-50%
Effect: CV environment
Row exclusion: i/_q vs i

Fisher's PLSD for F3-95%

	Mean Diff.	Crit. Diff.	P-Value	
i, i/_q	82.359	69.158	.0210	S

	Count	Mean	Std. Dev.	Std. Err.
i	17	3450.41	83.103	20.155
i/_q	19	3368.05	116.135	26.643

Means Table for F3-95%
Effect: CV environment
Row exclusion: i/_q vs i

Figure 3. 6 Significant Formant Differences: /i/ vs i/_q

Interpretation of the 2 graphs in terms of formant predictions for tongue movement is revealing. Following the assumptions of Borden et al (1994), F2 is commonly seen to reflect the tongue body backing position where a lower F2 represents a farther tongue body retraction. Clearly the /i/ preceding a /q/ is predicted to have a more retracted tongue body than neutral /i/. This is initiated as early as midway through the vowel. Interpretation of F3 must take into account more variables. The 50% measurement shows a value for /i_q/ significantly lower than the /i/ value. This likely reflects a more retracted tongue root position. However, F3 rises for the measurement taken at 95% into the vowel, which is closest to the uvular consonant. Here, it is not clear whether the rising is due to a lessening of the TR retraction, or in fact, as is more likely, a retraction instead in the direction of the uvula.

This general trend of F2 decreasing is consistent with results presented by Bessell (1998b:18) who finds that faucals, or retracted consonants, in Moses-Columbian and Coeur d'Alene exhibit this effect on preceding vowels, though maximum decrease occurred at different temporal points within the vowel production for each language. Partially similar to the Coeur d'Alene pattern, the MTS vowel data presented above illustrates that the /i/ preceding the uvular is maximally lower than a neutral /i/ at the closest point to the uvular consonant, however, significant differences begin well before midway through vowel production. This pattern is slightly different from Moses-Columbian where the vowel transition is gradient and evident at onset, midpoint, and offset rather than entirely an edge effect.

Next, although the average formant values vary between /i/ and /iq/, all the values for /i/ preceding the uvular do not entirely enter the expected range for an [ɪ]. That is, F1 values for both neutral /i/ and i/_q are similar, but F2 and F3 show ranges for i/_q which are in closer to those expected for an [ɪ]. Phonologically, /i/ in MTS is maintained to be transparent to all retraction effects and therefore, there is no [ɪ] present in the language (Bessell 1994, 1998a; Egesdal, 1993). This corroborates with Bessell's (1998) summary of the i/_Q environments in Moses-Columbian and Spokane. She states "Thus, despite evidence for /i/ initially resisting faucal coarticulation, it is not true that i/Q does not shift, or that it does not shift as much as other vowels. It is the timing of the shift which is delayed relative to other vowels, with the result tha the first third of the i/Q is minimally differentiated from i/nonQ" (Bessell, 1998b:23).

To corroborate with these acoustic predictions Figure 3.7 below illustrates tracings of the tongue for the peak advanced gesture made by the /i/ in both above mentioned contexts. The vowel preceding the uvular clearly shows a more retracted tongue root, farther tongue body backing, but an overall higher tongue body.

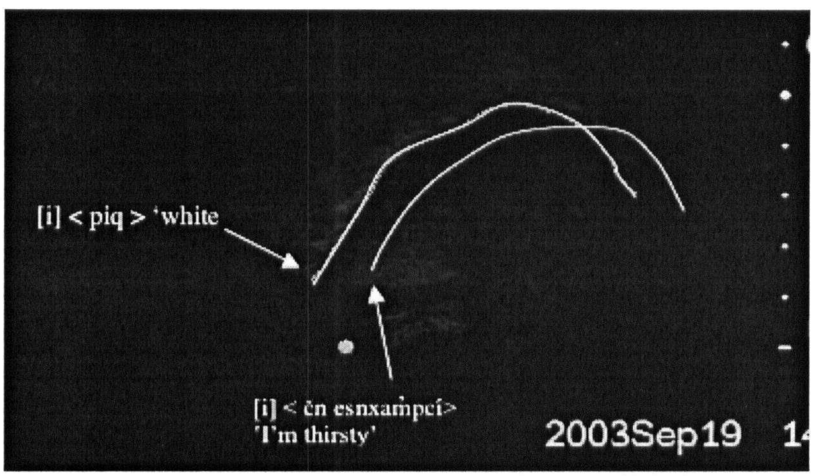


Figure 3. 7 Difference in Tongue Position: [i] versus i/_q

Both acoustic and articulatory evidence substantiate the auditory perception of a high front vowel somewhat in between an [i], and an [ɪ]. This is contrary to phonological predictions of /i/ transparency. However, it is likely that the lag time between the end of voicing of the vowel and the onset of the /q/, which averages around 22ms, covers what would be perceptually the lowest part of the vowel transition.

Next, examination of /i/ following the uvular /q/ yields far more variable results. The gestural conflict between the /q/ and the /i/ is generally resolved through a temporal compromise, resulting in a vowel transition. However, the amount of this transition is extremely variable. For example, according to Thomason's Salish Dictionary files (2000), the lexical suffix =qin 'head' is sometimes pronounced as [qi], and sometimes as

[qei] <qey> (in addition to [q^{ə}n/qən] when the vowel is unstressed). Interestingly, while not from the same morpheme, the uvular-high front vowel sequence *estaqí* /es-taq-i/ (ACT-wave-INTR.CONT.) 'waving at someone' was the sequence in which the pronunciation of the vowel was closest to [i].

The two images below illustrate the /q/ for each word, *estaqí* [ɛstaqí] and *sc̓mqín* [sc̓əmq^{e}ín] and the peak /i/ gesture for each word. It is obvious that both the locus of constriction for the /q/ and the final tongue position for the /i/ vowel is similar for both tokens. However, the length of the vowel /i/ voicing is significantly different for the two tokens and corresponds with the auditory perception of a vowel transition following the /q/ in *sc̓mqín* .

Table 3. 1 Variability of /i/ vowel length

Token	# of repetitions	mean vowel length
[sc̓əmq^{e}ín]	5	195 ms
[ɛstaqí]	3	95 ms

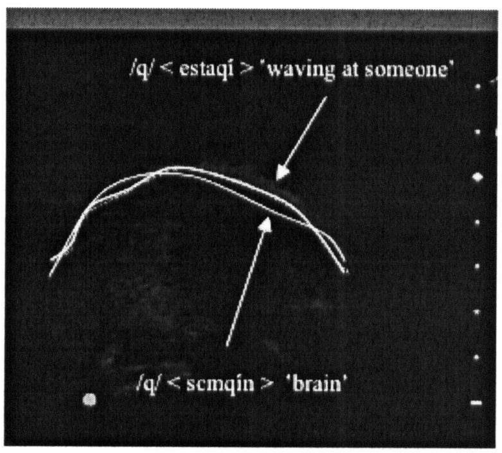


Figure 3. 8a. /q/ contact: sc̓mqín vs. estaqi

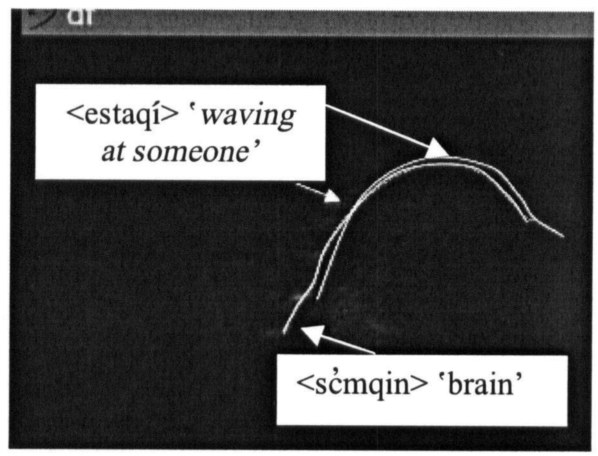
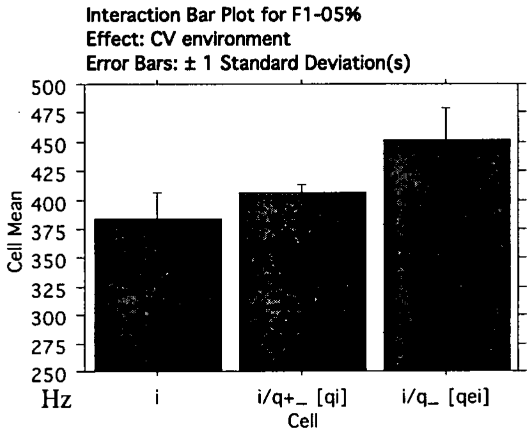


Figure 3. 8b. /i/: sc̓mqín vs. estaqí

The acoustic statistics for i/q _ [qei], i/q+_ [qi], and neutral /i/ are listed below in Figure Set 3.9. Notice that MTS /i/ vowel differences are for the most part resolved by midway through the vowel, though this is variable by token such that i/q+_ [qi] returns to the neutral /i/ value sooner than i/q _ [qei].[4] Furthermore, while both /i/ vowels in the environment following a uvular exhibit a significantly higher F1 at 05% into the vowel with an average of 400 to 450 Hz than as compared with 380Hz for the neutral /i/ vowel, these /i/ values do not reach the average range for the /e/ [ɛ] vowel which lies near 585 Hz.

[4] Because there are only 3 repetitions of the /qi/ [qi] environment, these conclusions merit further validation. However, this comparison serves well to illustrate the variability in all the i/q_ sequences utilized in Montana Salish.



Means Table for F1-05%
Effect: CV environment

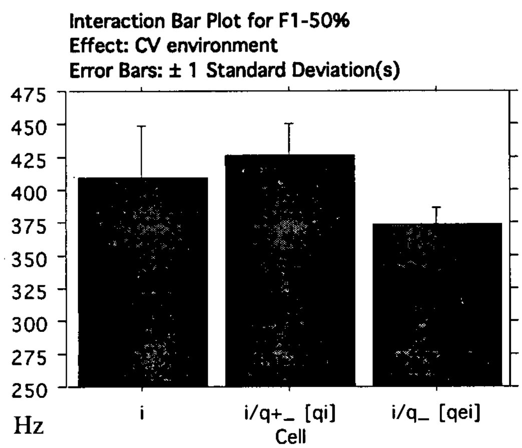
	Count	Mean	Std. Dev.	Std. Err.
i	16	383.875	22.178	5.544
i/q+_ [qi]	3	406.667	7.371	4.256
i/q_ [qei]	11	451.727	27.911	8.415

Fisher's PLSD for F1-05%
Effect: CV environment
Significance Level: 5 %

	Mean Diff.	Crit. Diff.	P-Value	
i, i/q+_ [qi]	-22.792	30.706	.1394	
i, i/q_ [qei]	-67.852	19.116	<.0001	S
i/q+_ [qi], i/q_ [qei]	-45.061	31.789	.0072	S

Figure Set 3. 9 Significant Pairings F1-05% - i/q+_ [qi] vs. i/q _ [qei] vs. /i/

Now consider the vowel measurements taken at midway through the vowel production as illustrated in Figure Set 3.10 below. Here, there are statistically significant differences only between neutral /i/ and the i/q_ [qei] tokens. Notice, unexpectedly, that the bar representing the [qei] sequence illustrates a lower F1 than the average for that of the neutral /i/ vowel. This difference is only ~30 Hz, but in the "wrong" direction such that it seems as though the /i/ in the environment following the uvular ([qei] sequence) has over compensated in tongue body height. Interestingly enough, this corresponds with the image presented previously in Figure 3.8b where the retracted /i/ has a higher tongue body than the non-retracted /i/, though it still maintains a farther back tongue body, dorsum, and root.



Means Table for F1-50%
Effect: CV environment

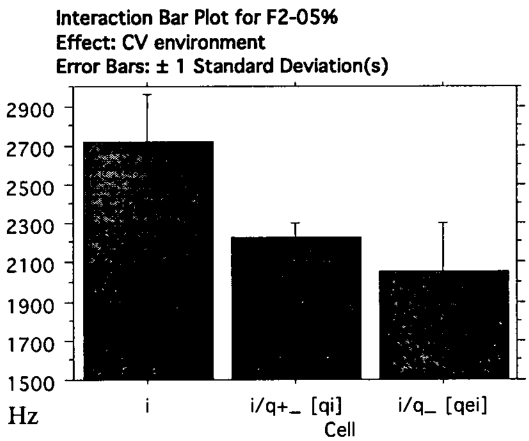
	Count	Mean	Std. Dev.	Std. Err.
i	16	409.500	38.749	9.687
i/q+_ [qi]	3	426.000	23.516	13.577
i/q_ [qei]	11	373.273	12.191	3.676

Fisher's PLSD for F1-50%
Effect: CV environment
Significance Level: 5 %

	Mean Diff.	Crit. Diff.	P-Value	
i, i/q+_ [qi]	-16.500	39.371	.3974	
i, i/q_ [qei]	36.227	24.510	.0053	S
i/q+_ [qi], i/q_ [qei]	52.727	40.759	.0132	S

Figure Set 3. 10 Significant Pairings: F1-50% - i/q+_ [qi] vs. i/q_ [qei] vs. /i/

Now consider the F2 changes for /i/ following a uvular stop. Consistent with other acoustic investigation of i/_q, the second formant for the vowel at onset is considerably lower when following a uvular consonant. However, unlike i/_q, all statistically significant differences are resolved by the vowel midpoint such that there are no significant differences between F2 at 50% into the vowel. The values at onset are presented in Figure Set 3.11 below.



Means Table for F2-05%
Effect: CV environment

	Count	Mean	Std. Dev.	Std. Err.
i	18	2719.944	235.198	55.437
i/q+_ [qi]	3	2228.333	72.831	42.049
i/q_ [qei]	11	2052.182	249.749	75.302

Fisher's PLSD for F2-05%
Effect: CV environment
Significance Level: 5 %

	Mean Diff.	Crit. Diff.	P-Value	
i, i/q+_ [qi]	491.611	297.209	.0021	S
i, i/q_ [qei]	667.763	182.396	<.0001	S
i/q+_ [qi], i/q_ [qei]	176.152	310.425	.2553	

Figure Set 3. 11 Significant Pairings: F2-05% - i/q+_ [qi] vs. i/q_ [qei] vs. /i/

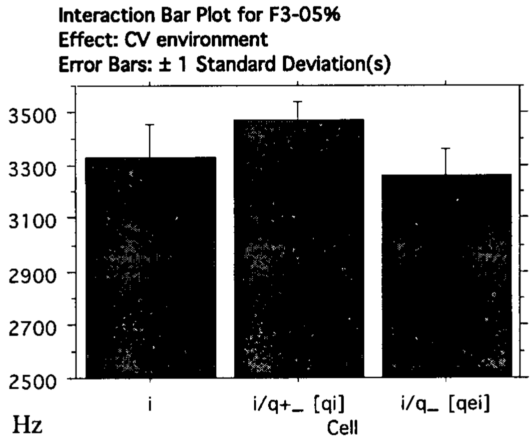
In the Montana Salish measurements, F2 for the /i/ following the uvular environment is 500-650 Hz lower than the average for neutral /i/, which puts the vowel onset near the average values for the /e/ [ɛ] vowel at 2200 Hz. However, results indicate that these F2 discrepancies between the value for neutral /i/ and i/q_ are mediated by 50% into the vowel as there are no statistically significant differences at the vowel midpoint or offset.

The two i/q _ environments in the current Montana Salish data only correspond with the first part of Egesdal's perceptual description which states "At most, there is a transitional on-glide, between uvulars and /i/; Q[ɛe], Q^w[ɔe]. Some speakers, however, show no such on-glide, with a higher vowel [e+] or [i-]; that suggest fronting of uvulars toward velars" (Egesdal 1993:22).[5] As is seen in the graphs for F2 in Figure set 3.11 and Table 3.1 the /i/ following the /q/ is longer in duration and lowers sufficiently to the /e/ [ɛ] vowel range as [$q^{\varepsilon\varepsilon}$i]. However, by midway into the vowel, F2 has returned to near the neutral [i] average. Egesdal's description inaccurately maintains that the /i/ vowel following a uvular only reaches an [e] as its final value.

Last in the acoustic comparison, the significant values for F3 are presented below. F3 does not provide distinguishing information between the either of the i/q _ sequences. Even at vowel onset closest to the uvular consonant, there is no statistically significant difference between the /i/ following the uvular, and the neutral /i/ (as based on a Fishers PLSD analysis). However, there is approximately a 200Hz difference between the two tokens of i/q _ such that F3 is higher for the i/q+_ sequence across a morpheme

[5] That is, no fronting of the uvulars towards velars has been substantiated.

boundary (which is also the more [i]-like sounding i/q_ sequence) indicating less tongue root retraction. This statistically significant difference is mediated by midway through the vowel.



Means Table for F3-05%
Effect: CV environment

	Count	Mean	Std. Dev.	Std. Err.
i	17	3330.765	124.078	30.093
i/q+_ [qi]	3	3473.667	66.252	38.251
i/q_ [qei]	9	3265.111	97.153	32.384

Fisher's PLSD for F3-05%
Effect: CV environment
Significance Level: 5 %

	Mean Diff.	Crit. Diff.	P-Value	
i, i/q+_ [qi]	-142.902	145.153	.0534	
i, i/q_ [qei]	65.654	95.552	.1697	
i/q+_ [qi], i/q_ [qei]	208.556	154.527	.0101	S

Figure Set 3. 12 Significant Pairings: F3-05% - i/q+_ [qi] vs. i/q_ [qei] vs. /i/

As noted, the pronunciation of the /=qin/ lexical morpheme is variable. The Montana Salish Dictionary files list *qín, qéyn, qeyn, qən, qn, qn̓, qéy, qa, q̓éy, qan, q̓éyn̓,* and *qi* as variants. While the cross-morphemic i/q+_ combination analyzed above is represented by only 3 repetitions of one token, taken in combination with the variation within the single lexical morpheme listed above, the hetero-morphemic i/q+_ production supports the generalization that the high vowel in all the i/q_ sequences is variable. Nevertheless, the final output of this vowel is at the offset always reaches the [i] production. This implies that /i/ is the phonological target and no phonologically specified retraction or lowering is taking place. Within this adjacent sequence, this variation in the /i/ production also points toward transition, or temporal compromise, as the chosen method of gestural conflict. This further implies that languages may not necessarily specify the amount of transition required for gestural resolution within each V/_C and V/C_ sequence.

More importantly, as demonstrated above, the uvular to /i/ interactions in Montana Salish conform to the general trend of retracted consonant interactions such that F1 rises, and F2 lowers in the environment preceding or following a retracted consonant. However, recall from Figure Set 3.10 that F1 at midpoint for i/q+_ [qi] surpassed the average for neutral /i/ suggesting a higher tongue body position for i/q+_ [qi]. This was validated by the articulatory results as illustrated in Figure 3.8b. Next, F3 for i/q_ vs. neutral /i/ was not statistically significant, while for i/_q demonstrated statistically significant pairings at both the midpoint and offset (95% into the vowel).

Now that the articulatory and acoustic results have been demonstrated for vowel interaction with a prototypical retracted consonant, these trends can be compared with those produced by the lateral consonants. Furthermore, the retracted TD and TR position of the uvular consonant can now be analyzed in contrast with the position and movement of the Montana Salish laterals.

Chapter 4 Lateral Tongue Movement: Mid-sagittal and Cross-sectional Articulatory Evidence

Now that the complete analysis for the uvular stop has been presented in Chapter 3, the articulatory results based on the mid-sagittal ultrasonic view are presented for the individual lateral consonants. The order begins with the lateral approximant, glottalized lateral approximant, lateral ejective affricate, and lateral fricative. These are in Sections 4.1.1-4.1.4 This mid-sagittal data is then followed in Section 4.2 by the coronal cross-sectional data for each of the laterals. Lastly, in Section 4.3, a joint comparison of the coronal and mid-sagittal articulatory data is presented. This contrasts the medial expansion/ lateral compression visible in the mid-sagittal angle of ultrasound imaging to the vertical and lateral movement visible in the coronal cross-section view.

4.1 Lateral Tongue Position and Movement: Mid-sagittal data

The following section endeavors to establish whether any of the four lateral consonants in Montana Salish are retracted or not. In order to accomplish this objectively, the articulatory images relevant to each of the four laterals are compared and contrasted to a proto-typical retracted consonant, represented through the uvular data presented in the previous section, and also to interspeech rest position. The comparison with the /q/ tongue positioning represents the descriptive terms of "uvularization" and establishes a benchmark of retraction as modeled by the uvular consonants. The comparison with interspeech rest has been chosen based on previous work by Gick et al. (submitted) who posit that inter utterance rest position is a language specific articulatory target. As demonstrated in Chapter 2, interspeech rest represents a tongue position which is medial within the vowel inventory at the initial TR measurement (#1) and also measurement (#2).

Section 4.1.1 Lateral approximant

The articulatory and acoustic properties of the lateral approximant, and indeed all the laterals in Montana Salish, are little described. However, Flemming et al. (1994) make one relevant descriptive comment on the lateral approximant and lateral fricative in Montana Salish. They state "The laterals /l/ and /l̓/ are pre-stopped in most environments by most speakers. Depending on its context it is realized as a voiced [ᵈl] or fricated [ᵈɬ] or [ᵈɮ] . When fricated, it can be phonetically similar to /ɬ/" (Flemming et al. 1994:7). This is consistent with the current study's findings. While not all productions of /l/ in other languages use full contact with the alveolar ridge (Scobie, p.c. 2004), because the Montana Salish /l/ is pre-stopped, contact is obligatory, thus giving a precise landmark for analysis of /l/ movement that is important in understanding the physical movement involved.

To orient the articulatory investigation on the lateral consonants, the image below illustrates the retracted tongue movement through the /l/'s initial and final position in the name Lamús. The blue line is the initial position and the (dotted) tan line is the final position. The bottom (yellow) tracing is an overlay of interspeech rest.

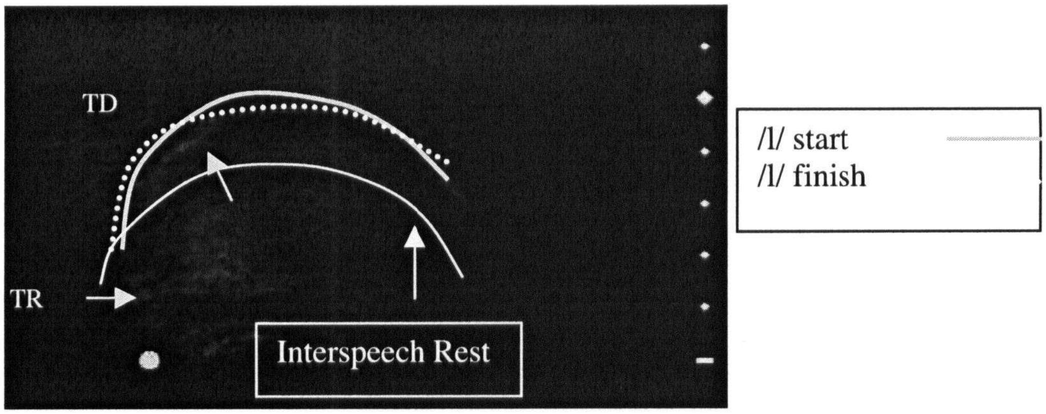


Figure 4. 1 Tongue initial and final position for /l/ in Lamús

Notice that there seems to be minimal retraction of the tongue root in the tracing above. The TB flattens slightly and the TD is pushed slightly back. However, note that the initiation of the tongue movement from interspeech rest requires that the TR advance, but the TD both raise and retract. The arrows on the above image indicate the direction of movement which occurs from the initiation of interspeech rest into the production of the word initial.

It is possible that during its production, the /l/ simply moves directly into the back /a/ which masks any retracted motion of its own. To make sure that there is not an inherent retraction movement which is masked by the following back position for the /a/ vowel, Figure 4.2 below shows the /l/ position in the word *líḱ*^{w}*lɛx*^{w} 'prairie, bare land'. The following comparison is a temporal illustration of the /l/ movement in the sequence /li/. Here tongue movement for the /l/ is clearly distinguishable. It is located between two non-retracted tongue positions; interspeech rest and the /i/ preceding the velar [ḱ^{w}]. The tongue position is initiated from a non-retracted interspeech rest and ends in a non retracted [i].

The images below are still frames extracted from the running video at every 33ms interval from the [li] sequence within the word *líḱ*^{w}*lɛx*^{w}. The labeled frame numbers indicate the continuation of voicing for the particular segment. Compare frame 2 to frame 5, which represent the initiation and end of the /l/ production. Note that the tongue root retraction is minimal for the /l/, especially in relation to the /i/ tongue root position. However, the flattening of the tongue body and the movement of the tongue dorsum towards the uvular area is very visible in the /l/ production.

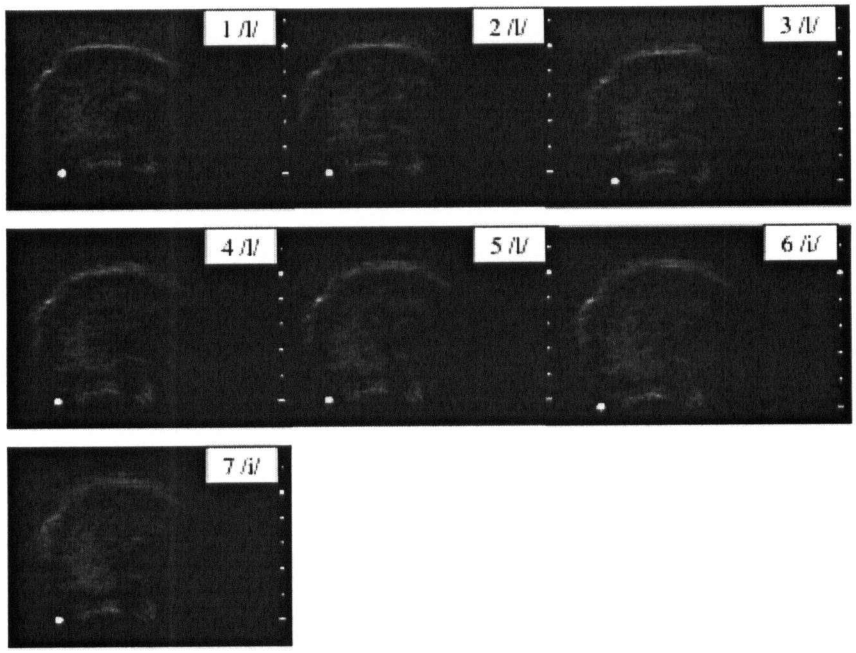


Figure 4. 2 Frame sequence at 33ms intervals for /li/ in *lík̓ʷlɛxʷ*

To establish the presence of retraction in the plain lateral approximant the next test is an objective comparison of the lateral approximant to interspeech rest. This is especially important because image overlays represent a single token as opposed to the temporal diagram presented above. The following comparison represents the measured positions along the tongue surface (as described in Chapter 2) averaged over numerous tokens and examples. In order to differentiate the possibility of co-articulatory effects, l/_i sequences have been distinguished from l/_a. Further elimination of confounding variables calls for additional differentiation within the l/_i sequences such that two subsets are differentiated: l/a_i and l/_i where any non back vowel or post-velar consonant can precede the /l/. These are each plotted against interspeech rest for the 5 measurement points along the tongue.

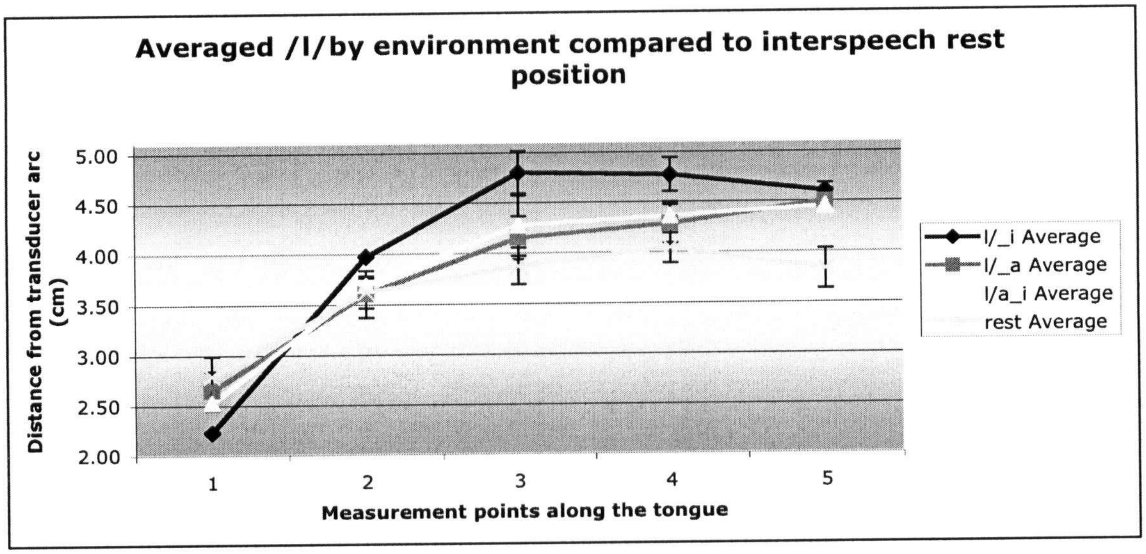


Figure 4. 3 /l/ separated by vowel environment vs. interspeech rest tongue position

The above graph compares the tongue position of /l/ in different environments to interspeech rest. For measurement #1 at the tongue root, there are statistically significant differences between all positions (l/_i to rest, l/_a to rest, l/a_i to rest, l/a_i to l/_i, l/_i to l/_a etc.) except l/a_i to l/_a. All /l/ sequences are less retracted at the TR than interspeech rest. Furthermore, since the l/a_i sequence is more retracted than the l/_i sequence it seems that the /a/ pulls the TR back despite of the high front vowel following the /l/. At measurement #2 (2cm up from the TR), the tongue position as compared to rest is reversed. Each of the laterals is more retracted than rest. This represents the lower TD area of the tongue. All pairings (l/_i to rest, l/_a to rest, l/a_i to l/_a, l/a_i to l/_i, l/_i to l/_a etc.) are statistically significant except l/a_i to rest. Similarly, at measurement #3 (4 cm up from the TR), all are significant except l/_a to rest. Note that, except for TT position (#5), all pairings with l/_i are significant.

As seen in the TR measurement (#1), all the /l/ positions are less retracted than interspeech rest position. However, the general trend at the second measurement, is that interspeech rest is now less retracted than the laterals. The same is true for the rest of the measurements. The two measurements which are closest to reflecting the TD position (#2 and #3), indicate that all the /l/ contexts have a greater protrusion at the TD area than does interspeech rest. The tables below list the significant differences between the above graphed points.

Table 4. 1 1-5 /l/ position statistics by vowel environment

Fisher's PLSD for TR (point 1)
Effect: CV context
Significance Level: 5 %

1

	Mean Diff.	Crit. Diff.	P-Value	
l/a_i, l/_a	-.080	.211	.4458	
l/a_i, l/_i	.318	.228	.0076	S
l/a_i, rest	-.264	.179	.0050	S
l/_a, l/_i	.398	.211	.0005	S
l/_a, rest	-.184	.157	.0229	S
l/_i, rest	-.582	.179	<.0001	S

Fisher's PLSD for TR-2cm (point 2)
Effect: CV context
Significance Level: 5 %

2

	Mean Diff.	Crit. Diff.	P-Value	
l/a_i, l/_a	.095	.219	.3830	
l/a_i, l/_i	-.266	.237	.0289	S
l/a_i, rest	.071	.186	.4465	
l/_a, l/_i	-.361	.219	.0020	S
l/_a, rest	-.025	.164	.7602	
l/_i, rest	.337	.186	.0008	S

Fisher's PLSD for TR-4cm (point 3)
Effect: CV context
Significance Level: 5 %

3

	Mean Diff.	Crit. Diff.	P-Value	
l/a_i, l/_a	.129	.212	.2271	
l/a_i, l/_i	-.482	.263	.0006	S
l/a_i, rest	.398	.207	.0004	S
l/_a, l/_i	-.611	.212	<.0001	S
l/_a, rest	.269	.136	.0002	S
l/_i, rest	.880	.207	<.0001	S

Fisher's PLSD for TR-6cm (point 4)
Effect: CV context
Significance Level: 5 %

4

	Mean Diff.	Crit. Diff.	P-Value	
l/a_i, l/_a	.084	.175	.3378	
l/a_i, l/_i	-.388	.216	.0008	S
l/a_i, rest	.318	.170	.0005	S
l/_a, l/_i	-.472	.175	<.0001	S
l/_a, rest	.233	.114	.0002	S
l/_i, rest	.706	.170	<.0001	S

Fisher's PLSD for TT (point 5)
Effect: CV context
Significance Level: 5 %

5

	Mean Diff.	Crit. Diff.	P-Value	
l/a_i, l/_a	-.055	.168	.5100	
l/a_i, l/_i	-.180	.206	.0849	
l/a_i, rest	.618	.162	<.0001	S
l/_a, l/_i	-.125	.168	.1419	
l/_a, rest	.674	.110	<.0001	S
l/_i, rest	.798	.162	<.0001	S

Since it has been demonstrated that the /l/ position is less retracted at the TR but more retracted at the TD than interspeech rest, an additional comparison to the uvular is necessary. In the previous literature, retraction has been termed as either "uvularization" or "pharyngealization" (Bessell 1998a; Doak 1992; Egesdal 1993; Johnson 1975; Shahin 2002) with TD generally considered the primary retraction locus for the first, and TR for the second. The following image compares the uvular position to the lateral approximant. There are two significant observations here. First, one sees an almost identical locus of TD retraction in the uvular area between an /l/ and the /q/. Second, this TD retraction is *not* coupled with a TR retraction for the lateral /l/ whereas there *is* TR retraction for the /q/. A tracing illustrating this is presented in Figure 4.4 below.

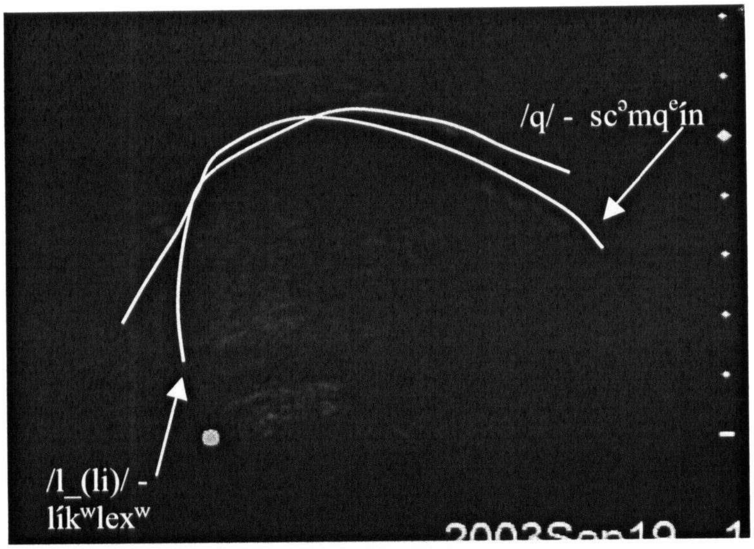


Figure 4. 4 Tongue position for /q/ vs. /l/ preceding /i/

The important focus of attention on Figure 4.4 above is not only the similar TD position between the two consonants, but also the distinctly different TR positions. The TR for the /q/ is both higher and back farther than that of the /l/ production. The /l/ production is neither "pharyngealized" nor quite "uvularized" as there is no TR movement, but instead is a retracted movement of its own which occurs without a secondary retraction movement. Since the lateral approximant exhibits a TD peak in the same area as the /q/, but does not have the same TT and TR position, it implies that there will be less retracted acoustic effects on adjacent vowels than the uvular.

As the evidence presented above has shown, the plain lateral approximant includes a retracted component to its production. Unlike some of the other laterals (still to be discussed), the inherent retracted /l/ movement is quite minimal. However, even without a large, dynamic movement of retraction, the overall target position of the /l/ is such that it provides enough gestural conflict for a transitional resolution to be necessary with certain vowels. Furthermore, it is important to highlight that the primary retracted component for the /l/ is the tongue dorsum and not the tongue root.

Section 4.1.2 Glottalized Lateral approximant

Figure 4.5 below shows the general tongue positioning difference for the high front vowel as opposed to the /l̓/. Figure 4.10 shows the position of the /l̓/ vs. the /q/. Similar to the plain lateral approximant, the glottalized /l̓/ exhibits both a general TB flattening and a distinct TD movement backward. The following image shows the /i/ and the following /l̓/ from the VC sequence in the word *i šil̓s* 'it settled'. Notice first that the peak in the tongue is in the direction of the posterior uvular region by the tongue dorsum, and second, that the /l̓/ TB height is not yet significantly lowered as it is still coming down from the higher TB position for the /i/. Also notice, similar to the plain lateral approximant, that the TR position for the /l̓/ is not very retracted.

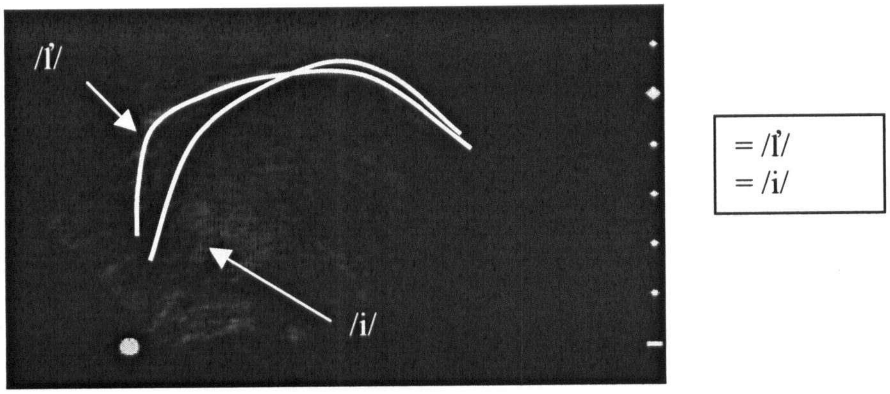


Figure 4. 5 /l/ vs. /i/ in i šiľs 'it settled'

Next, examination of the /ľ/ movement over time reveals an unambiguous retracted movement of the tongue. The following /ľľa/ sequence in Figure 4.6 is from the word *ľľac* 'red raspberry'.[1] Frames 1-3 show the entire TB lowering and flattening. Between frames 4, 5 and 6, there is a solitary TD movement back while the TR stays in place, and also between 5 and 6 the TT releases contact with the alveolar ridge. Frames 7 and 8 show a small TD rising. Frames 10 - 11 are the pause in the voicing between the articulations of the two glottalized lateral approximates, during which, the front TB and TT rises to contact the alveolar ridge. Note that the tongue root holds its position throughout this entire articulation until the initiation of the second lateral, at which point, it begins retracting to meet the targeted back position of the /a/ vowel. The major retraction movement for the /ľ/ is located at the tongue dorsum.

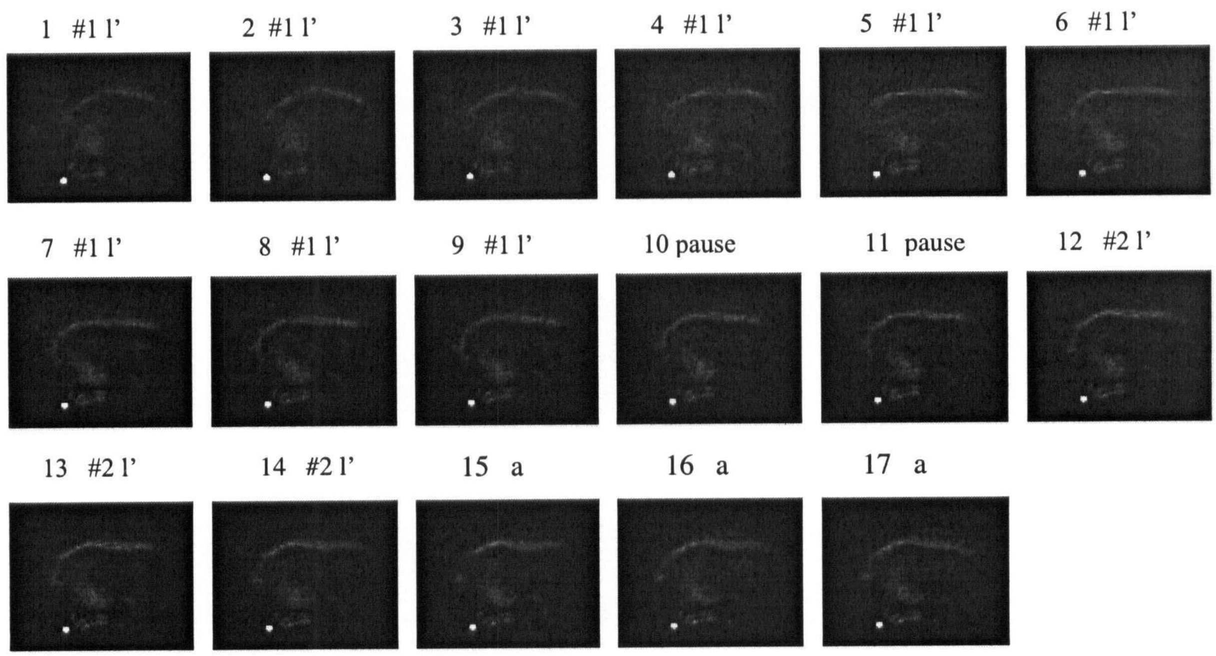


Figure 4. 6 Frame by frame sequence of ľľac 'red raspberry'

[1] Some additional repetitions were produced with a plain, not glottalized second /l/.

A summary of this retracted TD movement is illustrated in Figure 4.7 below. Tongue tracings of the first /l̓/ in the sequence (labeled above as #1 l̓) are taken at 2 frames, the initial /l̓/ production, and the final retracted tongue position for the same segment. These clearly illustrate the differentiation between TR and TD movement such that there is a minimal change in TR position, but a distinct TD movement.

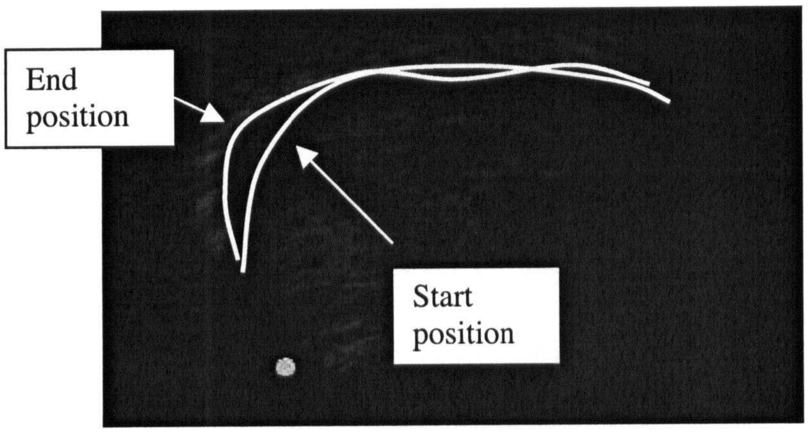


Figure 4. 7 Example of initial /l̓/ TD retraction: *l̓l̓ac*

The TD movement in the plain lateral approximant tracings and also the second glottalized lateral approximant is considerably less than the movement shown by the initial /l̓/ in the image above. It is possible that the variability in the trough of the tongue body, and thus the simultaneous tongue dorsum retraction, is a reflection of the amount of pressure on the transducer such that greater pressure is applied by the tongue muscles for the syllabic production of /l̓/ as opposed to the non-syllabic version.[2] If this is true, the difference between the first and second glottalized lateral in *l̓l̓ac*, as well as the difference between the plain /l/ and glottalized /l̓/ tongue positioning would then be a factor of the independent nature of the initial /l̓/, rather than a feature of its own.[3] That is, pressure (on the transducer) intensifies the more defined the consonant gesture, and this more dramatic movement is more commonly used during independent production.[4] This explanation is consistent with the difference in /l̓/ positioning represented by the /l̓/ in Figure 4.7 and the /l̓/ tongue position in Figure 4.9. The /l̓/ in the independent pronunciation exhibits a much more defined and clear movement.[5]

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[2] This line of thought is credited to M. Stone (p.c. 2004).

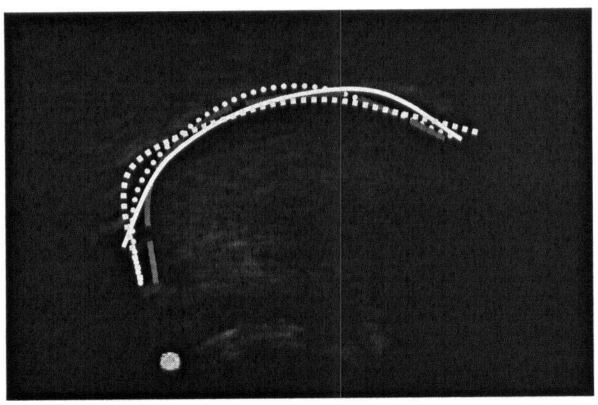
[3] In order to avoid unintended claims on a template of syllable structure, this type of l̓/_{C or #} is henceforth labeled as "independent".

[4] It is also worth noting that the initial /l̓/ in the first two repetitions of l̓l̓ac (out of five) was produced with the pre-stopping, and this is where the retracted gesture was most visible. The following three repetitions were not pre-stopped, had a less distinct motion, and also one of these was not pre-glottalized.

[5] For lack of additional tokens, the summed averages for the /l/ data does not include any syllabic productions of /l/, while the summed data for the /l̓/ does. However, comparisons within the /l̓/ data are separated in order to distinguish which results might be from the /l̓/ and which are possibly enhanced because of syllabic production. Because the non-syllabic /l̓/ production still exhibits TD retraction, it is considered a retracted consonant.

To investigate the possibility that the retraction is a factor of the independent nature of the consonant, a comparison was made between the independent-like /l̓/s in [k̓ʷúˀl̓] 'labor, work', and [ɛsk̓ʷúˀl̓l̓i] 'it is being born', and the non-independent /l̓/ and /l̓/ in [pᵊl̓í(p)] 'it drifted away', and [smúˀl̓ᵊmən] 'spear, war lance' (respectively).[6] [k̓ʷúˀl̓], [ɛsk̓ʷúˀl̠̓l̓i], and [l̠̓l̓ac] are additionally grouped by their similarity in position: l̓/_{C or #}, where as both the /l̓/s in [smúˀl̓ᵊmən] and [pᵊl̓í(p)] are released into a vowel.

Figure 4.8 below shows tracings of all four /l̓/s at their peak retracted movement from [k̓ʷúˀl̓], [ɛsk̓ʷúˀl̓l̓i], [pᵊl̓í(p)] and [smúˀl̓ᵊmən]. In general, their positions are very similar except for the tracing for the first /l̓/ in *esk̓ʷúl̓l̓i*, which has a greater protrusion backward at the tongue dorsum area. The real-time film of this token portrays a clear retracted movement back for the independent /l̓/ where the TD retracts and the TB flattens. The movement for *k̓ʷúl̓* is the same, though less dramatic. The /l̓/ in *pᵊl̓í(p)* shows no movement back, but this could be a function of its initiation from near schwa position which has a more retracted TR and TD position than the /u/ in *esk̓ʷúl̓l̓i* and *k̓ʷúl̓*. There is also no flattening of the TB for *pᵊl̓íp*. The word *smúl̓mn* illustrates an /l̓/ posture, but does not exert enough distinctiveness to produce a trough (i.e. no TB flattening and no TD retraction at all).



esk̓ʷúˀl̠̓l̓i	··········
pəl̠̓í(p)	――――
k̓ʷúˀl̠̓	‐‐‐‐‐‐‐‐
smúl̠̓mn	— — — -

Figure 4. 8 Independent vs. non-independent /l̓/

Graphically, it seems that the independent productions of /l̓/ exemplify a greater retracted movement, but quantification of these comparisons must be made in order for this claim to be conclusive. To quantify these descriptions, Figure 4.9 below shows the plotted pairings between the independent /l̓/ and non-independent /l̓/ and rest. Only measurements #1 and #2 showed statistically significant differences between the two sets of /l̓/s. All other points of measurement were not statistically significant. (For a list of all statistics for the following comparison, see Appendix B.)

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[6] These tokens were chosen singularly based on their availability. The lateral in pəl̓í(p) was produced with some voiced frication. It seems that anytime there is lateral frication, the /l/ gesture is not as distinct. However, it is as of yet still unclear when frication (voiced or voiceless) is used and when it is not.

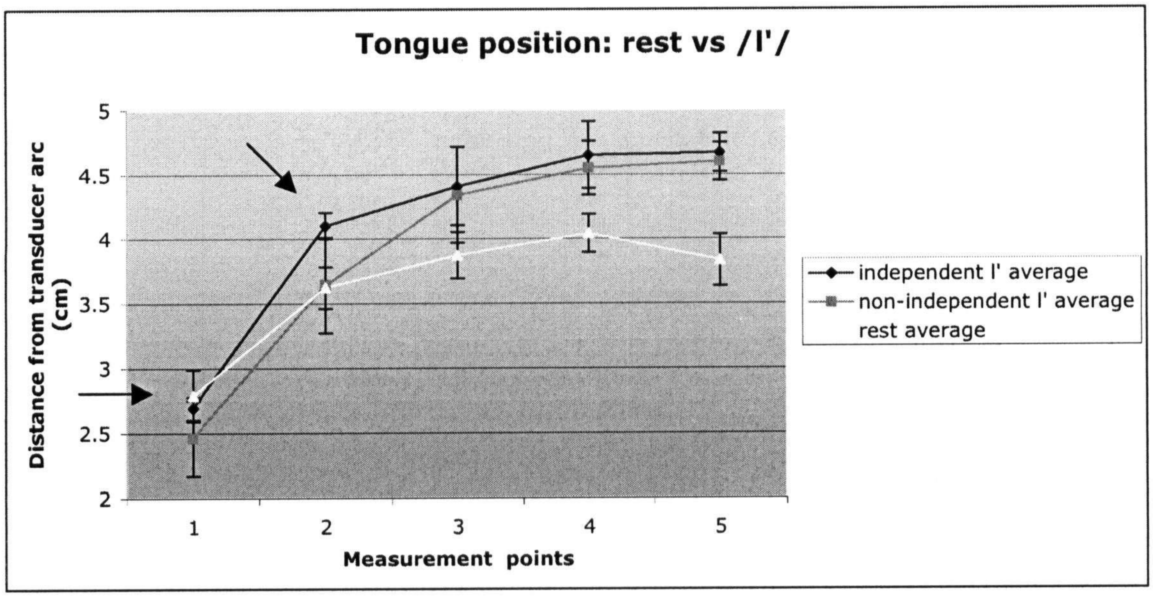

Figure 4. 9 Independent and non-independent /l̓/ vs. rest

As the graph in Figure 4.9 illustrates, interspeech rest position begins with the most retracted tongue root at measurement (#1), but quickly reverses position by the second measurement for both glottalized /l̓/s. The difference at these two measurement points is statistically significant. (See Appendix B for a list of statistics for this comparison). As expected from a "rest" position, interspeech rest continues with lower tongue body and tongue tip (measurements #4 and #5). While it seems that overall tongue root position for both glottalized laterals is less retracted than rest, the tongue position at the tongue dorsum is more retracted for the laterals than rest. Again, this underscores the importance of treating tongue root and tongue dorsum retraction separately. This movement is most visible in the independent pronunciation, but is also inherent in the plain productions.

It seems clear that when a glottalized lateral approximate is independent, the amount of retraction is greatly magnified. While no examples of independent plain lateral approximate were available in this study, it is predicted that this same pattern will hold as well for those consonants as well since it is a function of the phonetic production, and not a phonological specification. Regardless, the overall /l̓/ position and movement seems to be that of a retracted segment, with the caveat being that this is variable by vowel context and independent or non-independent nature.

Lastly, from the above discussion, it is apparent that the glottalized lateral utilizes a clear movement by the tongue dorsum. If the retraction of this consonant patterns with its non-glottalized counterpart, the direction of this movement should be similar. The following tongue tracing represents a comparison with the uvular stop. Here, notice that the retraction is in a slightly different area than that of the plain lateral approximant. However, a similar trend is visible with the TD being the main locus of retraction, and the TR not being as predominant.

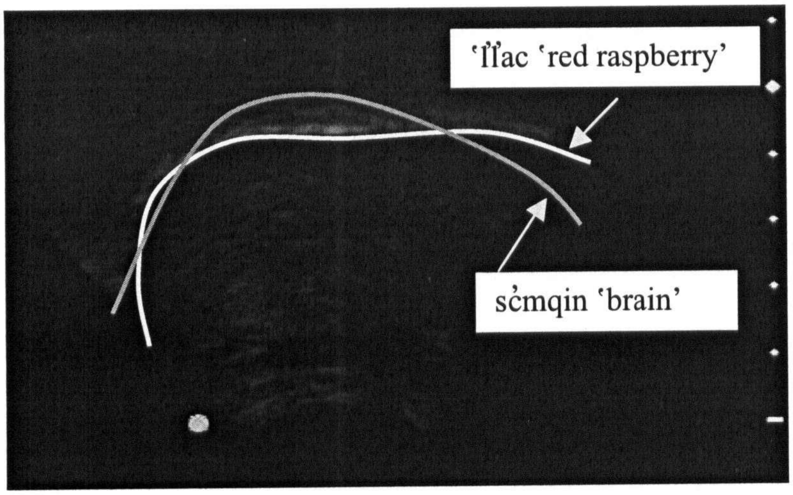

Figure 4. 10 Tracings of /q/ vs. /l̓/ at peak retracted movement

The articulatory data presented above demonstrate the retraction movement inherent in the Montana Salish productions of the glottalized lateral approximant. Similar to its plain counterpart, this lateral uses a primary retraction in the area of the TD and no retraction by the TR. Furthermore, a generalization which has fallen out from the available data, is that retraction, as a function of the physical movement, is greatly enhanced by the independent nature of the consonant. Independent pronunciation seems to be coupled with enhanced tongue movements, and for the /l̓/, this is shown by an exhibition of greater TD retraction.

Section 4.1.3 Lateral Fricative

The next lateral consonant under investigation is the lateral fricative. To visually situate the position of the lateral fricative within the oral cavity, the Figure 4.11 presents tracings of the /ɬ/ overlaid with tracings of interspeech rest and the /i/ vowel. The /i/ and lateral fricative are taken from the same sequence /iɬ_#/ from the word *miɬ* 'too'. The compiled image shows two overlaid images of the tongue with tongue edge tracings. The first, and darker, inner line is taken from the peak advanced movement of tongue for the vowel /i/, while the outer line, shows the peak movement back made by the lateral fricative. The gesture following the fricative production then preceded forward again to make the closure for the /č/ in the phrase *Miɬ čta ɬu Malí* 'Mary is too skinny'. When the /iɬ/ sequence is followed by a consonant or vowel (or rest) gesture, which is more retracted than the /ɬ/, the tongue motion for the /ɬ/ simply continues back.

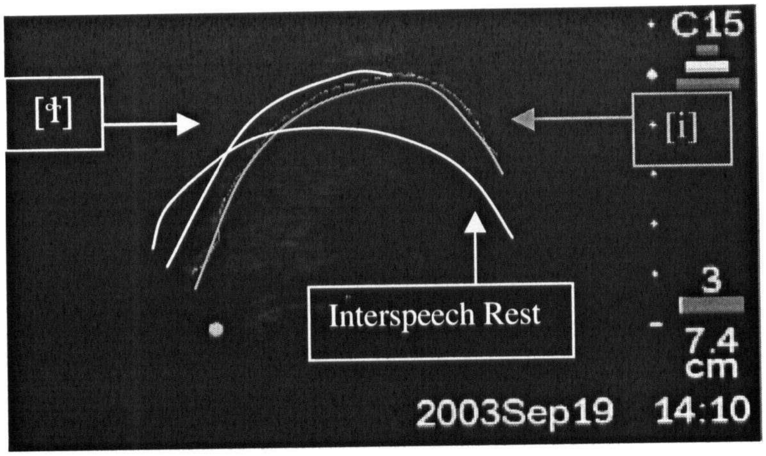

Figure 4. 11 Tongue tracings for /i/ and /ɬ/ in <miɬ> vs. interspeech rest position

Notice that at the tongue root, the /ɬ/ production is almost half way in between the tongue position for the /i/ and the tongue position for interspeech rest. However, at the TD area, the /ɬ/ holds its shape, while interspeech rest lowers. In this tracing, there is no distinct TD retraction evident.

Because the /ɬ/ tongue position does not reach the interspeech rest position at the TD or TR position, it also will not reach the back tongue shape for the uvular consonants. However, to keep the comparisons standard across all the laterals, the following image is provided in order to illustrate the different positions of these two consonants. The tongue tracings are taken from the /q/ in *estaqí* 'waving at someone' and the /ɬ/ in *ɬkʷɬakʷɬs* 'slapping noise of wet moccasins'.

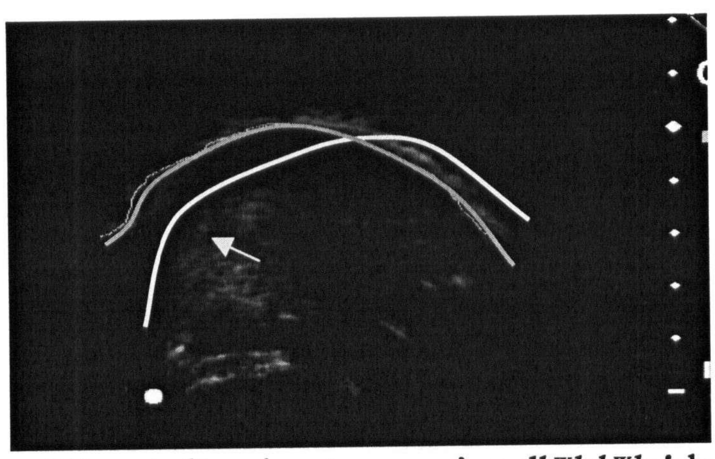

Figure 4. 12 /q/ vs. /ɬ/ in *estaqí* 'waving at someone' vs. *ɬkʷɬakʷɬs* 'slapping noise of wet moccasins'

Notice the advanced TR and high TB for the lateral fricative. Also, note the small curve at the lower TD area on the lateral fricative. This slight peak is somewhat reminiscent of the dorsal movement for the glottalized lateral approximant and the plain lateral approximant. However, this small TD curve is not always visible in all the /ɬ/ examples, and the amount is extremely variable.

All differences shown in the above illustrations are statistically significant for each of the measurement locations, which represent TR, and TD location. Most importantly, it is clear from the data presented above, that despite the variable TD peak shown in Figure 4.12, the lateral fricative has a target tongue position that does not include an inherent retracted movement in the same capacity as the previously discussed lateral approximants. That is, unlike the /l/ and /l̓/, the fricative does not conclusively demonstrate a retracted TD or TR movement. However, as the tongue tracings have shown, there does seem to be a slight TD curve which is reminiscent of the TD movement of the glottalized lateral approximant.

Section 4.1.4 Lateral Ejective Affricate

The last of the four Montana Salish laterals to be investigated is the lateral ejective affricate. Since this sound is phonetically a combination of the [t̓] and the [ɬ] phonemes, it is predicted to pattern with the tongue position for the lateral fricative. However, if the components are instead [t̓] and [l], then the tongue position should pattern with that of the lateral approximant. However, as the articulatory data presented below illustrates, neither is the case.

Instead, the lateral ejective affricate provides us with a very clear example of a retracted movement of the tongue different from any of the previously discussed laterals. Articulatory images reveal both tongue root and tongue dorsum retraction upon release of the glottal closure.[7] This retracted movement is shown in Figure 4.13 where the inner tracing represents the tongue at the initiation of the /ƛ̓/ (at the time of TT constriction at the alveolar ridge), and the outer line, the peak back movement after the /ƛ̓/ release. Since the release is both lateral and towards the back of the oral cavity, the tongue anterior position does not necessarily change. Note the distinction in the locus of tongue retraction as compared with the image for the /l/, /l̓/, and /ɬ/ above. Here the TR is retracting back and 'up', with the attached TD accompanying this massive TR movement. Recall that all previous lateral retraction has been only in the locus of the tongue dorsum.

[7] That is, at the time of ejection, since all lateral affricates are always released.

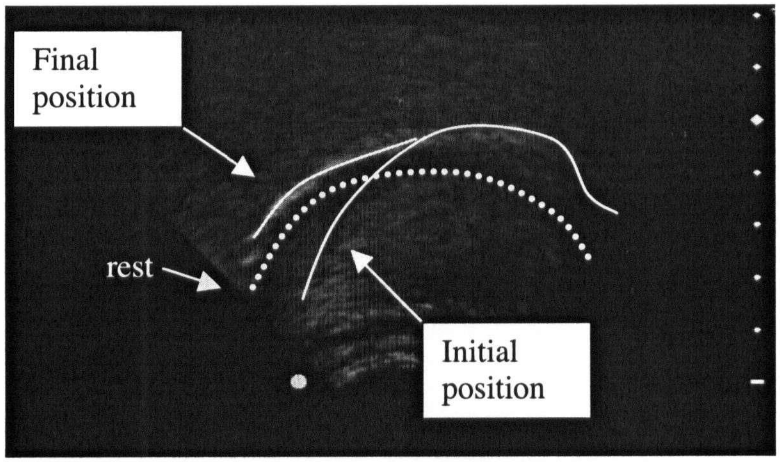

Figure 4 .13 <kʷiƛ̓t> /ƛ̓/ initial position vs. final position

To exemplify the amount and direction of retraction, the following image (Figure 4.14) shows overlaid tracings of the tongue for a uvular consonant upon contact with the oral cavity and the lateral ejective affricate at both tongue tip contact and ejective release.[8] The motion demonstrated here is a retraction both in the tongue dorsum area and the tongue root area with larger movement being in the latter. The final position for the /ƛ̓/ is similar to the /q/ in that both TD and TR have been retracted.

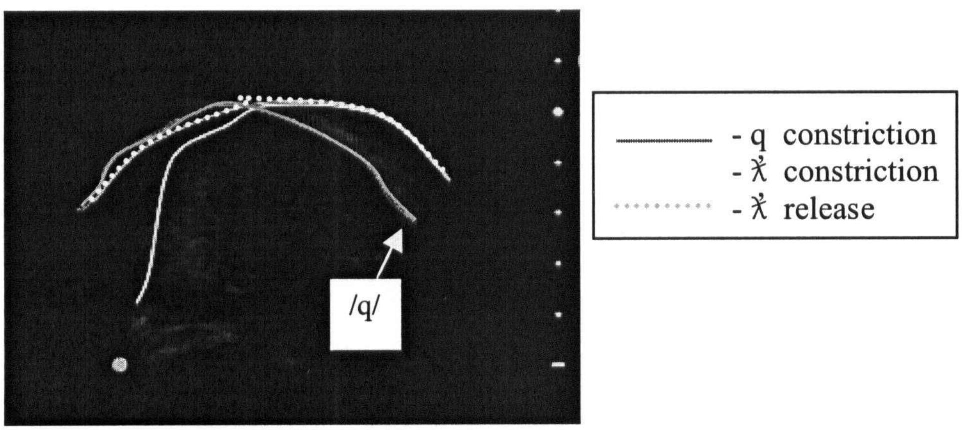

Figure 4. 14 /ƛ̓/ initial and final position vs. /q/

Despite the retracted movement of the TR into the pharynx, this consonant cannot be phonologically categorized with the pharyngeals. In addition to the distinction made by the lateral movement involved in the /ƛ̓/, its distributional patterns and phonological restrictions with respect to the vowels, as presented in Chapter 2, do not show any similarity to the class of pharyngeals.

This next discussion illuminates an additional component of the lateral ejective affricate's release. The following image (Figure 4.15) represents tongue tracings from the second non-ejective lateral affricate in the word *inƛ̓ƛ̓ƛ̓í* [inƛƛƛ̓í] whereby (as a result of a phonological process of de-glottalization) only the last lateral affricate in a sequence

[8] Frames are extracted from <estaqí> and < čn púƛ̓>.

is glottalized, though all are released.[9] It is obvious in the real-time film, and is visually represented here, that the lateral affricate release is primarily a function of the tongue dorsum. The tongue body flattens very slightly, and the tongue dorsum protrudes directly back, with the tongue root following by nature of being attached, rather than as a separate or distinct movement.

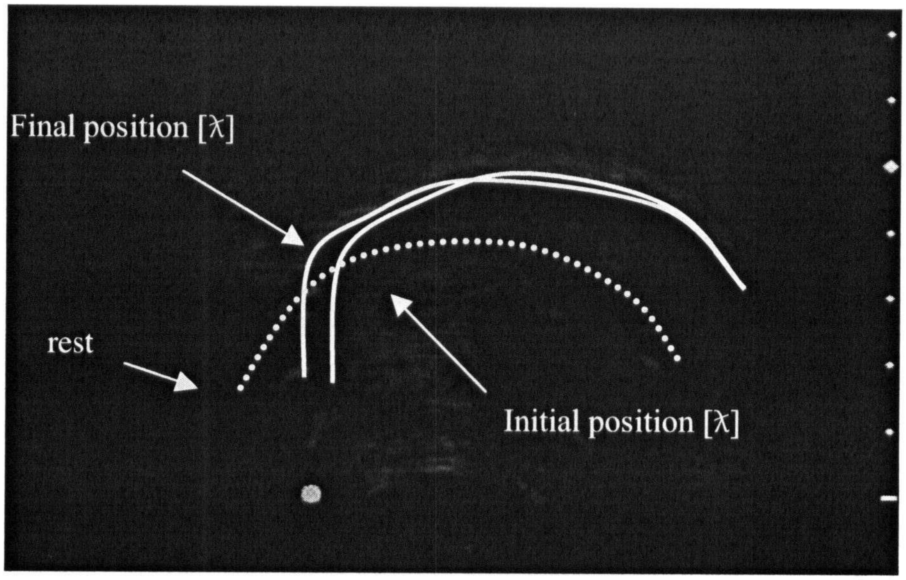

Figure 4. 15 Lateral Affricate Tongue Dorsum Release

As seen in the above figures, the lateral ejective affricate demonstrates a clear case of tongue root retraction. However, when viewed independent of the ejective release, the [ƛ] also exhibits retraction specifically in the locus of the TD. Nevertheless, during the [ƛ̓] release, the TR movement is primary. The retraction demonstrated here is unique among the laterals. Notice both the initial and final position as compared to interspeech rest. The TR is much less retracted than interspeech rest, while the TD illustrates a small, but distinct retracted peak.

It is probable that there is a biomechanical explanation for the extreme tongue root retraction of the lateral ejective affricate which would also clarify why this is not a function of the ejectives in general. Motivation for this claim is supported by additional literature on other non-lateral segments. For !Xoo clicks, Traill (1985) notes that there is a TD retraction which occurs after the release of the posterior constriction. More recently, Miller-Ockhuizen (2004) describes a TD/TR retraction gesture in the [!] which occurs the release of the click in the Khoekhoe language. Similarly, Thomason (p.c. 2004) notes that there is one historical reference to a non-post-velar ejective influencing adjacent vowels differently than its non-ejective counterpart. She cites Mengarini (1877-79) who writes <ko> for words which are [k̓ʷ]u but <ku> for [kʷ]u.

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[9] The only time the non-ejective lateral affricate is found in Montana Salish is as a result of this phonological deglottalization process. It does not exist independent of this process, which, in addition, is applicable to all sequences of stops and affricates, not just the lateral ejective affricate.

In Montana Salish, among the laterals, this dramatic retracted TR movement is unique to the /ƛ̓/ and only takes place when the consonant is ejected. During the release of the ejective, which occurs while the TT is still maintaining contact with the alveolar ridge, and the sides of the tongue are shooting down, the tongue root (or, variably the entire posterior region of the tongue) is forced backward. Contact in the front of the mouth by the TT is coupled with the requirement that the large amount of displaced tongue volume move somewhere and these joint stipulations result in a dramatic tongue movement back.

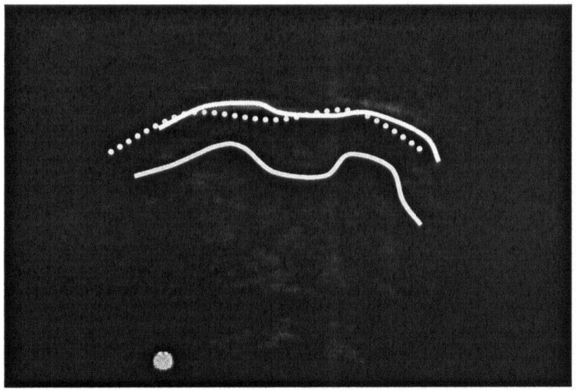
Thus, the common thread between these clicks, the lateral ejective affricate, and the labialized velar ejective, lies in the large volume of tongue that is displaced with a dramatic, and ballistic tongue movement.[10] Ejectives, which do not require large amounts of tongue volume displacement, are not predicted to exhibit any retracted movement of the tongue. The observation for Montana Salish that the [t] and [t̓] do not utilize any TR or TD retraction supports this hypothesis.[11]

4.2 Lateral Tongue Position and Movement: Coronal Cross-section data

In another approach to viewing Montana Salish laterals, coronal cross-section data was collected and examined. Since mid-sagittal imaging of the tongue only reveals the front to back motion of the tongue and the nature of a lateral consonant is its release to the sides, discussion of the movement from the view of a coronal cross section is merited to facilitate full understanding. The following images illustrate the lateral movement for three of the four lateral consonants; lateral approximant, lateral ejective affricate, and lateral fricative. No data was available for the glottalized lateral approximant, but it is hypothesized to pattern similarly to the plain lateral approximant.

The following Figure 4.16 is a coronal cross-section tracing of a plain lateral in the sequence [la]. Notice the deep groove along the centerline of the tongue during the final production of the /l/. Here the sides of the tongue have risen to form peaks on either side.[12] Subsequently, the entire tongue body returns to near the initial /l/ position during the production of the /a/ vowel. The movement is not only in the raising or lowering of the sides of the tongue, but in the overall lowering and raising of the tongue, while maintaining the groove along the tongue centerline.

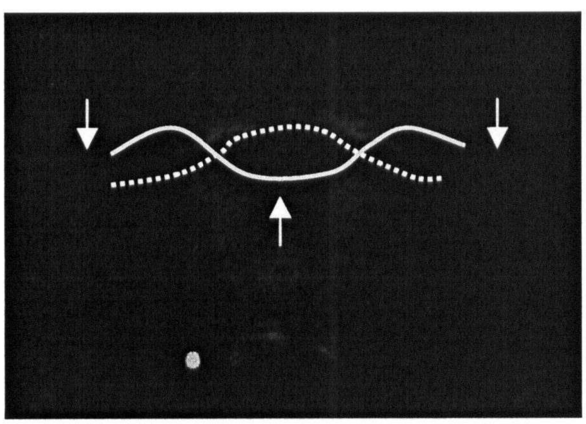
[10] Use of the phrase "ballistic tongue movement" is cited to Gick (p.c. 2004).
[11] Comparison of [t] to [t'] is based on descriptive observation only and has not been examined statistically.
[12] Unfortunately, the speaker's head was not still for these sets of tokens so the tongue is also seen to drift slightly to the right of the ultrasound view screen.



Blue = l beginning ....
Purple = l end
Yellow = a mid

Figure 4. 16 Coronal Cross Section Lateral movement: /l/

Next, the cross-sectional data for the lateral ejective affricate is presented. It is especially important to view the mid-sagittal data with the coronal cross-section view in mind, because this helps explain the drastic TR movement which occurs only for this segment. While glottal pressure is building up for the lateral ejective affricate, both the right and left sides of the tongue are raising towards the teeth to form an air pocket. At the same time, the center-line of the tongue is forming a concave dip. When the air is released, the center and sides switch directions. The center-line of the tongue shoots upward towards the hard palate, not making contact, but forming a convex hump, at the same time the sides of the tongue have instantaneously shot down towards the bottom of the mouth. This movement is illustrated in Figure 4.17 by tracings taken at peak pressure build up before the release, and the tongue position after the release.[13]



- Initial position
.......- Final position

Figure 4. 17 ƛ̓ cross-sectional release

It is probable that this movement simultaneously corresponds to the large TR movement as seen from the mid-sagittal view. As the tongue forms to make the defined gesture for the /l/, the side peaks and inner bowl are created. Then, upon pressured release

[13] Since the coronal cross-section films were of poor quality and scope, the movement illustrated in this image is likely less dramatic than actual production. That is, ultrasound images of non-Montana Salish speakers producing a lateral ejective affricate show a greater contrast between the center and sides of the tongue at initial and final position.

of the sides, the previous bowl turns convex. The TR as an attached part of the tongue, is a part of this convex peak. This concave turned convex movement is represented on the mid-sagittal angle by the TR retraction back and upward into the pharynx.

It should be clear from the above presented coronal and mid-sagittal data that the TR movement of the lateral ejective affricate occurs after the lateral affricate has been released. Since release of the lateral occurs simultaneously with the sides of the tongue dropping down (i.e. lateral movement, the TR movement cannot be a function of laryngeal movement during ejection). Gick et al. (2004b) in their study of cross-linguistic timing of liquids conclude that two independent gestural events often have variable timing. Therefore, if the TR movement and the TD or TB movements were independent gestures, then variable timing is expected. One may order before another in one production while another time, the order may be reversed. However, articulatory data investigation conducted here shows that the order of events for the production of the lateral ejective affricate in Montana Salish never switches order. The timing of the TR movement and lateral movement of the sides of the tongue is locked with the TR movement always occurring last. This implies that this TR movement is a direct result of the tongue displacement which occurs after the lateral affricate's release and lateral movement.

Lastly, coronal cross-sectional images from the lateral fricative are examined. The following sequence of frames in Figure 4.18 illustrate the movement of the lateral fricative as viewed from the coronal cross-section along the tongue centerline. Notice the rounded and high position of the tongue at interspeech rest, before the start of the lateral fricative. In frames 3-6, during the lateral fricative, a distinct groove develops along the centerline of the tongue while the sides remain raised. In the /a/ vowel, represented in figures 7-10, the tongue centerline rises to match the position of the sides, and then continues to rise to form a convex curve for the final production of the /a/ vowel.[14]

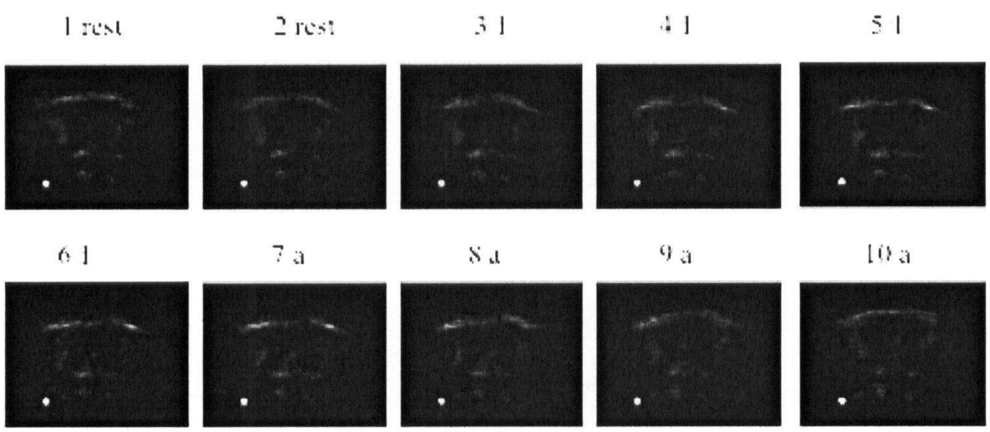


Figure 4. 18 Coronal Cross-section: sequential frames for /ɬa/

[14] Unfortunately, these images are less clear along the side view of the tongue. This is likely because the coronal cross-sectional data was not collected along a prescribed angle and is very variable in quality.

While not as much as the /l/, /l̓/ or /ƛ̓/, the lateral fricative demonstrates the same concave center groove and raised sides while the whole tongue height rises and lowers. The general movement is such that the body of the tongue lowers, while the sides press outward. These coronal cross-section images show that despite the minimal movement of the tongue as seen in the mid-sagittal view, the tongue is making definitive gestures laterally.

These images illustrate a dynamic movement of the tongue during lateral production which is not visible along the mid-sagittal field. While the TR is obviously not visible in the coronal cross-section, the lateral gestures of the tongue are clear and some of these correspond to the TR movement along the mid-sagittal angle. These movements are imperative in understanding the overall tongue gestures involved in the lateral consonants production.

As mentioned previously, imaging along the coronal cross-section plane assists in deciphering what retraction is biomechanically required, and which is not. Consider the TD retraction in the lateral approximants. The coronal cross-sectional images show the whole tongue surface lowering while maintaining the peaks and grooves required for "lateral" production. Since the tip/blade of the tongue is already in contact with the alveolar ridge, there is no place else for the tongue to go in the front direction. Therefore, while the whole horizontal surface of the tongue is lowering for the /l/ production, the only direction the remaining parts of the tongue can go are laterally and back. This is because the tongue is a volume preserving unit such that movement in one area always equates to a corresponding movement is some other area. Therefore, this lowering along the horizontal plane of the tongue as seen in the coronal cross-sectional view, requires that the tongue either retract toward the back of the mouth (neither pharynx nor uvular is inherently specified), and/or expand laterally. The lateral approximant simply utilizes both of these expansions. Unfortunately this does not necessarily clarify why the expansion back is TD as opposed to TR, but only why expansion can possibly be phonetically explained. It is possible that similar to a languages unique specification of gestural conflict resolution (either vowel laxing/lowering or vowel transitioning), a language specifies where the tongue moves for the laterals: either back or sideways, or in the case of Montana Salish, both.

If the same approach is applied to the lateral ejective affricate a slightly different conclusion concerning retraction is reached. Here again, lateral production physically requires that tongue expansion go somewhere, but this is confounded by the ejective nature of the lateral affricate. Here the coronal cross section illustrates a distinct tongue center protrusion "up" as the sides of the tongue drop "down. This up motion along the center of the tongue is correlated to the distinct TR retracted movement as seen on the mid-sagittal imaging. In this case, lateral compression is forced to be resolved by expansion in TR area.

4.3 Coronal Cross-section vs. Mid-sagittal Articulatory Data

As demonstrated above, comparison and assessment with the coronal cross-sectional data for articulatory movement is critically important, especially for the lateral segments, which, as their name implies, are distinguished by their movement in the sides of the tongue. In many of the mid-sagittal images of the tongue during lateral production, it seems that the laterals (especially the lateral approximates and lateral ejective affricate) have a larger amount of tongue body present in the ultrasound viewing field than the vowels or other consonants. It is hypothesized that this impression is a reflection of a physical tongue narrowing such that a smaller mid-sagittal view is in opposition to a larger view of the coronal cross-section. In other words, because the tongue is a volume preserving unit, and only the tongue edge is outlined on the ultrasound machine, the more space is filled with the tongue on the mid-sagittal view, the more the tongue is narrowing and rising in the coronal cross-section angle.

This type of observation is best visible in the line chart in Figure 4.19 illustrating the distance from the transducer arc for measurement locations #1-#5.[15] The equivalent of a tongue narrowing is then a larger space under the curve of the graph. Take for example, the graph comparing interspeech rest position to all the lateral consonants. Here it seems that rest (and the other vowels which cluster and pivot around rest) generally has a lower overall tongue position than the laterals (except the lateral fricative), and therefore is laterally expanding in the horizontal direction, which is not displayed within the ultrasound viewing field. The lateral fricative patterns with the vowels by pivoting along the hypothetical fulcrum between measurements #2 and #3 for interspeech rest position. Overall, interspeech rest maintains a significantly lower overall tongue position than the glottalized lateral approximant.

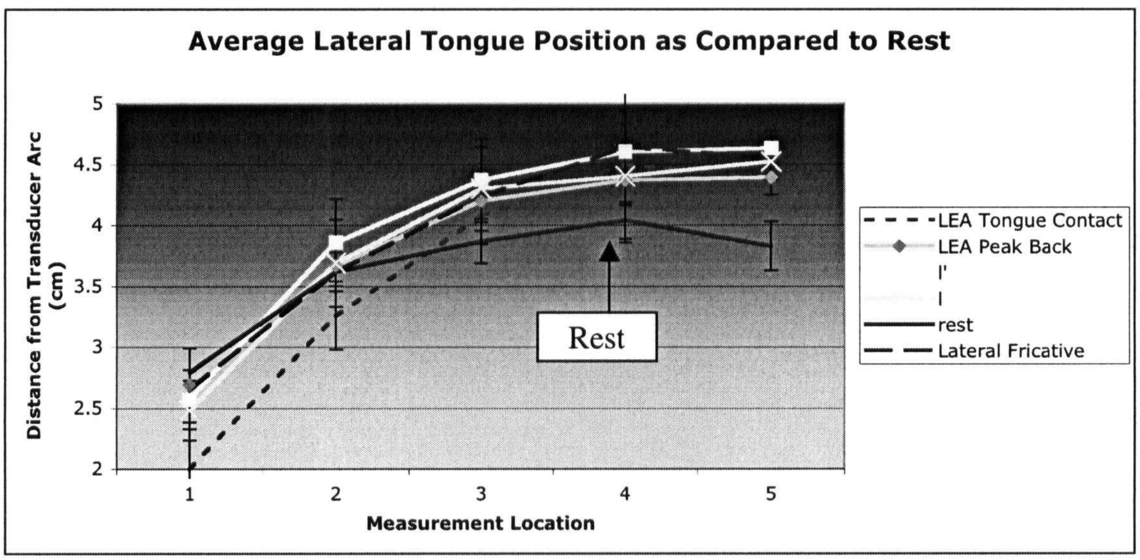


Figure 4. 19 Averaged /l/, /l̰/, /ɬ/, and /ƛ̓/ vs. interspeech rest position

Here, based on a Fisher's PLSD comparison, there is a significant difference (< .05%) between rest position and all the other laterals for measurement #1, only the lateral ejective affricate (labeled LEA) at tongue contact position for measurement #2, and

[15] Recall that measurement 1 begins at the TR and measurements 2-4 are taken 2cm up along the tongue outline. Measurement 5 is from the most visible part of the TT to the transducer arc.

again, for all the laterals at measurements #3, #4, and #5. This is consistent with the individually illustrated laterals in the previous sections.

The above graph illustrates the comparison between the medial expansion of the average interspeech rest position and lateral compression of the lateral consonants. Interspeech rest position is marked by tongue expansion along the horizontal plane, while the laterals pattern with vertical expansion (lateral compression).

In order to examine the validity of this hypothesized trend, a comparison of the "average distance from tongue surface to transducer arc", as a representation of compression and/or expansion, was created by comparing the average overall distance of each lateral to the averaged overall distance for interspeech rest and the vowel positions. This was compiled by summing each of measurement points (#1-#5) for each token, taking that average, and then plotting it against the computed averages for the other tokens (/i/, /a/, /e/, /u/, /rest/, /l/, /l̓/, /ɬ/, and /ƛ̓/). The "average distance from tongue surface to transducer arc" exemplifies a measure of medial expansion/lateral compression, through arbitrary numerical values.

Figure 4.20 below validates this pattern for /l/ as compared with the front vowels. Here, significant pairings between the vowels (except /e/ [ɛ]), rest, and /l/, demonstrate the medial expansion as visible in the mid-sagittal view of the tongue. The large medial expansion results in the tongue filling up the space of the ultrasound view. That is, the larger amount of tongue visible in the mid-sagittal view corresponds to higher average numbers along the Y-axis as plotted in the line graphs. Since the tongue is volume preserving, the center peak of the cross-sectional view corresponds to a lateral narrowing along the vertical plane. As expected, the lateral approximate /l/ illustrates the most medial expansion as compared to the other tokens. This graph illustrates that the medial expansion corresponds with the /l/ as compared to the vowels. The statistical significance pairings are presented below.

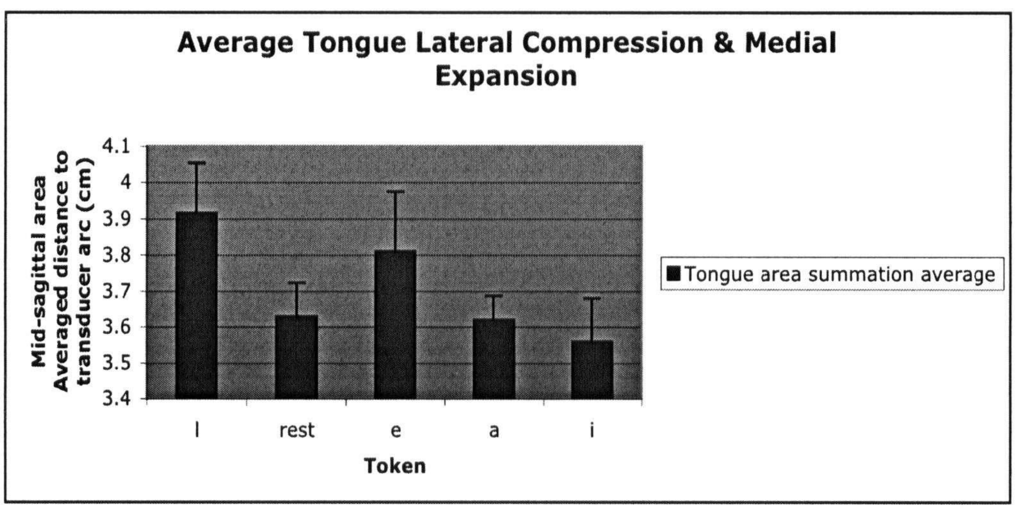


Figure 4. 20 Lateral compression and medial expansion for /l/ vs. vowels

Table 4. 2a-b /l/ Lateral Compression Statistics

Fisher's PLSD for Distance to transducer arc (cm)
Effect: Token
Significance Level: 5 %

	Mean Diff.	Crit. Diff.	P-Value	
a, e	-.182	.093	.0002	S
a, i	.063	.085	.1476	
a, I	-.240	.080	<.0001	S
a, rest	-.009	.084	.8297	
e, i	.245	.087	<.0001	S
e, I	-.058	.082	.1634	
e, rest	.173	.086	.0001	S
i, I	-.303	.073	<.0001	S
i, rest	-.072	.077	.0690	
I, rest	.231	.072	<.0001	S

A

Means Table for Distance to transducer arc (cm)
Effect: Token

	Count	Mean	Std. Dev.	Std. Err.
a	14	3.628	.068	.018
e	13	3.810	.165	.046
i	19	3.565	.120	.028
I	26	3.868	.138	.027
rest	20	3.637	.094	.021

B

The same comparison of medial compression and lateral expansion is illustrated below for the lateral ejective affricate, glottalized lateral approximate, lateral approximate, and lateral fricative as compared to interspeech rest.

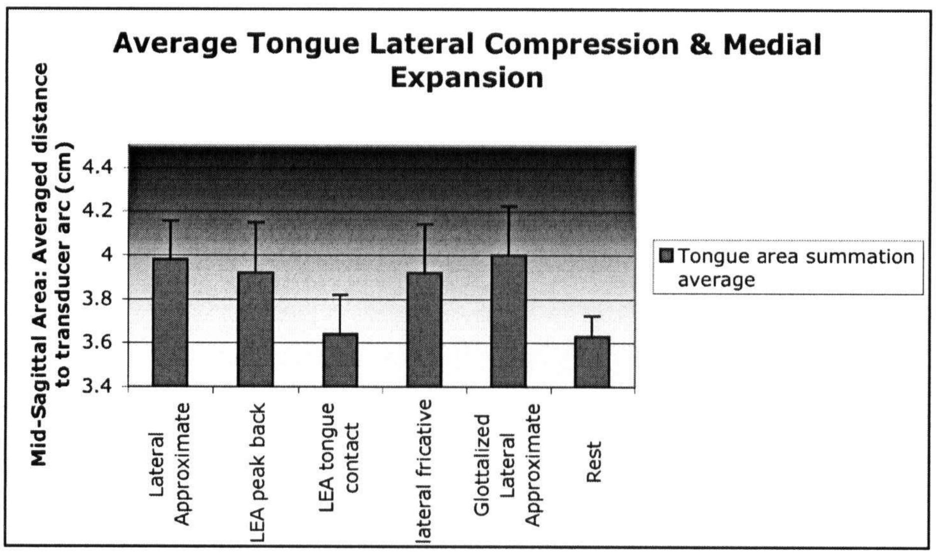


Figure 4. 21 Lateral compression and medial expansion measurements

Table 4. 3a-b Lateral Compression Statistics

A

Means Table for Averaged Distance from Transducer Arc (cm)
Effect: Token

	Count	Mean	Std. Dev.	Std. Err.
Glottalized Lateral Approximate	23	3.997	.225	.047
Lateral Approximate	29	3.981	.176	.033
Lateral Fricative	91	3.924	.222	.023
LEA Peak back gesture	49	3.924	.229	.033
LEA Tongue contact	49	3.645	.180	.026
Rest Position	21	3.633	.094	.020

B

Fisher's PLSD for Averaged Distance from Transducer Arc (cm)
Effect: Token
Significance Level: 5 %

	Mean Diff.	Crit. Diff.	P-Value	
Glottalized Lateral Approximate, Lateral Ap...	.016	.112	.7745	
Glottalized Lateral Approximate, Lateral Fr...	.073	.094	.1264	
Glottalized Lateral Approximate, LEA Peak ...	.073	.102	.1568	
Glottalized Lateral Approximate, LEA Tongu...	.352	.102	<.0001	S
Glottalized Lateral Approximate, Rest Posit...	.365	.121	<.0001	S
Lateral Approximate, Lateral Fricative	.057	.086	.1938	
Lateral Approximate, LEA Peak back gesture	.057	.094	.2351	
Lateral Approximate, LEA Tongue contact	.336	.094	<.0001	S
Lateral Approximate, Rest Position	.348	.115	<.0001	S
Lateral Fricative, LEA Peak back gesture	2.041E-4	.071	.9955	
Lateral Fricative, LEA Tongue contact	.279	.071	<.0001	S
Lateral Fricative, Rest Position	.291	.097	<.0001	S
LEA Peak back gesture, LEA Tongue contact	.279	.081	<.0001	S
LEA Peak back gesture, Rest Position	.291	.105	<.0001	S
LEA Tongue contact, Rest Position	.012	.105	.8214	

There are several points to notice from Figure 4.21. First, note that there are statistically significant differences between the glottalized lateral approximate and rest, the lateral approximate and rest, the lateral fricative and rest, and the lateral ejective affricate (LEA) peak backward release movement and rest, but not between rest and the lateral ejective affricate position at tongue contact with the alveolar ridge. Second, note the large difference between the lateral ejective affricate at initial and final release position. Recall from the discussion of this consonant as viewed from the angle of the coronal cross section, that the center of the tongue created a groove during /ƛ̓/ initiation, and a convex peak at /ƛ̓/ release. This corresponds to the numerical difference of the two /ƛ̓/ as represented on the Y-axis of the above graph. Third, note that with the exception of the /ƛ̓/ at initiation, all the laterals exemplify a large amount of medial expansion as compared to interspeech rest position. This is shown by the large numerical difference along the Y-axis.

As seen in the above graph, the positions of the lateral consonants, in comparison to rest position, imply that there are large amounts of medial expansion during the lateral production. Recall the movement of the lateral ejective affricate from Figure 4.13. Here the final position for /ƛ̓/ is with a peak along the centerline of the tongue. This centerline peak is consistent with the same drastic movement in the tongue body and tongue root which are viewed in the mid-sagittal ultrasound data.

The same is true of the lateral fricative. While creating and maintaining a small groove along the centerline of the tongue, the entire tongue body lowers, and simultaneously protrudes the sides of the tongue out laterally. The sides then subsequently lower. This is shown as a larger number in the lateral expansion graph (Figure 4.21).

4.4 Summary

In summary, this chapter has presented articulatory and acoustic evidence demonstrating the retracted nature of the /l/, /l̓/, and the /ƛ̓/ consonants. These 3 laterals exhibit a distinctive retracted movement which is clearly visible in the ultrasound imaging and is especially noticeable when compared to interspeech rest position and the tongue position for the uvular consonants. The lateral fricative does not exhibit a retracted movement, however, there is inconclusive evidence that predicts that there is some movement in the area of the TD.

Furthermore, the data presented necessitates that the tongue root and tongue dorsum be treated independently in terms of the gestural functions. Only the TD exhibited major retraction for the two lateral approximants, while the TR was the primary locus of retraction for the lateral ejective affricate. These distinctions are summed in the table below.

Table 4. 2 Summary of Lateral Retraction

	Retracted	TD movement	TR movement
/l/	√	√	no
/l̓/	√	√	no
/ɬ/		variable	no
/ƛ̓/	√	no	√

Determining phonological status is another important aspect of this differentiation of retraction between the lateral approximants and the lateral ejective affricate. Since the tongue is a volume preserving hydrostat, compression in one area of the tongue is always in opposition to expansion in another area. In the case of the lateral consonants, this means that while some tongue root retraction is a phonetic byproduct of movement in the tongue dorsum area, this is to be distinguished gesturally from true phonologically specified tongue root retraction. The lateral approximants demonstrate variable TR placement, but this is only a byproduct of the TR's attachment to the TD. The TD maintains the locus of gestural specification. Consider also the lateral ejective affricate. Here tongue retraction is tongue root retraction whereby the tongue root projects back. The glottalized lateral approximate is defined by tongue dorsum retraction, whereby the tongue dorsum moves back, without an additional movement up or down. However, because the parts of the tongue are interconnected, this movement back in the tongue dorsum also creates a smaller movement back of the tongue root. In other words, in addition to the distinct locus of retraction that is different for the lateral approximants as compared to the lateral ejective affricate, the retraction for the latter can be primarily explained as a biomechanical byproduct. That is, rather than a specified articulatory target, the retracted movement for the /ƛ̓/ is a function of the ejected lateral release.

Chapter 5 Coarticulatory effects of Lateral Consonants on Vowels

5.1 Introduction and motivation for experiments

Since the physical events associated with tongue retraction have been clearly established by data presented in the previous chapters, it needs to be determined how this retraction affects adjacent vowels. As demonstrated with the uvular stop investigation in Chapter 3, dynamic movements and position of the selected consonants and adjacent vowels are greatly reflected through the acoustic signal. The following section presents the results from the investigation into the coarticulatory effects of adjacent vowels. This includes both measurements of the acoustic effects of the lateral consonants as well as additional articulatory description of lateral-vowel and vowel-lateral interactions. The acoustic and articulatory procedure is the same as that described in Chapter 2. Beginning with the lateral approximant and glottalized lateral approximant, following with the lateral fricative, and ending with the lateral ejective affricate, both pre- and post-consonant vowel effects are presented.

In the following investigation two primary methods of analysis are used in order to determine whether the consonant is retracted or not. First, the acoustic effects of the lateral consonants on adjacent vowels are examined with the assumption that co-articulatory consonant effects will be present in the vowel formants. That is, if the laterals are retracted, then one expects a rising of F1, a lowering of F2, and a rising/lowering of F3 (raising- if tongue retraction is in the uvular area, lowering-if tongue retraction is to the pharyngeal area) for the vowels adjacent to the laterals. Second, coarticulatory interactions are examined through ultrasound imaging such that lateral tongue positioning is measured in different vowel contexts.

5.2 Lateral Approximant

Section 5.2.1 Lateral approximant coarticulatory interactions: acoustics

To begin the investigation of retraction by the laterals, acoustic evidence from the lateral approximant is examined. Since the lateral approximant demonstrates a retracted tongue position in the direction of the uvula by the tongue dorsum, acoustic effects on the adjacent vowels are predicted.[1] These include a lower F1, lower F2 and higher F3. In order to investigate this, two measurements are taken at 50% and 95% into the vowel for preceding vowel contexts, and 05% and 50% for following vowels. These averages are directly contrasted with the same positions for the neutral vowel contexts. Beginning with the assumption that if /l/ is retracted, the most salient and visible effects would be on the high front vowel, /i/ is examined first.[2] These two segments would have final tongue positions in the greatest opposition with a high front tongue body position for the

[1] The Wilson (2003) Nuu-chah-nulth study models the necessity of distinguishing pre- and post-consonantal vowel positioning.

[2] *No i/_l, a/_l, e/_l, u/_l, e/l_, or u/l_ data in non-retracted environments were available for comparison.

/i/ vowel and a back position for the /l/. Statistically significant differences in the pairing between i/l_ and /i/ formant values are listed below.[3]

Upon commencement of this comparison, it became evident in Chapter 4 that i/al_ and i/l_ needed to be treated independently because of the co-articulatory effects of the preceding /a/ vowel. As well as the affect that the lateral can have on the adjacent vowel, the vowel in return affects the lateral tongue positioning. Gestural examination of these co-articulatory vowel effects on the lateral approximant support the separate analysis of i/al_ and i/l_, and are presented in the subsequent articulatory section.

Table 5.1 Acoustic Measurements for i/l_ and i/al_ vs. /i/

Significant differences:	Averages:	Significance levels	# of Tokens
F2 05%- i/al_ : i	Hz: 2348 : 2720	<.0001	15:18
F2 05%- i/l_ : i	Hz: 2290 : 2720	<.0001	12:18
F2 50%- i/al_ : i	Hz: 2698 : 2909	.0027	15:18
F2 50%- i/l_ : i	Hz: 2570 : 2909	<.0001	12:18
F3 05%- i/al_ : i/l_	Hz: 3248 : 3124	.0204	15:12
F3 05%- i/l_ : i	Hz: 3124 : 3330	.0001	12:18
F3 50% i/al_ : i	Hz: 3267 : 3417	.0002	15:18
F3 50% i/l_ : i	Hz: 3197 : 3417	<.0001	12:18

Interpolation of these significant formant values identifies significantly more TB backing for both i/al_ and i/l_ than neutral /i/ (reflected in F2) and also more TR retraction for either i/al_ or i/l_ than neutral /i/ (F3). These acoustic differences continue to persist up to the midway point of the vowel production. These suggest that the vowel /i/, when preceded by /l/, has a greater tongue body backing and more tongue root retraction than /i/ in a non-retracted environment.

However, unlike the i/q_ sequences investigated in Chapter 3, there is no significant difference in the first formant between the neutral /i/ value and the values from the i/al_ or i/l_ sequences, and there is a significant difference in F3 for i/al_ and i/l_ whereas there is not for i/q_. This F3 difference continues to persist through the midpoint of the vowel. Nevertheless, a similar pattern emerges for F2, although as expected, the amount of retraction is less for the /l/ than the /q/. The i/q_ F2 difference between the retracted and non-retracted vowel ranges between 500-650 Hz, while the i/al_ and i/l_ F2 differences ranges between 350-400 Hz. Recall from Figure 3.11 the i/q_ F2 average of ~2090 Hz. This presents a gradient scale of retraction as implied through the acoustics. Here, as expected, /q/ has the largest lowering effect on F2, while the /l/ lies part way in between /q/ and the non-retracting consonants.

Next, while lowering the /i/ vowel, affect of the /l/ on a following /a/ vowel is the opposite. Here, the acoustic measurements indicate that /l/ seems to raise and front the tongue body of the following /a/ as compared to the /a/ in a neutral position. Thus, it is

[3] Formant significance values were only listed in tables if the mid point and the edge measurements coincided in significance. For example, if a V/_C context had midway (50%) as significant, but not 95%, then it was not included.

clear from the acoustic measurements, that /l/ has a strong effect on the adjacent vowels which advances the low vowel /a/, but retracts the high vowel /i/. Averages for a/l_ sequences as compared with neutral /a/ are presented below.

Table 5.2 Acoustic Measurements for a/l_ vs. /a/

Significant differences:	Averages:	Significance levels	# of Tokens
F1-05% a/l_ : a	Hz: 763 : 837	.0081	15:22
F1-50% a/l_ : a	Hz: 792 : 905	.0002	15:22
F2-05% a/l_ : a	Hz: 1638 : 1456	.0002	15:22
F2-50% a/l_ : a	Hz: 1499 : 1419	.0170	15:22

The trend for /l/ to raise the second formant of the following /a/ vowel is reminiscent of a similar pattern in Arabic as described by Alwin (1996). He finds that F1, (but not F2 as above) *lowers* after a uvular whereas it rises after a pharyngeal. Bessell (1991) documents that F1 values *rise* for the Moses-Columbian Salish /a/ following a uvular. She uses these findings to suggest that the Moses-Columbian Salish uvular is produced farther back than the Arabic uvular. While F1 for /a/ in Montana Salish does not pattern with the Moses-Columbian data, it does match the trend demonstrated in the Arabic a/Q_ environments.

This acoustic data is consistent with the articulatory data presented in Chapter 3. Recall from Figure 4.4 the image of /q/ vs. /l/ which places the TD in roughly the same locus of retraction but the TR and TT in different locations. The acoustics match this difference in primary retraction location. There are acoustic effects as the result of these conflicting gestures between the consonant and the adjacent vowel, but they are less substantial for the lateral approximant to vowel interactions than they are for the uvular-vowel interactions. At formant onset measurement (05%), i/q_ had the largest difference in F2 on the following /i/ vowel such that it averaged near 2090Hz, where i/l_ averaged higher at approximately 2300 Hz.[4] These two values were both significantly lower than the average /i/ value near 2700 Hz and the difference between all three values were statistically significant.

The important focus of attention in the /q/ vs. /l/ tongue positioning (Figure 4.4) is not only the similar TD position between the two consonants, but also the distinctly different TR positions. The TR for the /q/ is both higher and farther back than that of the /l/ production. This difference is reflected in the second formant.[5] By taking the tongue positions (as demonstrated by the tracings in Figure 5.1) into consideration with the acoustic results, it seems clear that the tongue root position and tongue dorsum both contribute to the transitioning and lowering effects on the following vowel. The second formant seems to correlate with more than just TB advancement or retraction. The difference in effects on the F2 values of adjacent vowels must be contingent on the TR as well, not just the TD or TB since the TD position is similar for /q/ and /l/, but the TR

[4] This i/q_ represents the combination of all i/q_ words used in Chapter 3 section 3.

[5] F3 is predicted to indicate the TR (and/or TD) position. It does not do so for the /q/, but variably does for the /l/ comparisons. This discrepancy is not clearly understood and is a likely result of the many-to-one acoustic to articulatory relationship.

position is not. The difference in the /q/ and /l/ lies both in the TR and the TT position and this is evident in the changes to F2.

Section 5.2.2 Lateral approximant coarticulatory interactions: articulation

Since there are notable acoustic effects of the lateral on the following vowels, another look at tongue positioning is merited, this time in comparison with the vowels. The acoustics suggest that the lateral approximants generally pattern to raise the low vowels, but lower the high vowels, therefore this should be evident in their articulatory positioning. That is, from the acoustic results, we expect that the /l/ position lies medially between the /a/ and /i/ position.

In order to orient the tongue position of the lateral approximant in relationship to the vowels in Montana Salish, Figure 5.1 illustrates a comparison of the most fronted /l/ (l/_i/) to rest, /e/, /i/, and /a/. Here tongue tracings outline the position at the midway through each segment. It is clear that measurement #1 (tongue root to transducer arc) is numerically the most reflective of TR retraction but that the TD movement is somewhat between measurements #2 and #3. Here an entire tongue tracing best illustrates any retraction which occurs in the TD area.

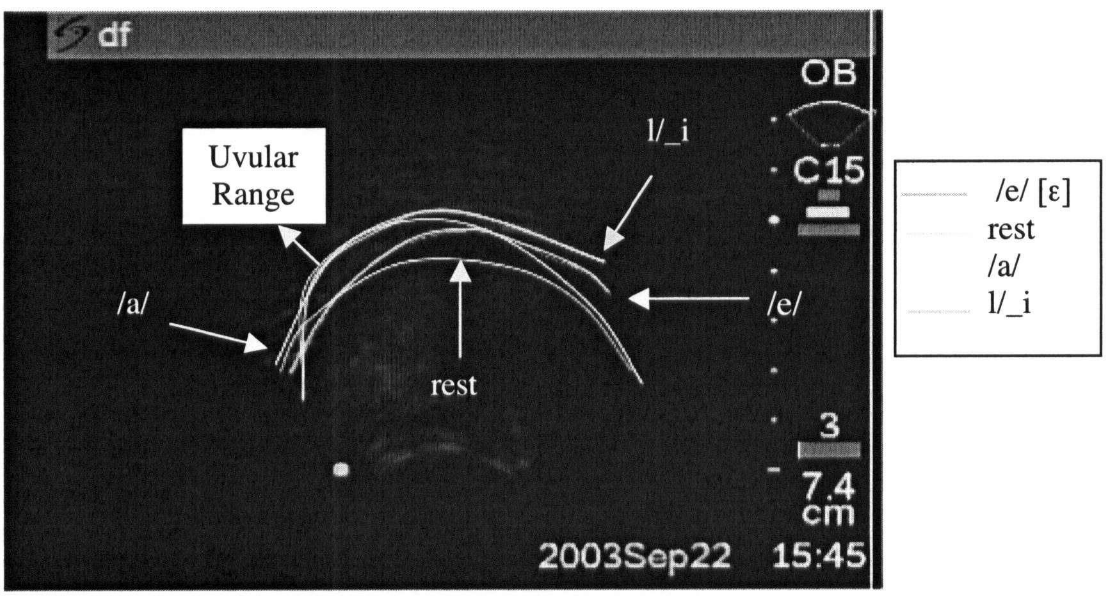
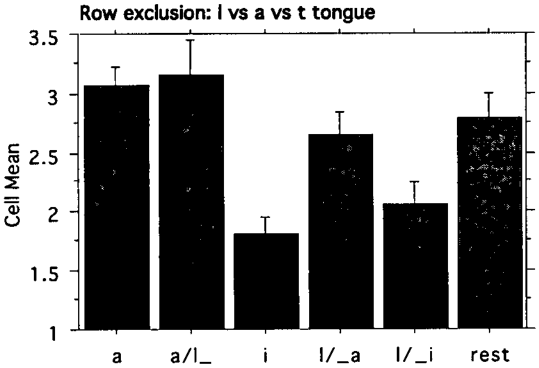


Figure 5. 1 Tongue shape tracing for l/_i compared to /e/, rest, and /a/

The image in Figure 5.1 reinforces two points. First, the TR position for the /l/ is much more advanced than that of the /a/, /e/, or interspeech rest, while the TD position is retracted as much as the /a/ position (with all other segments much more advanced at the TD locus). Second, the lateral approximant is unique among the above segments as being the one segment with only TD retraction. The /a/ vowel has greater TR retraction than the /l/. This is consistent with the findings reported in the previous chapter.

Next, since the above illustrative description is a tracing of a single segment overlaid onto other tracings, it is important to have an objective comparison of tongue positioning. The following examination presents the tongue position averaged over multiple tokens and repetitions for the /l/ in various environments. From this investigation a pattern of retraction has developed. This trend, whereby the amount of gestural retraction is contingent upon the environment, seems to display itself throughout the Montana Salish lateral consonants. For example, an l/_i combination such as in the word *líḱʷlɛxʷ* 'prairie, bare ground' does not utilize any tongue root backing as it is initiated from interspeech rest position, nor is its /l/ position (taken at the midpoint of the /l/), very retracted in oral cavity. This is because interspeech rest already has a fairly retracted TR position. However, an /l/ preceding an /a/, such as in *nčlátkʷ* 'cold water', is much more retracted in its overall tongue position (midway through production) and demonstrates both a tongue root and tongue dorsum movement back into the /a/ vowel. The graph in Figures 5.2 illustrates the significance of this observation. For the first measurement of tongue root position (measurement point #1, Figure 5.2), all differences between /i/, l/_i, /t/, rest, l/_a, a/l_, and /a/, are significant except a/l_ to /a/, l/_a to rest, l/_i to /t/, and /i/ to /t/. Take note of the large difference in tongue position for /l/ preceding /i/ versus /l/ preceding /a/.

Interaction Bar Plot for TR to transducer (cm)
Effect: Token (environment)
Error Bars: ± 1 Standard Deviation(s)
Row exclusion: l vs a vs t tongue



Means Table for TR to transducer (cm)
Effect: Token (environment)
Row exclusion: l vs a vs t tongue

	Count	Mean	Std. Dev.	Std. Err.
a	15	3.067	.148	.038
a/l_	8	3.146	.298	.105
i	20	1.815	.143	.032
l/_a	8	2.647	.188	.066
l/_i	12	2.067	.189	.055
rest	21	2.794	.202	.044

Fisher's PLSD for TR to transducer (cm)
Effect: Token (environment)
Significance Level: 5 %
Row exclusion: l vs a vs t tongue

	Mean Diff.	Crit. Diff.	P-Value	
a, a/l_	-.080	.164	.3382	
a, i	1.252	.128	<.0001	S
a, l/_a	.419	.164	<.0001	S
a, l/_i	.999	.145	<.0001	S
a, rest	.272	.127	<.0001	S
a/l_, i	1.332	.157	<.0001	S
a/l_, l/_a	.499	.188	<.0001	S
a/l_, l/_i	1.079	.171	<.0001	S
a/l_, rest	.352	.156	<.0001	S
i, l/_a	-.833	.157	<.0001	S
i, l/_i	-.253	.137	.0004	S
i, rest	-.980	.117	<.0001	S
l/_a, l/_i	.580	.171	<.0001	S
l/_a, rest	-.147	.156	.0648	
l/_i, rest	-.727	.136	<.0001	S

Figure 5. 2 /l/ TR measurement split by environment

Figure set 5.2 above illustrates the tongue positions relative to each other for the measurement taken at the tongue root (#1). As expected, all /l/ productions are more retracted than /i/. However, since that /l/ position is variable, there is an additional difficulty in making an absolute claim on the amount of /l/ retraction. That is, for the initial tongue root measurement (#1), /l/ retraction is directly correlated to the following vowel such that if the vowel is high, the tongue root does not retract as much as if the vowel is low. In either environment, the amount of tongue root retraction lies between the /a/ and the /i/ with "rest" position lying between the /l/s and /a/. This yields the ranking of retraction as: a > rest > l > i. In addition, at the point of measurement for the tongue root (#1), neither /l/s preceding /i/ or /a/ surpass the mean 'rest' position for the tongue root location, (i.e. smaller number on the Y-axis than 'rest') indicating that this second measurement must be interpreted in relation to the tongue shape as a whole. Without interpreting the entire tongue shape, not just tongue root, one comes to the initial conclusion that, either 'rest' is not a good representative of the medial position, or that /l/ is simply not retracted.

In fact, however, this vowel retraction data corroborates the previous chapter's description of the /l/ retraction. If the TD is the primary articulator involved in the retraction movement, not the TR, then the TR is not necessarily specified in its gestures. That is, the TR does not maintain an exact target position, while the TD does. Therefore TR variability by vowel context is not surprising.

Also, recall from the discussion on the acoustic effects of the lateral approximant (Section 5.2.1), that variability by vowel environment was also visible in the acoustic signal. This corroborates the TR measurements presented above. F2 is higher for the low /a/ vowel in the a/l_ sequence and as illustrated below, the TR position is also less retracted than an /a/ vowel. Similarly, F2 lowers in the /i/ vowel adjacent to a lateral just as the TR position for the l/_i sequence is more advanced than the TR position for the l/_a sequence. While F2 is generally seen to imply TB backing or advancing position, this cannot be physiologically separated from its connection to the TR. Again, this discrepancy is a likely result of the many-to-one acoustic articulatory relationship.

From the above investigation two general observations can be made. First, it is clear that the retracted nature of the /l/ is variable by vowel context and in overall shape. That is, its target gestural position is always more retracted than an /i/ vowel and less retracted than and /a/ vowel. Within this general range, the exact tongue position depends on context. The /l/ is more fronted next to a high vowel, but more retracted next to a low vowel. Second, not only do the vowels effect the /l/ position, but the /l/ range of retraction also has equal effects on the adjacent vowels. The /l/ lowers the acoustic formants (F2) for the /i/ vowel, but raises those for the low /a/ vowel. This suggests that the tongue position of the vowels also varies. It seems that the lateral approximant demonstrates that not unexpectedly, coarticulation works in both directions.

5.3 Glottalized lateral approximant

Section 5.3.1 Glottalized lateral approximant coarticulatory interactions: acoustics

Next, continuing with the acoustic investigation into the laterals, is the glottalized lateral approximant. As described in Flemming et al. (1994), this is a pre-glottalized consonant. The table below illustrates the significant pairings of formant values for the i/l̓_ to neutral /i/ analysis. A lower F2 for i/l̓_ implies more tongue body backing than neutral /i/, which even continues up until the midpoint of the vowel. Similarly, lower F3 at both 05% and 50% into the vowel implies more TR retraction for the vowel following the glottalized lateral. These are shown in the table below.

Table 5.3 Acoustic Measurements for i/l'_ vs. /i/

Significant differences:	Averages:	Significance levels	# of Tokens
F2 05%- i/ l̓_ : i	Hz: 2459 : 2720	.0041	10:18
F2 50%- i/ l̓_ : i	Hz: 2699 : 2909	.0106	10:18
F3 05%- i/ l̓_ : i	Hz: 3199 : 3331	.0078	9:17
F3 50%- i/l̓_ : i	Hz: 3288 : 3417	.0334	9:17

Recall that a statistically significant F2 and F3 formant pairing was found for plain /l/ as well. However, as was also the case with the plain lateral approximant, the amount of retraction on the /i/ following the /l̓/ is significantly less than when the same vowel follows a uvular. At vowel onset, the i/l̓_ F2 sequence averages 230 to 310 Hz higher than that of the i/q_. The i/l̓_ sequences for the second formant are also 100 to 150 Hz higher than those of the plain lateral approximant i/l_ sequences, although the difference between the /l/ and /l̓/ effects on the /i/ are mediated sometime beyond the midpoint of the vowel (50%). That is, the /i/ following either of the two lateral approximants does not reach [i] values until sometime beyond 50% into vowel production.

Next, Table 5.4 presents the average values for the i/_l̓ sequence as compared with the /i/ preceding a neutral consonant. These results do not parallel the results of /i/ in the environment following /l̓/. Here, F2 indicates more tongue body backing for /i/ when preceding the /l̓/, but this is neutralized sometime before the midpoint of the vowel. This is consistent with the acoustic trends presented in Bessell (1991) who found F2 lowering for i/_Q. In my data F1 and F3 showed no significant difference at all.

Table 5.4 Acoustic Measurements for i/_l' vs. /i/

Significant differences:	Averages:	Significance levels	# of Tokens
F2 95%- i/_l' : i	Hz: 2670 : 2925	.0044	9:18

While the general trend of the i/_l̓ acoustic effects pattern with those presented in previous studies of uvular consonant vowel effects such as Bessell (1991, 1998a), the above results to not entirely pattern with those found for the uvulars of this study. That is, /q/ in Montana Salish exhibits significant F2 effects on the preceding /i/. These begin midway through the vowel (50%) and have maximal differentiation occurring at the closest point to the uvular. However, only the closest measurement to the glottalized lateral approximant demonstrates a statistically significant difference between the /i/ vowels in the neutral and lateral environments. Furthermore, as was shown in Figure 3.6, F3 for i/_q was statistically significant. There is no statistically significant difference in F3 present for the i/_l̓ sequence.

Next, available data allows for an additional comparison of the /e/ and /a/ environments. Looking first at the effects of a preceding /l̓/ on a following /e/ and /a/, significant comparisons are listed below.[6]

Table 5.5 Acoustic Measurements e/l'_ vs /e/

Significant differences:	Averages:	Significance levels	# of Tokens
F1 05% - e/l̓_ : e	Hz: 638 : 532	.0020	14 :18

[6] No ul̓, el̓, al̓ or l̓u data was available for comparison.

F1 50% - e/ľ_ : e	Hz: 668 : 584	.0080	14 :18

Table 5.6 Acoustic Measurements for a/l'_ and a/l'l'_ vs. /a/

Significant differences:	Averages:	Significance levels	# of Tokens
F2 05% - a/ľ_ : a	Hz: 1817 : 1456	.0001	6 : 22
F2 05% - a/ľ_ : ľľa	Hz: 1817: 1366	.0002	6 : 22
F2 50% - a/ľ_ : a	Hz: 1627 : 1419	.0011	6 : 22
F2 50% - a/ľ_ : ľľa	Hz: 1627 : 1456	.0095	6 : 22

First, the higher F2 for the a/ľ_ implies that /ľ/ actually pulls the TB farther forward in the case of a following /a/, but the reverse is true following /e/. As seen in Table 5.5 lower F2 implies that the TB is pulled back as compared with the vowel /e/ [ɛ] in a neutral environment. That is, neutral /e/ reflects a higher TB than /e/ following the glottalized lateral approximant. Results for the a/ľ_ vowel parallel those for the a/l_ sequence where F2 is higher in the /l/ environment than in the non-/l/ environment. Therefore the implications are that there is fronting of the tongue body for the /a/ following the /ľ/ (or /l/) as compared with the TB position of an /a/ in a neutral environment. The absence of any data with e/l_ prohibits comparison with e/ľ_.

An interesting feature which arises from the articulatory examination of the /ľ/ is that there is a distinction between the acoustic effects of an /ľ/ produced independently and the /ľ/ produced non-independently.[7] The two sets of tokens represented in Table 5.6 (above) for the glottalized lateral approximant preceding an /a/ are analyzed separately. That is, repetitions of the /a/ vowel in the word representing two /ľ/ in a row, /ľľac/ [ˀlˀlats] 'red raspberry', is examined separately from the single /ľ/ found in such words as the name p̓ľásuwe [p̓ᵈľásuwɛ] 'Frank' (Figure Set 5.4). F1 and F3 showed no significant results on the adjacent /a/ vowel, either with the /ľ/ tokens separated, or when all the /ľ/ and /ľľ/ examples were grouped as one. However, F2 results for these two tokens varied. This variability in the influence of /ľ/ vs. /ľľ/ on the following /a/ is shown by the formant differences in the spectrogram images below.

The scattergram shows the F2 ranges for the /a/ vowels following /ľ/ and /ľľ/ as paired against neutral /a/. The two images below illustrate the formants for these two words (*ľľac and p̓ľásuwe*). Notice that in columns two and three (from the left), both F2 values at onset and midway through the vowel are significantly different for the two productions of a/ľ_. That is, F2 for the /a/ preceded by two glottalized lateral approximants is much lower than F2 preceded by a single /ľ/.

[7] As per discussion in Chapter4, "independent" /ľ/ refers to ľ/_{C or #}.

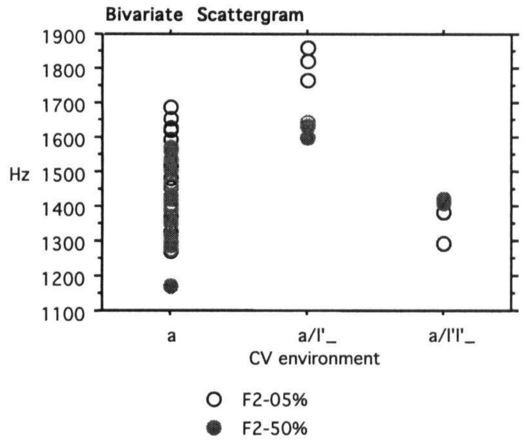


Figure 5. 3 Scattergram of neutral /a/ vs. /l'/

Two spectrograms of the analyzed tokens are presented below to show the variation in the second formant. Note that as is often found in Montana Salish glottalized resonants, glottalization (on the second /l̓/ in *l̓l̓ác*) is realized as variably pronounced laryngealization. Also note the burst-like onset which is apparent on the /l̓/ in *p̓l̓ásuwe.*

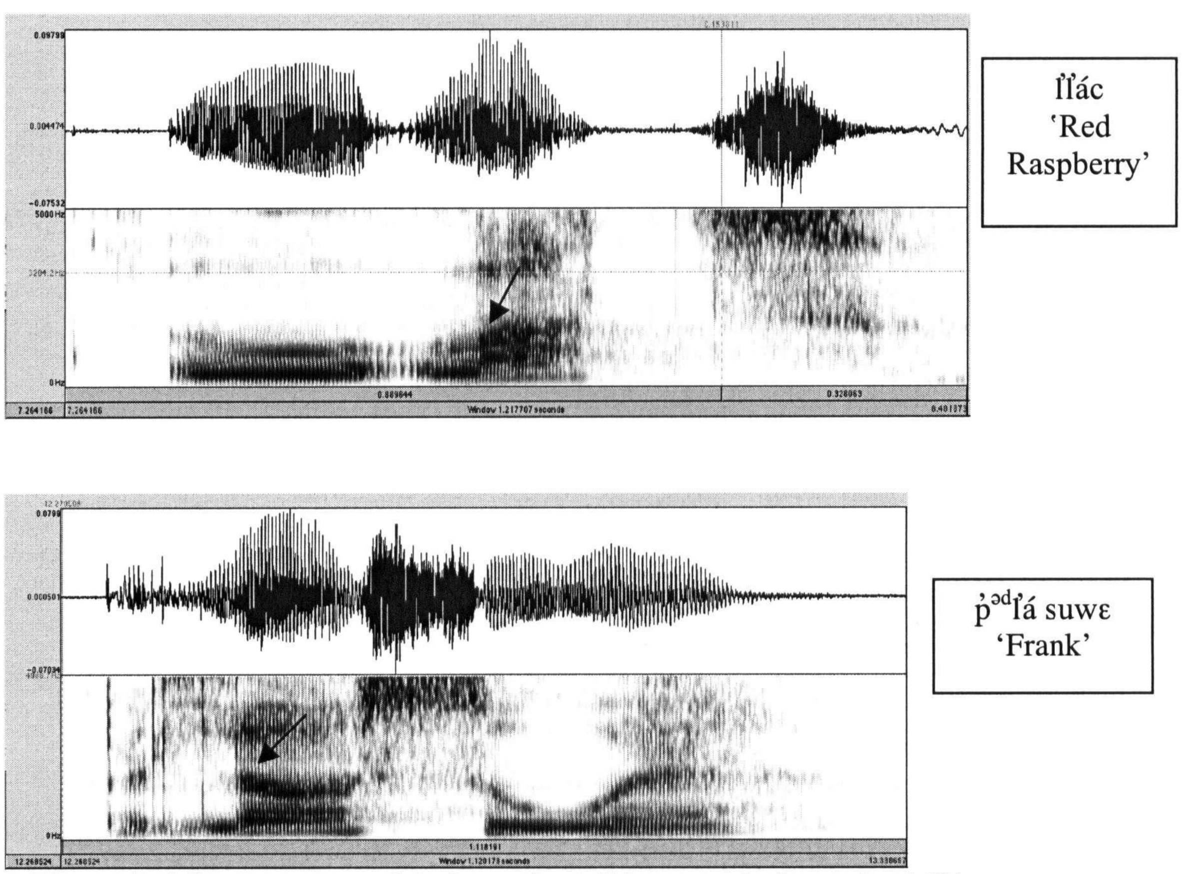


Figure 5. 4 Spectrogram of independent /l'/ vs. non-independent /l'/

As the images in Figure Set 5.4 show, F2 of the /a/ following the /l̓l̓/ production is clearly influenced by the initial /l̓/ through lowering the first part of the second formant. The focal points are indicated by the arrows on the above two images. The onset of the vowel /a/ is initially higher in *l̓l̓ác* than it is in *p̓l̓ásuwe*.

Overall summary of the acoustics highlight the general trend of F2 rising on a low vowel /a/ when following the glottalized lateral approximant, but lowering on the high vowel /i/. This is the same pattern that was exemplified by the plain lateral approximant. However, the illustrated F2 lowering for a vowel adjacent to /l̓/ is not as great as that which occurs when the vowel is adjacent to a uvular consonant.

Section 5.3.2 Glottalized lateral approximant coarticulatory interactions: articulation

Next, the tongue position of the glottalized lateral approximant is plotted as compared to the vowels. This image represents the averaged tongue position at each of the 5 measurement points along the tongue for all of the /l̓/ tokens. Notice that the TR position of the /l̓/ is less retracted than that of /e/, /a/, or interspeech rest, but by the second measurement up along the tongue surface, these positions have reversed. Now the /l̓/ presents the most retracted position. All comparisons at the initial TR measurement (#1) are statistically significant whereas the difference between /l̓/ and /a/ is mediated and is no longer statistically significant at measurement (#2). Additional statistics are included in Appendix B.

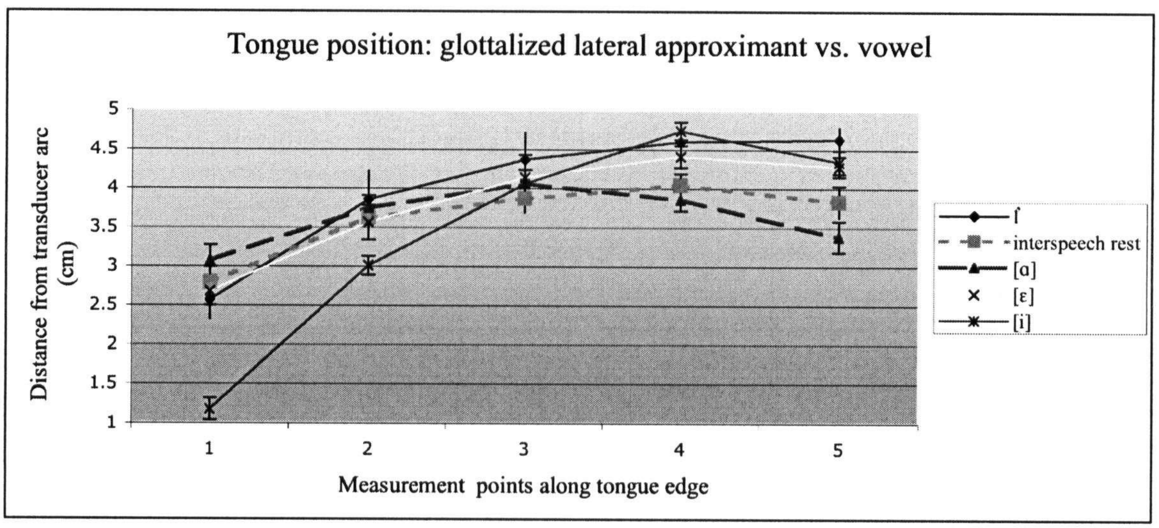


Figure 5. 5 Glottalized lateral approximant tongue position as compared to /i/, /e/, /a/, and interspeech rest

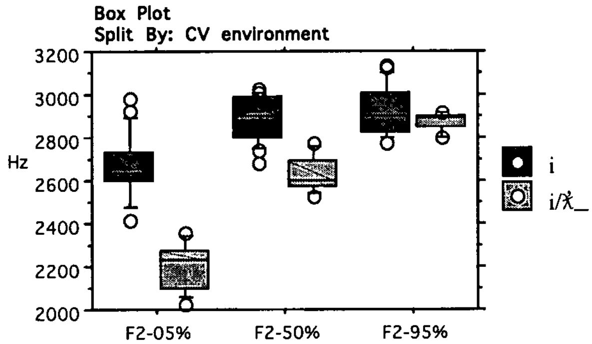
As is shown in Figure 5.5 above, the tongue position for the glottalized lateral approximant has significantly more advanced TR, but a more retracted TD as compared with interspeech rest and the /e/ and /a/ vowels. While F2 is generally seen to reflect TB advancement and retraction, this articulatory investigation suggests that F2 also reflects

TR and TD positioning. Again, this underscores the necessity for a direct look at the articulators rather than relying on inferences from the acoustic signal.

5.4 Lateral ejective affricate

Section 5.4.1 Lateral ejective affricate coarticulatory interactions: acoustics

Next, acoustic results for the /ƛ̓/ - vowel interactions as paired against the vowels in non-retracted environments are listed in the tables and figures below, beginning with the i/ƛ̓_ sequence. Here the transition [ƛ̓$^{\text{əi}}$i] between the initiation of the vowel adjacent to the lateral ejective affricate, and the end of the vowel, is distinctly audible. F1 and F3 demonstrate no significant differences between /i/ in either a neutral environment or following the /ƛ̓/. However, F2 measurements support this perceived transition and are shown in Figure 5.6. At 05% into the vowel, there is a distinct range for the vowel in each the two contexts, which does not have crossover. As shown in the significantly low F2 average, the acoustic measurements for the /i/ vowel in the i/ƛ̓_ sequence imply the movement of tongue body backing. There is a gradual resolution of the /i/ vowel such that the /i/ in i/ƛ̓_ does not reach proximity with the neutral /i/ values until sometime between the midpoint and 95% into the vowel. Despite that Flemming et al. (1994:9) documented an average glottal lag time of 87ms (-/+ 18) for the /ƛ̓/, this is not enough time for the gestural conflict between the /i/ target position and the /ƛ̓/ target position to be resolved. Therefore, since the 05% measurement of this study indicates 05% beyond the onset of voicing, and voicing begins after the glottis is no longer closed, the presence of transitory vowel effects still evident on the adjacent vowels implies that not all the gestural conflict is resolved during the glottal closure.



Means Table for F2-05%
Effect: CV environment

	Count	Mean	Std. Dev.	Std. Err.
i	18	2664.389	146.877	34.619
i/ƛ_	10	2208.900	112.291	35.509

Fisher's PLSD for F2
Effect: CV environment
Significance Level: 5 %

	Mean Diff.	Crit. Diff.	P-Value	
i, i/ƛ_	455.489	110.179	<.0001	S

Means Table for F2-50%
Effect: CV environment

	Count	Mean	Std. Dev.	Std. Err.
i	18	2886.833	104.055	24.526
i/ƛ_	10	2625.000	83.276	26.334

	Mean Diff.	Crit. Diff.	P-Value	
i, i/ƛ_	261.833	78.935	<.0001	S

Means Table for F2-95%
Effect: CV environment

	Count	Mean	Std. Dev.	Std. Err.
i	18	2925.278	118.951	28.037
i/ƛ_	10	2875.900	43.116	13.634

	Mean Diff.	Crit. Diff.	P-Value
i, i/ƛ_	49.378	80.645	.2194

Figure 5. 6 Acoustic statistics for i/ƛ_ vs neutral /i/

Furthermore, note that the i/ƛ_ F2 average at 05% into the vowel (2208 Hz) is remarkably close to the F2 average for the i/q_ sequence at the same point in time (2050-2200 Hz) (Figure Set 3.11). In addition, while the i/q_ sequence showed no significant differences by midway through the vowel, the /i/ in the i/ƛ_ sequence does not match neutral /i/ until sometime between 50% and 95% into the vowel.

Continuing with the acoustic results for the other vowel to lateral ejective affricate interactions, more variability is demonstrated. The pairings with significant differences are listed below in Table 5.7. For the a/ƛ_ sequence, both F1 and F2 show significant differences between the neutral /a/ and the same vowel following the lateral ejective affricate. F1 differences are neutralized by midway through the vowel, but F2 differences persist through the midpoint of the vowel. The acoustic results for /a/ following the lateral ejective affricate indicate that it has a higher and more advanced tongue body than neutral /a/. This is discussed in greater detail below.

Here, the lower F3 formant averages for e/ƛ_ entail greater tongue root retraction than neutral /e/. Interestingly, F1 was significant for e/l̓_ sequences and F3 was not. Lastly, through higher F1 values, u/ƛ_ exemplifies a lower tongue body than neutral /u/. These F1 differences for u/ƛ_ and /u/ are neutralized by midway through the vowel.

Table 5.7 - Significant V/ƛ_ sequences

Significant differences:	Averages:	Significance levels	# of Tokens
F1 05%- a/ƛ_ : a	Hz: 668 : 837	<.0001	12:22
F2 05%- a/ƛ_ : a	Hz: 1641 : 1456	.0002	12:22

F2 50%- a/ƛ̓_ : a	Hz: 1568 : 1418	.0001	12:22
F3 05%- e/ƛ̓_ : e	Hz: 3050 : 3327	<.0001	10:18
F3 50%- e/ƛ̓_ : e	Hz 3107 : 3352	<.0001	10:18
F1 05%- u/ƛ̓_ : u	Hz 444 : 406	.0114	15:23

The a/ƛ̓_ results are somewhat similar to the a/l_ and a/l̓_ data presented in the previous two sections. Recall that F1 for a/l_ was lower than neutral /a/ and F2 for a/l_ was higher than neutral /a/, and these effects continued past midpoint of the vowel. Here the F1 a/ƛ̓_ data at 05% is lower than the average of 763 Hz of the a/l_ sequences. However, F1 for a/ƛ̓_ is neutralized by the midpoint. F2 for both a/l_ and a/ƛ̓_ continues past 50% into the vowel, and the 1641 Hz for a/ƛ̓_ almost exactly matches the 1638 Hz average for a/l_. Like the gradual resolution for the i/ƛ̓_ sequence presented above, it takes longer for the a/ƛ̓_ formants to match the neutral /a/ averages than either of the lateral approximants. However, of the laterals thus far, the glottalized lateral approximant exhibits the highest F2 average (~1800 Hz) as compared with neutral /a/ (~1400 Hz).

Next, consider the V/_C sequences presented in the table below. Here, only /e/ [ɛ], and /i/ exhibit statistically significant differences between the vowel preceding the lateral ejective affricate and the same vowel averaged over neutral environments. As the results listed in Table 5.8 show, there is an anticipatory effect from the lateral onto the preceding vowels. For the i/_ƛ̓, at 95% into the vowel, there is a significantly lower F1 at 352 Hz than for the /i/ in neutral environments whose F1 averages at 395 Hz. This indicates a higher tongue body for the /i/ adjacent to the /ƛ̓/.

Table 5.8 - Significant V/_ƛ̓ sequences

Significant differences:[8]	Averages:	Significance levels	# of Tokens
F2 50% - e : eƛ̓	Hz: 2202 : 2297	.0032	18:8
F2 95% - e : eƛ̓	Hz 2117 : 2285	.0003	18:8
F1 50% - i : i/_ƛ̓	Hz 421 : 378	.0137	18:17
F1 95% - i : i/_ƛ̓	Hz 395 : 352	.0214	18:17
F2 95% - i : i/_ƛ̓	Hz 2925 : 2802	.0380	18:17

While the differences listed above are still statistically significant, the mean difference as compared with all other V/_C and V/C_ interactions is minimal. For example, F2 95% for /e/ vs. e/_ƛ̓ differs by 168Hz. Additionally, F2 50% for /e/ vs. e/_ƛ̓ differs by only 95Hz and /i/ vs. i/_ƛ̓ by 123 Hz. Recall the larger variation between neutral and "retracted" /i/ from the i/_l̓ comparison in Table 5.4. The mean difference between /i/ and i/_l̓ averaged near 255 Hz.

Furthermore, note the variability in significance levels and mean differences for these interactions as compared with the values listed for the CV sequences. The V/C_ differences at the closest measurement to the consonant for i/l_ and i/q_ each averaged

[8] No significant differences were found between /u/ and u/_ƛ̓ for any formants. There was not enough a/_ƛ̓ data available for comparison.

several hundred hertz, 261Hz and between 492-668 Hz respectively.
In particular, there appears to be a greater average difference in means between the V/ƛ_ sequences and the V/_ƛ sequences such that a vowel preceding the lateral ejective affricate is always less affected than a vowel following the lateral consonant. The second formant at 95% into the vowel indicates greater tongue back backing than neutral /i/ with a mean of 2802 Hz for the i/_ƛ combination and 2925 Hz for the neutral /i/. When compared to the F2 average at onset for the i/ƛ_ of 2209Hz, the greater V/_ƛ effects are clear.

The /ƛ/ vowel interactions exhibit an important trend. In the environment of the lateral ejective affricate as reflected in the lower F2 values, the high front vowel /i/ is retracted in tongue body position but the low back vowel /a/ is more advanced. This implies that the /ƛ/ targeted tongue body position lies somewhere between these two vowels, and is certainly not more retracted than the /a/. This pattern of retraction of the high vowel and advancement of the low vowel is mirrored in the glottalized and non-glottalized lateral approximants, as well as the lateral fricative.

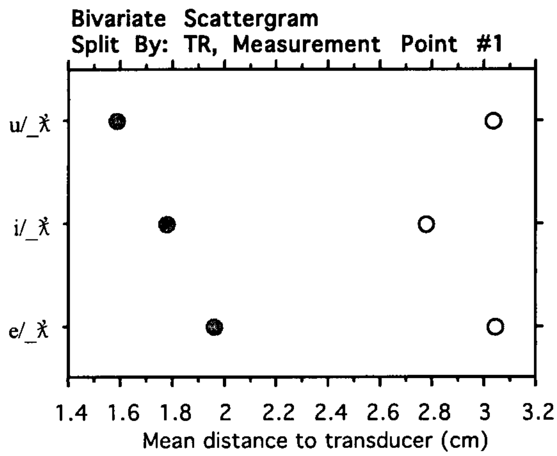
A summary of the acoustic data for the V/ƛ_ combinations demonstrates that while tongue body height and backness are affected, (F1 and F2 respectively), tongue root positioning is not (F3). Out of all the vowel-lateral ejective affricate combinations, F3 showed statistically significant differences only for the e/ƛ_. Since articulatory examination in Section 4.1.4 has clearly shown the large variability in TR positioning, F3 results are expected. Lack of F3 results is a likely result of the many-to-one acoustic-articulatory relationship and further highlights the importance of looking directly at the articulators. Nevertheless, it is possible that the lack of demonstrable F3 results suggest that the tongue root position is dependent upon the preceding vowels, otherwise some of the vowel contexts would exhibit significant differences in F3 when compared with the neutral vowel. That is, lack of F3 results suggest that the ultimate TR position could be entirely dependent on the adjacent segment in which case, it would be more advanced for an /i/, but more retracted for an /a/ and this accommodation would not create statistically significant differences in the acoustic signal. This suggests that rather than the TR movement being an articulatory target specified by the phonology, it is a phonetic byproduct whose final position is largely dictated by the surrounding environment.

Section 5.4.2 Lateral ejective affricate coarticulatory interactions: articulation

In consideration of this prediction made on the basis of the acoustic results, which is that the TR exhibits a phonetic movement dictated by vowel environment, a comparison of the tongue position of the lateral ejective affricate by vowel context is presented in Figures 5.7a-b along with Tables 5.9-10.[9] These graphs represent measurements of the TR position as viewed along the mid-saggital plane (measurement #1). These graphs illustrate the correlation between the amount of TR retraction backward upon release of the lateral ejective affricate and the adjacent vowel environment.[10] The tongue

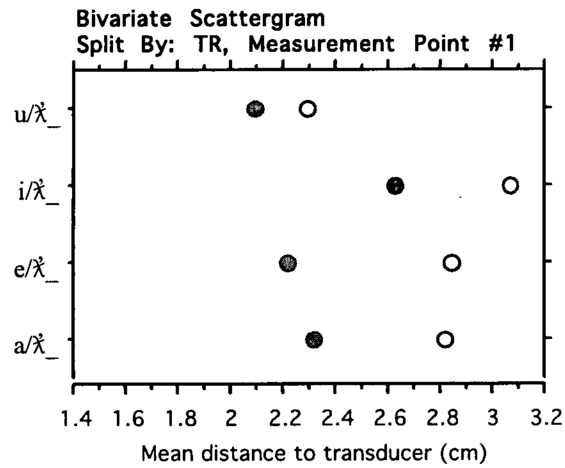
[9] No a/_ƛ sequences were available for comparison.
[10] Note that the /i/ and /u/ positions appear to be unexpectedly reversed. However, this observation is mitigated by various factors. TR position for both vowels are very advanced. /u/ is a back vowel by nature of its tongue dorsum and tongue body position, not its tongue root location. Finally, note that current data

constriction measurement is the still frame extracted form the real time ultrasound imaging of the tongue at the *time* of the lateral ejective affricate's tongue tip constriction at the alveolar ridge. The measurement for the TR retraction is taken at the *time* of the tongue's peak movement backward towards the pharynx.



○ Final TR Position (Peak back movement)
● Initial TR position(at time of tongue constriction)

Figure 5.7a V/_ƛ TR position



○ Final TR Position (Peak back movement)
● Initial TR Position (at time of tongue constriction)

Figure 5.7b V/ƛ_ TR position

Table 5.9 Descriptive Statistics: V/_ƛ
Split by Environment; Time of Measurement

Mean distance to transducer from TR (cm)		Std. Dev.	# of Tokens
u/_ƛ - initial	1.58	.067	3
u/_ƛ - final	3.03	.131	3
i/_ƛ - initial	1.77	.160	9
i/_ƛ - final	2.77	.481	9
e/_ƛ - initial	1.96	.060	5
e/_ƛ - final	3.04	.040	5

Table 5.10 Descriptive Statistics: V/ƛ_

Mean distance to transducer from TR (cm)		Std. Dev.	# of Tokens
u/ƛ_ - initial	2.09	.185	14
u/ƛ_ - final	2.29	.251	14
i/ƛ_ - initial	2.63	.059	3

has only 3 tokens of u/_ƛ. Furthermore, the /i/ and /u/ are seemingly reversed in expected tongue root position when following the /ƛ/ as well. However, this is probably because all examples of i/ƛ_ are preceded by two articulations of [ƛ] which would establish the TR in a farther back position.

i/ƛ̓_ - final	3.07	.185	3
e/ƛ̓_ - initial	2.22	.449	11
e/ƛ̓_ - final	2.84	.155	11
a/ƛ̓_ - initial	2.32	.480	15
a/ƛ̓_ - final	2.82	.348	15

The above analysis of the amount of retraction demonstrates extreme variability in TR position as a function of vowel environment beyond that of the other laterals. Statistical compilation of lateral ejective affricate articulatory results also demonstrate a large standard deviation by vowel environment in the peak tongue backing motion of the tongue movement as well as the TR position at the time of lateral contact.[11] Since the backward movement by the /ƛ̓/ TR has no specific target, it implies that there is no phonological target. This variation suggests that the tongue retraction movement is a phonetic volume-preserving by-product created by the release of the lateral ejective. There is, therefore, no necessary gestural target. If there is no target, then variability of this sort, where the vowel has overriding determination in tongue root position, is expected.

Furthermore, a visual comparison of all the laterals via the ultrasound imaging reveals that the large TR release movement is isolated to only the lateral ejective affricate. That is, despite its TR movement, belonging to the class of laterals is not enough for phonological retraction to occur.

This variability by vowel context is consistent with the pattern found in the acoustic data. Recall from Figure 5.6 that /ƛ̓/ significantly lowered the F2 values for a following /i/ such that this retracted vowel did not reach neutral /i/ values until between the midpoint and the final edge of the vowel production. Figure 5.7b above shows that i/ƛ̓_ exhibits the greatest degree of retraction in its peak release tongue position (3.07cm from the transducer arc), thereby helping to explain why it takes the longest for /i/ to reach actual [i] formant averages. This does not equate to the largest difference in movement from initial to final /ƛ̓/ position, but simply the most retracted final tongue position. Unexpectedly, this large TR movement is *not* reflected in the F3 measurements, since no statistically significant differences were found, but only in F2.

As shown in the previous chapter, the lateral ejective affricate demonstrates a clear case of tongue root retraction. This retraction is reflected in the acoustic effects on the adjacent vowels, but because of the glottal pause, much of the gestural resolution can take place without the entire audio signal of the vowel being affected. It is predicted that there would be a greater acoustic affect on the adjacent vowels from such a large amount of tongue root retraction if the tongue resolution did not partially take place during glottal closure. Nevertheless, since acoustic effects are present, and the large TR movement is visibly distinct, it is very interesting to question why the lateral ejective affricate has never been posited to pattern with the other retracted consonants.

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[11] Clarification of the tongue constriction measurement is necessary: this is the still frame extracted from the real time ultrasound imaging of the tongue at the *time* of the lateral ejective affricates tongue tip constriction at the alveolar ridge.

5.5 Lateral Fricative

Section 5.5.1 Lateral fricative coarticulatory interactions: acoustics

Lastly, coarticulatory investigation into the effects of the retraction on the lateral consonants concludes with the lateral fricative. The acoustic effects are presented first. Previous research has not documented any perceptual differences for vowels adjacent to lateral fricatives, nor have any distributional differences been listed in the Montana Salish dictionary files for vowels adjacent to the lateral fricative. However, the current acoustic investigation of F1, F2, and F3 between vowels in neutral contexts and the vowels adjacent to the lateral fricative, reveals a handful of statistically significant differences. The data for the V/ɬ_ sequences are listed below.

The first table lists the significant differences between neutral /i/ and the /i/ following the lateral fricative. Notice that the /i/ in the lateral context shows a higher F1, lower F2, and lower F3. This implies that the /i/ following the lateral fricative has a lower TB, more TB backing, and more TR retraction, than neutral /i/.

Table 5.11 Acoustic measurements for i/ɬ_ vs. /i/

Significant differences:	Averages:	Significance levels	# of Tokens
F1 05% - i/ɬ_ : i	Hz 436 : 398	.0152	20:18
F2 05% - i/ɬ_ : i	Hz 2458 : 2664	<.0001	20:18
F2 50% - i/ɬ_ : i	Hz 2732 : 2875	.0012	20:18
F3 05% - i/ɬ_ : i	Hz 3120 : 3331	<.0001	20:17
F3 50% - i/ɬ_ : i	Hz 3283 : 3417	.0011	20:18

The /u/ following the lateral fricative similarly shows significant differences in both the second and third formant. Here, however, the opposite tongue movement is implied. The higher F2 for u/ɬ_ indicates TB advancement, and the lower F3 indicates more TR retraction.

Table 5.12 Acoustic measurements for u/ɬ_ vs. /u/

Significant differences:	Averages:	Significance levels	# of Tokens
F2 05% - u/ɬ_ : u	Hz 1724 : 1406	.0004	13:23
F2 50% - u/ɬ_ : u	Hz 1399 : 1198	.0015	13:23
F3 05% - u/ɬ_ : u	Hz 2926 : 3167	<.0001	13:19
F3 50% - u/ɬ_ : u	Hz 3146 : 3279	.0002	13:20

As seen in Table 5.13, the e/ɬ_ sequences show differences only in the third formant. Here a lower F3 for the /e/ [ɛ] following the fricative is indicative of more TR retraction. Neither the F1 nor the F2 formant values yield any significant differences between the neutral and non-neutral vowels.

Table 5.13 Acoustic measurements for e/ɬ_ vs. /e/

Significant differences:	Averages:	Significance levels	# of Tokens
F3 05% - e/ɬ_ : e	Hz 3141 : 3326	.0002	9 : 18
F3 50% - e/ɬ_ : e	Hz 3327 : 3353	.0001	9 : 18

Lastly, the a/ɬ_ sequence in Table 5.14 below shows significant differences from the neutral vowel only in the second formant. Here F2 for /a/ is much higher when following the lateral fricative. This is indicative of an advanced TB position.

Table 5.14 Acoustic measurements for a/ɬ_ vs. /a/

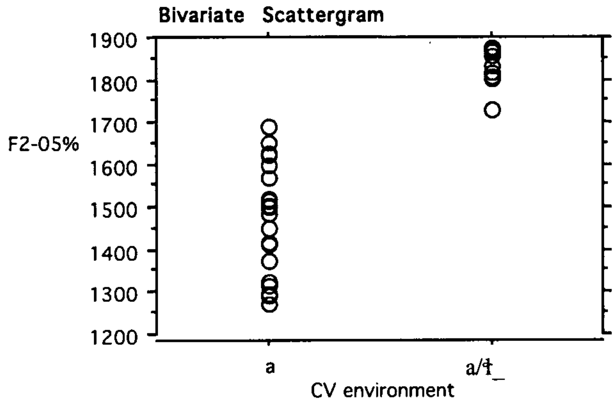
Significant differences:	Averages:	Significance levels	# of Tokens
F2 05% - a/ɬ_ : a	Hz 1829 : 1456	<.0001	9 : 22
F2 50% - a/ɬ_ : a	Hz 1542 : 1418	.0018	9 : 22

As the tables above illustrate, there is no significant difference for F1 between u/ɬ_ and /u/, e/ɬ_ and /e/, or a/ɬ_ and /a/. There is however a significant difference for i/ɬ_ and /i/ at 05% into the vowel such that F1 implies that the vowel in i/ɬ_ has a higher tongue body than the same vowel in a neutral environment.

F2 for i/ɬ_ vs. /i/ entails more TB backing for the /i/ following the fricative. However, both F2 averages for /u/ and /a/ following the lateral fricative indicate a more fronted TB than the corresponding neutral vowel, that is, a TB fronting as opposed to backing. Therefore, F2 seems to indicate that /ɬ/ fronts the TB position of the back vowels, but retracts the TB position of the high front vowel.

F3 shows an independent degree of tongue root retraction for the vowel in the e/ɬ_ sequence as opposed to the neutral /e/. Here the /ɬ/ retracts the tongue root of the following /e/ vowel. Similarly, F3 for /u/ and /i/ imply that the TR is more retracted for the vowel in the /ɬ/ context. There were no significant differences in F3 for the a/ɬ_ sequences.

The a/ɬ_ vs. /a/ and u/ɬ_ vs. /u/ data is worth further elaboration because the lateral fricative actually works to raise the formants of the following vowel, despite the vowel's back position. This raising seems regardless of vowel height, as it affects both /a/ and /u/. The figure below illustrates a more detailed look at the significant differences between F2 for /a/ following the lateral fricative, and /a/ averaged over neutral environments. Here the frequencies for /a/ following the lateral fricative indicate a more fronted tongue body.

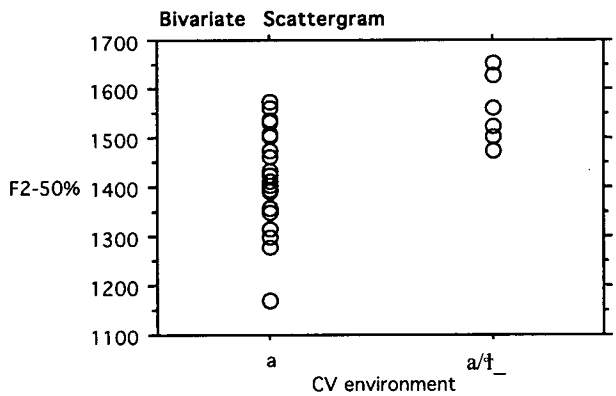


Means Table for F2-05%
Effect: CV environment

	Count	Mean	Std. Dev.	Std. Err.
a	22	1456.273	134.850	28.750
a/ɬ_	9	1828.889	45.504	15.168

Fisher's PLSD for F2-05%
Effect: CV environment
Significance Level: 5 %

	Mean Diff.	Crit. Diff.	P-Value	
a, a/ɬ_	-372.616	94.858	<.0001	S



Means Table for F2-50%
Effect: CV environment

	Count	Mean	Std. Dev.	Std. Err.
a	22	1418.773	99.777	21.273
a/ɬ_	9	1542.222	62.026	20.675

Fisher's PLSD for F2-50%
Effect: CV environment
Significance Level: 5 %

	Mean Diff.	Crit. Diff.	P-Value	
a, a/ɬ_	-123.449	73.596	.0018	S

Figure 5. 8 Acoustic statistics for a/ɬ_ vs neutral /a/

Interpretation of the F1 and F2 results in light of the retracted and non-retracted lateral fricative in Moses-Columbian Salish as described in Bessell (1998) exemplify that while there is a statistically significant difference between the /i/ following the /ɬ/ and the /i/ in a non-retracted environment, this may not equate to a distinct retracted /ɬ/ phoneme in Montana Salish. Bessell (1998a:147-148) found an average F2 difference at vowel onset between the retracted /ɬ/ and non-retracted /ɬ/ ranging between 600-700 Hz while the present MTS F2 measurements average only ~200 Hz apart. The Moses-Columbian measurements for F1 on the /i/ vowel similarly rose 150-200 Hz while MTS F1 measurements average only 38 Hz apart.[12] No F3 data is presented in Bessell's work for comparison with the present results.

Next, the V/_ɬ sequences are examined. The formant averages for both /e/ and /u/, entail that the vowel in the context of the lateral fricative has a slightly lower tongue body than the neutral vowels. This is indicated by the higher first formant and is presented below in Table 5.15.

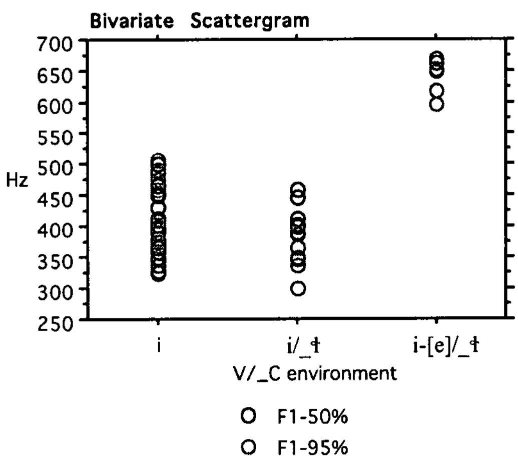
[12] Bessell's measurements occur at vowel onset which can be interpreted in comparison with the current study's measurement at 05% into the vowel. Bessell lists two speakers with the 150-200Hz range for F1. However, her third speaker (ED) did not show any change in F1.

Table 5.15 Acoustic Measurements /e/ vs. e/_ɬ and /u/ vs. u/_ɬ

Significant differences:	Averages:	Significance levels	# of Tokens
F1 50% - e : e/_ɬ	Hz 584 : 740	.0008	18 : 7
F1 95% - e : e/_ɬ	Hz 556 : 726	.0008	18 : 7
F1 95% - u : u/_ɬ	Hz 406 : 465	.0245	20 : 7

Upon investigation of the i/_ɬ sequences it became evident that the tokens separated into two patterns. Because these two patterns were acoustically quite distinct, further investigation became necessary in order to determine whether these effects were due to the lateral fricative or whether they were external. Multiple repetitions of two words, *miɬ* 'too much' and *nt̓iɬk̓ʷ* 'dirty water' comprised the i/_ɬ sequences used in this analysis. Of the eight total *miɬ* productions, there were four whose vowel quality is distinctly closer to an [e], than an [i]. All of the *miɬ* examples were taken from the same sentence *miɬ čta ɬu mali* 'Mary is too skinny'. However, for lack of additional i/_ɬ sequences, all of these tokens have been included in the overall i/_ɬ average.

The primary difference in the i/_ɬ sequences is visible in the first formant. The i/_ɬ results are separated into two perceptually based categories, both of which are paired against the neutral /i/ values. That is, these two categories distinguish those four *miɬ* tokens which have [e] from all the other examples of /i/ preceding the lateral fricative. Therefore, the first [iɬ] is comprised of all the i/_ɬ sequences which are perceptually pronounced with an [i], and the second, (represented in the third column in Figure 5.9) is comprised of the remaining tokens with an auditory perception of a lowered vowel near to a phonetic [e].[13] The statistical means and significance pairings are show in the tables below.



Fisher's PLSD
Effect: V/_C environment
Significance Level: 5 %

	Mean Diff.	Crit. Diff.	P-Value		
i, i/_ɬ	4.736	36.441	.7917		
i, i-[e]/_ɬ	-233.139	47.405	<.0001	S	**F1-50%**
i/_ɬ, i-[e]/_ɬ	-237.875	52.517	<.0001	S	

	Mean Diff.	Crit. Diff.	P-Value		
i, i/_ɬ	42.278	41.839	.0478	S	
i, i-[e]/_ɬ	-223.972	54.428	<.0001	S	**F1-95%**
i/_ɬ, i-[e]/_ɬ	-266.250	60.297	<.0001	S	

Means Table for F1-50%
Effect: VC environment

	Count	Mean	Std. Dev.	Std. Err.
i	18	417.611	49.163	11.588
iɬ	8	412.875	25.425	8.989
iɬ_[e]	4	650.750	22.765	11.383

Means Table for F1-95%
Effect: VC environment

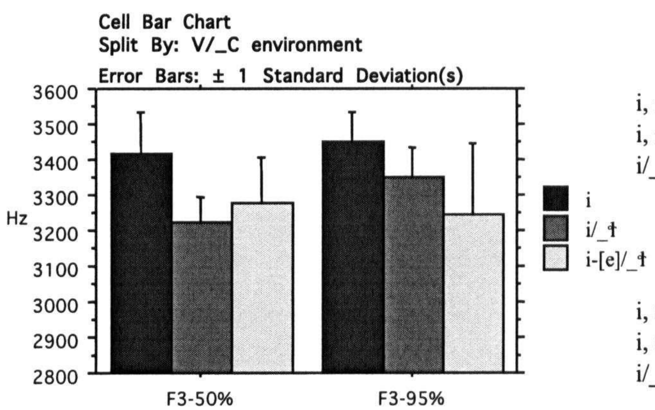
	Count	Mean	Std. Dev.	Std. Err.
i	18	392.778	56.858	13.402
iɬ	8	350.500	26.849	9.492
iɬ_[e]	4	616.750	26.912	13.456

[13] Please note that this [e] is the phonetic representation even though <e> is the standard orthographic convention for what is phonetically realized as [ɛ].

Figure 5.9 F1 /i/ vs i/_ɫ separated into perceptual categories

Note that even when the i/_ɫ words are separated perceptually, the [i]/_ɫ tokens still show a statistically significant difference from the neutral /i/ values at F1 95%. However, although not shown, when all the i/_ɫ sequences are grouped as one category, regardless of vowel quality, the statistical significance between /i/ preceding /ɫ/ and the neutral /i/ values disappeared.

A similar statistical comparison for F2 reveals no significant difference between any of the pairings, either when the i/_ɫ sequences are separated perceptually or when they are combined all together. However, statistically significant differences are evident in the third formant as shown in Figure 5.10 below. Here, F3 is statistically significant for all pairings against neutral /i/. That is, there is a significant difference between neutral /i/ paired against i/_ɫ and also against i-[e]/_ɫ (separated perceptually). However, no significant difference was found between the two perceptually separated sets of i/_ɫ tokens.



Fisher's PLSD for F3-50%
Effect: V/_C environment
Significance Level: 5 %

	Mean Diff.	Crit. Diff.	P-Value	
i, i/_ɫ	192.014	94.189	.0003	S
i, i-[e]/_ɫ	137.889	122.530	.0288	S
i/_ɫ, i-[e]/_ɫ	-54.125	135.741	.4204	

Fisher's PLSD for F3-95%
Effect: V/_C environment
Significance Level: 5 %

	Mean Diff.	Crit. Diff.	P-Value	
i, i/_ɫ	100.578	103.966	.0573	
i, i-[e]/_ɫ	208.662	121.669	.0017	S
i/_ɫ, i-[e]/_ɫ	108.083	141.325	.1276	

Means Table for F3-50%
Effect: V/_C

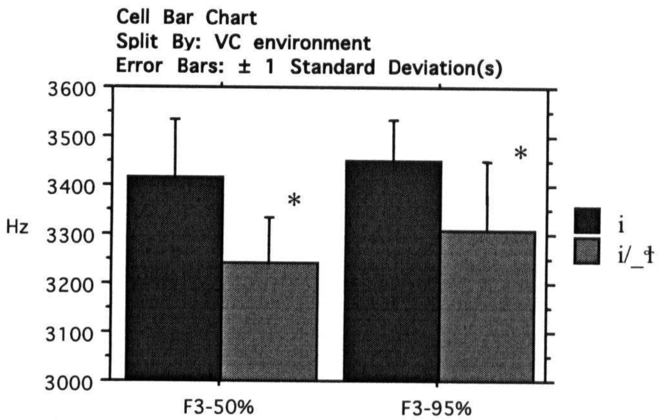
	Count	Mean	Std. Dev.	Std. Err.
i	18	3416.889	117.227	27.631
i/_ɫ	8	3224.875	69.538	24.585
i-[e]/_ɫ	4	3279.000	126.034	63.017

Means Table for F3-95%
Effect: V/_C

	Count	Mean	Std. Dev.	Std. Err.
i	17	3450.412	83.103	20.155
i/_ɫ	6	3349.833	85.563	34.931
i-[e]/_ɫ	4	3241.750	202.462	101.231

Figure Set 5.10 F3 /i/ vs i/_ɫ perceptual categories

Next, even when all twelve of the i/_ɫ tokens are combined, the difference between the third formant values remains at both 50% and 95% into the vowel. This is shown in the Figure 5.11 below. Statistically significant differences are denoted by the two stars above the columns in the bar graph. If these the tokens with retracted /i/ to [e] were taken from a different set of words, it could be plausible to suggest that these differences in F3 reflect a distinction in the amount of TR retraction in the /ɫ/ production as a result of two /ɬ/ and /ɬ̣/ phonemes. However, since these results primarily reflect variability within pronunciation of single word, the cause of the difference is not clearly understood.



Means Table for F3-50%
Effect: V/_C environment

	Count	Mean	Std. Dev.	Std. Err.
i	18	3416.889	117.227	27.631
i/_ɬ	12	3242.917	90.108	26.012

Means Table for F3-95%
Effect: V/_C environment

	Count	Mean	Std. Dev.	Std. Err.
i	17	3450.412	83.103	20.155
i/_ɬ	10	3306.600	144.382	45.657

Figure Set 5.11 F3 /i/ vs i/_ɬ combined

Interestingly, the patterns above are only partially consistent with the trends presented in Bessell (1998a). In her data, the Moses-Columbian Salish retracted lateral fricative was primarily visible through its effects on the lowered F2 of the adjacent vowel. In the Montana Salish data presented here, F2 does lower on the adjacent high vowels, but only minimally as compared with the retracted fricative in Moses-Columbian Salish (Bessell 1998a:147-148). For example, /i/ following retracted /ɬ̣/ in Moses-Columbian Salish had an average range for F1 between 388Hz and 547Hz. (Data for /i/ preceding the lateral fricative was not documented in that study). However, for i/ɬ_ sequences in Montana Salish the /i/ values averaged near 439 Hz as compared to a neutral /i/ average of 398Hz. In addition, the F2 results for the lateral fricative in Montana Salish suggest a fronting of the TB for the u/ɬ_ and a/ɬ_ back vowels, but not any retraction. Bessell (1998a:148) documents a change in F2 for Moses-Columbian /i/ at vowel onset from near 2300Hz when following the non-retracted lateral fricative, to near 1600Hz when following the retracted lateral fricative. Montana Salish /i/ changed only from 2664Hz to 2458Hz at the 05% measurement point. F3 results in the current acoustic investigation were variable but as Bessell (1998a) did not report any F3 results for the i/ɬ_, comparison is not possible.

The overall implications of an acoustic investigation of the lateral fricative are similar to the previous vowels. While sometimes supported by significant differences in F1 or F3, only F2 consistently displayed retracted effects for each of the lateral-vowel interactions. The third formant shows low values for only some of the vowels (/i/, /u/, and /e/ following /ɬ/, and only /i/ preceding /ɬ/), just as there was only a significant correlation for F3 in the investigated i/_q but not the i/q_ sequences. It is possible that the minimums and maximums for the third formant signal are simply balancing out between each other as a result of constrictions and extensions of the tongue. Not only does this lack of consistency support the necessity of a direct investigation into the articulators involved, but it further suggests that the third formant does not prove most informative or consistent in its implications of tongue movement. F1 also seems to be equally variable in reflecting tongue body movement whereby it did not consistently show significant differences for each of the vowel contexts, only i/ɬ_, e/_ɬ, u/_ɬ, and i/_ɬ (only when separated into [i]/_ɬ and [e]/_ɬ sequences). Nevertheless, summary of the acoustic comparison with the retracted and non-retracted lateral fricative in Moses-Columbian Salish does not show continuity with the /ɬ/ results for Montana Salish. These results suggest that there is only one /ɬ/ in Montana Salish and it is not retracted.

Section 5.5.2 Lateral fricative coarticulatory interactions: articulation

Since the acoustic investigation has revealed certain coarticulatory effects, three methods are used to investigate articulatory retraction by the lateral fricative in relation to the vowels. The first compares the lateral fricative to the /i/, /a/, and /e/ [ɛ] vowels to demonstrate its position within the mouth, with interspeech rest position included for reference. The second compares the position of the lateral fricative in the /a/ and /i/ vowel contexts in order to demonstrate the varying position of the lateral fricative. The last comparison illustrates the /i/ vowel tongue position in the context of /ɬ/ as paired against the neutral /i/ vowel tongue position.

The following graph in Figure 5.11 illustrates the average /ɬ/ tongue position as compared with the /i/, /e/ and /a/ vowels, and also with interspeech rest position. The plotted values for /ɬ/ represent the average from all the /ɬ/ tokens. Notice that the TR placement for the lateral fricative at measurement points #1 and #2 is very similar to the position of the /e/ [ɛ] vowel. There is no statistically significant difference between the /e/ and the /ɬ/ at these first two initial measurement positions. Both of these segments are also less retracted than interspeech rest, and /a/ vowel TR position. The TR difference between /ɬ/ and rest, /i/, and /a/ is statistically significant.

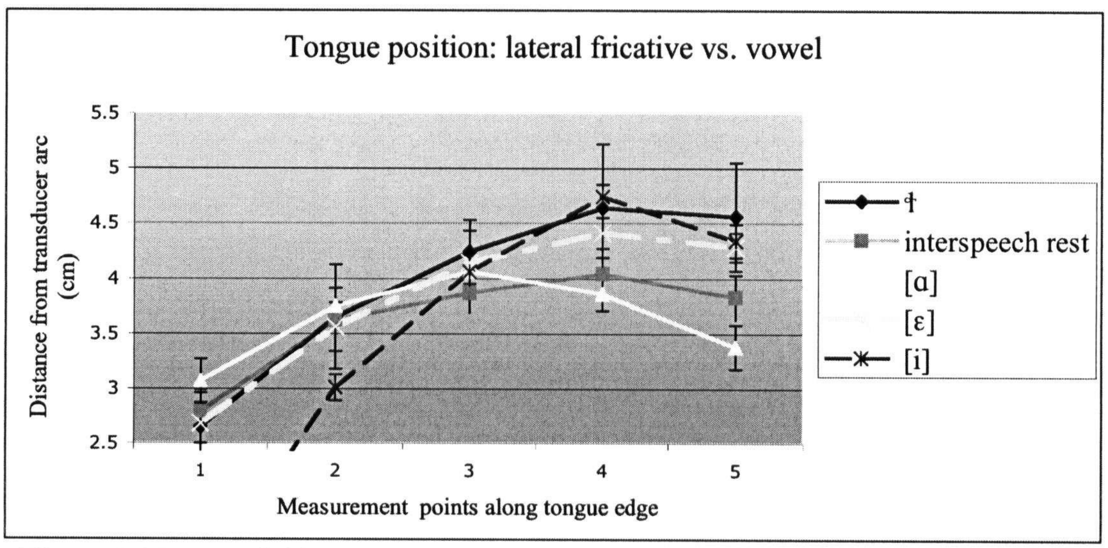


Figure 5.11 Lateral fricative tongue positioning as compared to /a/, /e/, /i/, and rest

Table 5.16 Measurements for lateral fricative vs. vowels tongue position

Mean tongue position (cm)	TR		TR up 2cm		TR up 4cm		TR up 6cm		TT to trans	
	Avg:	St.dev	Avg:	St.dev	Avg:	St.dev	Avg:	St.dev	Avg:	St.dev
ɬ	2.65	0.31	3.65	0.47	4.24	0.29	4.64	0.58	4.56	0.49
rest	2.79	0.2	3.62	0.16	3.87	0.18	4.04	0.15	3.83	0.2
[ɑ]	3.07	0.15	3.75	0.15	4.06	0.17	3.86	0.14	3.38	0.15
[ɛ]	2.68	0.18	3.56	0.22	4.14	0.29	4.41	0.14	4.28	0.13
[i]	1.18	0.14	3.01	0.12	4.06	0.18	4.74	0.11	4.34	0.15

In complement to the emerging lateral consonant pattern where by the TR of the lateral is less retracted than /a/, interspeech, and resides near the /e/ [ɛ] position, notice that unlike the previous laterals, by the second measurement point, the /ɬ/ has not completely reversed position with the vowels and become more retracted. That is, the lateral approximants presented a more retracted tongue position at measurement #2, but here the lateral fricative has not quite surpassed the other vowels in its distance from the transducer arc.

One additional trend which is observed in the above graph and corresponding table, is that the /ɬ/ has a very large standard deviation as compared with either the vowels or interspeech rest position. This large variance indicates the /ɬ/ relationship to its adjacent vowel environment. That is, the /ɬ/ tongue position is correlated with vowel context. This variation is shown below. In Figure 5.12, the inner dashed line is the initial frication following the /i/ vowel. The middle line is the position of the tongue during the end of the lateral frication (word finally). The outer dotted line is the midpoint for the frication for the a/ɬ_ sequence. Notice the gradient tongue root and dorsum positioning for each of these V/ɬ_ sequences even while the tongue body maintains stable placement.

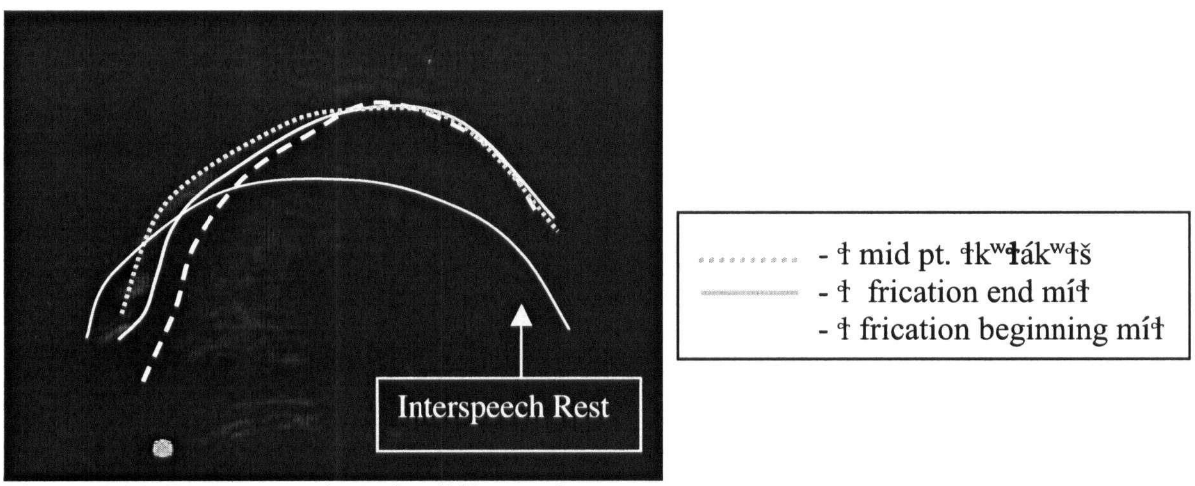


Figure 5.12 Tongue tracings for /ɬ/ by environment

However, despite this more retracted position as compared with the high front vowel, this /ɬ/ position back does not quite reach the interspeech rest position.[14] Recall

[14] Recall from Section 5.5.1 that the vowels in the *miɬ* tokens were separated into [e] and [i]. The tongue tracing used here represents /ɬ/ taken from a *miɬ* repetition where the vowel was pronounced [i].

from Figure 5.11, that only the /a/ vowel was more retracted in TR position than interspeech rest, although /e/ [ɛ] tongue position was close to rest for measurement #1 at the TR. Upon evaluating the /ɬ/ position in relation to this data, it becomes clear that /ɬ/ does not exhibit an overall retracted tongue position. That is, since the TR for /ɬ/ in a retracted or non-retracted vowel environment never reaches the amount of retraction displayed by interspeech rest, /e/ or /a/, it does not seem plausible to consider it a physically "retracted consonant".

Furthermore, note from the above tongue tracings, that the tongue body and tongue tip for the /ɬ/ are consistently produced in the same location. That is, unlike the TR and the TD areas of the tongue, the TB maintains the target position for the production of the lateral fricative. The variable TR position signifies that the gestural target is only specified for the TB position, and not the TR or TD.

Since the TB and TT position for the lateral fricative remain constant regardless of environment, it suggests that the lateral fricative tongue position is specified only for the TB (but not the TR and TD), with the range of tongue root movement being dictated by the adjacent segment environment. However, while the final TR position is not specified exactly, it maintains a positional range that corresponds to the fricative production. This TD and TR range resides in between the advanced tongue position for a high front vowel and the retracted tongue position for a low back vowel. Thus, its position as shown in the image above is consistent with the acoustic measurements which indicated that the lateral fricative fronts the tongue body position of the /a/ and the /u/ but retracts the tongue body position of the already front /i/ vowel.

One last comparison is presented to establish the nature of tongue retraction for the lateral fricative. Since the acoustics indicate a lowering of the adjacent /i/ vowel (via the second formant), and the plotted graph 5.11 illustrates that the /ɬ/ is in a more retracted position than the high front vowel, it is necessary to examine whether the lateral fricative affects the average tongue position of the adjacent /i/ vowel. The chart and table below illustrate the average tongue positions based on measurements 1-5 for the /i/ vowel preceding the /ɬ/ paired against the /i/ vowel in neutral contexts. Here, it seems that the /ɬ/ does not compromise the tongue positions for the high front vowel except at the initial TR position. Only measurement point #1 at the base of the TR exhibits a statistically significant difference between the /i/ adjacent to the /ɬ/, and the /i/ in a neutral environment. However, the numerical difference at this measurement locale is not large with the i/_ɬ TR position at 1.77cm from the transducer arc, and the neutral /i/ at 1.81cm from the same point. This does seem to correspond to the acoustic difference found for F3 for the same /i/-lateral fricative sequence.

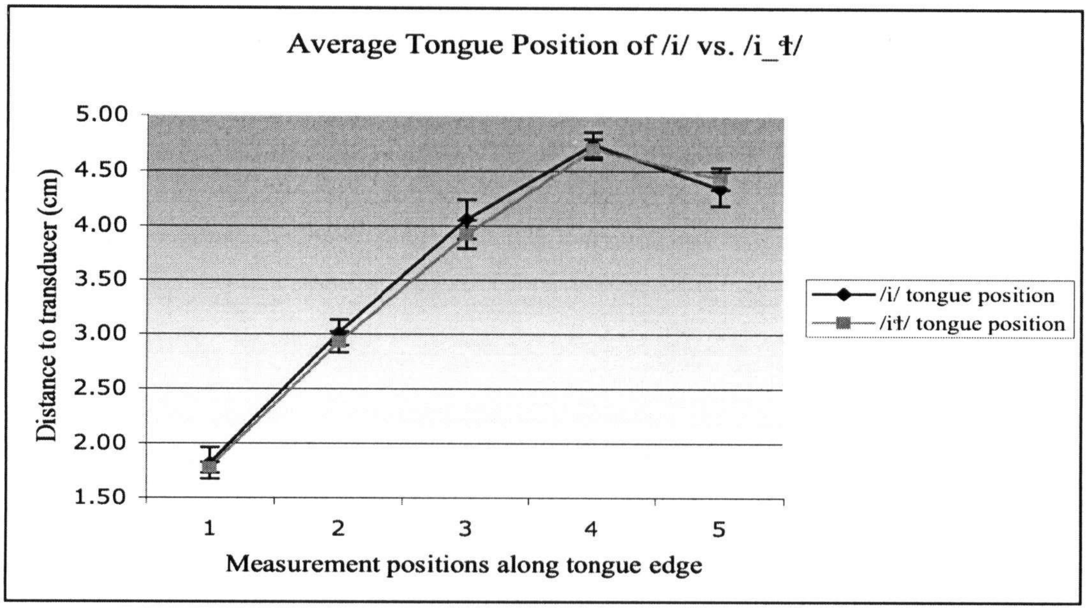


Figure 5.13 /i/ tongue position: neutral /i/ vs. i/_ɬ

Table 5.17 Mean tongue position for neutral /i/ vs. i/_ɬ

Number of tokens		TR cm		TR up 2cm		TR up 4cm		TR up 6cm		TT to trans		TT to TR	
		Avg:	St.dev	Avg:	St.dev	Avg:	St.dev	Avg:	St.dev	Avg:	St.dev	Avg:	St.dev
18	/i/	1.81	.143	3.01	.120	4.06	.181	4.74	.110	4.34	.161	6.43	.203
12	i/_ɬ	1.77	.05	2.93	.096	3.92	.132	4.69	.090	4.43	.102	6.54	.097
Significant		yes		no		no		no		no		no	

Through considering all the above examinations, it should be clear from the data presented above, that the lateral fricative has a target tongue position that does not include an inherent retracted movement which is anything close to that of the other laterals. Despite the lateral fricative's ability to influence the adjacent /i/ vowel TR position, the overall tongue position of the lateral fricative is clearly advanced as compared to interspeech rest. In addition, unlike the three other laterals, /l, lʼ, ƛʼ/, the fricative does not demonstrate a retracted TD or TR movement. Taken in consideration with the lateral fricative acoustic results, it is apparent that the lateral fricative instead holds a medial TB position in between the back and front vowels. This medial targeted tongue position acts to raise the back vowels, but lower the front vowels, even though only the TR position varied for the /i/ vowel in the i/_ɬ sequence as compared with the neutral /i/ position. Furthermore, while the TB and TT positions seem stable, the corresponding TR and TD positions are variable such that the tongue position of the /ɬ/ is fronted next to those same high vowels, but more retracted next to the low vowels.

In addition to this medial tongue position there is small, variably produced TD peak that showed up on a few of the /ɬ/ repetitions. This small peak was only visible irregularly and does not act or look similar to the TD gesture for the lateral approximants (Figures 4.1 and 4.7). An example of this is illustrated in Figure 5.12. for the /ɬ/ tongue tracing in *ɬkʷɬ̱ákʷɬš*. Regardless, the overall evidence for the lateral fricative does not seem to group with the retracted tongue movements utilized by the other lateral consonants. The lateral fricative does not exhibit a retracted movement by either the TD or the TR.

5.6 Coarticulatory interactions: acoustic and articulatory conclusions

The overall coarticulatory examination as presented in the current chapter has confirmed the retracted status of the /l/, /ľ/, /ɬ/, and /ʎ̊/. The acoustic results form a general trend for vowel interaction with the lateral consonants, though the amount of formant change is variable by consonant. This is most consistently visible through the second formant. Common to all the laterals is this pattern of retracting the tongue position of the high vowels, but advancing the tongue position of the low vowels. That is, the laterals demonstrate a general lowering of F2 for the adjacent high vowel (specifically /i/), and a rising of F2 for the adjacent low vowels (specifically /a/). This proved consistent for both V/C_ as well as V/_C contexts.

To illustrate this pattern, the table below presents the V/_C sequences for each of the four laterals as compared with both /a/ and /i/. Here it is clear that F2 rises for all lateral-/a/ sequences, and lowers for all lateral-/i/ combinations. Furthermore, the variable and inconsistent F1 and F3 results are visible. It is not clear why the drastic F2 lowering which spans the entire vowel in the i/ʎ̊_ sequence is not also manifested in the F3 and F1 formants.

Table 5.18 Formant effects on the vowel by V/C_ context

Lateral to Vowel Sequence	F1 effect	F2 effect	F3 effect
i/l_	none	lower	lower
a/l_	higher	higher	none
i/ľ_	none	lower	lower
a/ľ_	none	higher	none
i/ʎ̊_	none	lower	none
a/ʎ̊_	lower	higher	lower
i/ɬ_	higher	lower	lower
a/ɬ_	none	higher	none

Because the laterals have conformed to the general pattern of advancing the low back vowel tongue body position, but retracting the high front vowel tongue body position, their coarticulatory effects upon the adjacent vowels are those of consonants with a medial tongue position located between the high and low vowel positions. Nevertheless, there can be no doubt that these medial tongue positions exhibit a large coarticulatory effect on the adjacent vowel. Interpreted in addition with the articulatory evidence, which demonstrates that the overall tongue position itself also varies by the vowel context, it seems that the designation of an articulatory target is specified for the individual locus along the tongue, rather than encompassing the whole muscle. In each of the laterals, the TR and TD are variable in position, while the TB and TT/tongue blade, are stable. Within the TR and TD, the TD includes a specified retracted gesture for the lateral approximants, but achievement of this target is dictated by adjacent contextual coarticulatory influences. The TR does not exhibit a retracted gesture for any of the laterals, even though for the lateral ejective affricate it exemplifies a retracted movement as a phonetic byproduct of other gestures.

Furthermore, this coarticulatory information provides further enlightenment in the function of phonetics and phonology for the lateral consonants. All the laterals show coarticulatory effects similar to the acoustic patterns, and variable TR and TD positioning as a function of vowel context. However, these are hypothesized to occur as result of different types of retraction. For example, the /ɬ/ does not exhibit a phonetically retracted movement to its tongue movement (either TR, TD or TB), but coarticulatory vowel interaction does show a difference in ultimate tongue position such that the TR and TD position of the /ɬ/ are more advanced when adjacent to an /i/ than when they are adjacent to an /a/. Similarly, the TR position for /l/ is more advanced when adjacent to and /i/ as compared to the /l/ adjacent to an /a/, as is the TR positioning for the /ƛ'/. The lateral approximants differ from the lateral ejective affricate in type of tongue retraction, yet they all show retraction effects on the adjacent vowels.[15]

[15] It is still not clear why the lateral ejective affricate has never been proposed to pattern with the other retracted laterals.

Chapter 6 Discussion of Results

It is clear from the data presented in the previous chapters that articulatory retraction is a function of some laterals in Montana Salish. The lateral approximant, glottalized lateral approximant, and lateral ejective affricate all exhibit some retracted movement by the tongue, though to varying degrees and in different directions. Alone among the laterals, the fricative does not display a distinct retracted movement in its overall position and shape. All of the lateral consonants show coarticulatory retracted effects and variability by vowel context. These observations do not entirely comply with the initial proposal of the study. As proposed in the initial hypothesis, /l/ and /l̓/ exhibit a retracted tongue movement most similar to the uvulars as compared with the other laterals, (though this movement is still quite distinct and is discussed more below). However, contrary to the initial proposal, the /ƛ̓/ also demonstrated a large retraction movement by the tongue and has an ultimate tongue position that is phonetically closer to the pharynx than the other laterals. Phonological and distributional patterning of the /ƛ̓/ is entirely distinct from the uvulars and pharyngeals which are also produced with a tongue retraction into the pharynx. The primary investigated movements are summarized in the table below.

Table 6. 1

Locus of Tongue Movement	l	l̓	ɬ	ƛ̓	ƛ[1]	q
TB	no	no	no	no	(no)	no
TD	yes	yes	var	no	(yes)	yes
TR	no	no	no	yes	(yes)	yes

6.1 Tongue Dorsum vs. Tongue Root Retraction

The retraction exhibited by the Montana Salish lateral reveals something more: an important differentiation between tongue root and tongue dorsum retraction. The lateral approximants exhibit TD retraction, while the lateral ejective affricate exhibits TR retraction. While many studies on Salish retraction have not distinguished TR from TD retraction, there is a general distinction in the retraction literature (as described by Bessell 1998a; Cole 1987; Doak 1987; and Shahin 2002) between uvularization and pharyngealization. However, as the articulatory investigation into the Montana Salish uvular consonant production discussed in this study demonstrates, production in the uvular area is also coupled with a tongue presence in the pharyngeal area. This is consistent with the claims of Shahin (2002:24) who cites the Arabic /χ/ (and the other uvulars) as being comprised of a primary uvular and a secondary pharyngeal articulation. Shahin (2002:24) claims that "uvular articulation does not occur without pharyngealisation" (sic). Note that in terms of Browman and Goldstein (1986, 1992), designation of primary and secondary gestures both equate to phonological gestures.

[1] Parentheses are used to denote the non-phonemic status of this particular sound, and because analysis of the [ƛ] is based on multiple repetitions of only one word.

Furthermore, data in this current study illustrating both the Nuu-chah-nulth (Wilson 2003) and Montana Salish uvular stop exemplifies variability in tongue position for this consonant (and set of consonants) by language. As seen through the variable uvular position between the MTS and NCN /q/, the "secondary articulation" of the TR may exhibit more or less presence in the pharynx for the uvular consonants in different languages. Nevertheless, it is present for all the uvulars. It is possible that the degree of TR is specified in each language, but it is more likely that as with other sounds, languages simply differ in exact phonetic realization of the uvular consonants.

Description of the back articulators for the retracted coronals is slightly less meticulous, for lack of previous articulatory investigations into these sounds. Bessell (1998a:125) states that these underlying retracted coronals "involve some lowering and/or backing of the tongue". This movement, however, does not pattern the same as that of the uvular consonants. The lateral approximants within the Montana Salish languages demonstrate that unlike the uvular stop /q/, the MTS /l/ does not involve primary or even secondary pharyngealisation. No TR movement is necessarily coupled with the TD retraction. Futhermore, even within the exhibited TD retraction, there is still variability in its overall position with respect to uvularization. Sometimes the TD position for the /l/ is entirely in the TD area range for the uvular even though the /l/ TR does not mimic the uvular TR position. However, other times, the consonant /l/ does not reach this extreme peak TD position so similar to the uvular position. This was illustrated in the /li/ sequence in *lík̓ʷlɛxʷ* and also the TD movement of the first /l̓/ in the *l̓l̓ac* sequence (Figures 4.2 and 4.6).

This new evidence suggests that while uvularization may not occur without pharyngealization as Shahin claims for her Arabic data, the TD movement of the lateral approximants may occur without a distinct TR movement. This is also contrary to Bessell (1990:9) who cites that retracted coronals are produced with a secondary tongue root retraction. Egesdal's (1993:22) description of the retracted /l/ which specified it as pharyngealized, unrounded, not uvularized or velarized, is also not correct for the laterals investigated in this study. While the current investigation can make no claims on the historically retracted /l/ phoneme, the presently documented /l/ does not fall in this category of a pharyngealized consonant. The articulatory data presented here has clarified that lateral retraction it is not necessarily uvularized or pharyngealized, but another distinct gesture such that this posterior uvular area is targeted only by the TD and not the TR.

However, as the acoustic and vowel harmony evidence suggests, distinction between the tongue root and tongue dorsum movements does not necessarily equate to two different types of phonological retraction. The acoustic effects of tongue dorsum versus tongue root are slightly different, (variably evident F3 and F1); however, through F2 the overall effects are still generally the same. All the laterals raise the low vowels and lower the high vowels. This variability of tongue movement in what determines the outcome of the acoustic signal again underscores the necessity of consulting articulatory evidence. Nevertheless, phonological implications of retraction have been suggested only for the two lateral approximates (i.e. the two segments with tongue dorsum as their primary retracting gesture). The lateral ejective affricate has no known phonological retraction effects despite its large effect on the adjacent vowels acoustic signal. That is, in Montana Salish, /ƛ̓/ is not claimed to participate in regressive or progressive retraction

(Egesdal 1993), nor has it been listed as a retracted segment in any Interior Salish language even though a large TR movement into the pharynx is demonstrated by the /ƛ̓/. This would imply that unlike the established retracted triggers like /Q/ and /ʕ/, etc., the retracted movement of the lateral ejective affricate does not lower adjacent or non-adjacent vowels. However, as clearly demonstrated in the previous chapters, this consonant not only exhibits the largest TR retraction, but it has definite acoustic effects on adjacent vowels, including /i/. These are present despite the glottal nature of this sound.

Phonetic actuality therefore does not restrict the lateral ejective affricate from participating in the phonological retraction processes in which /l/ and /l̓/ are proposed to participate. In all these cases, this local conflict is resolved via the transitory temporal compromise and via not complete vowel laxing/lowering. For whatever reason the two lateral approximants are posited to participate in phonological lowering, which includes non-local interactions of vowel lowering, but the lateral ejective affricate is restricted to immediate vowel transitioning in local contexts. However, if phonological retraction initiates from phonetic effect, then it is unclear why the /ƛ̓/ is not included with the other retracted laterals in phonological processes.

A deeper look at /ƛ̓/ reveals something more than the first impression of only TR retraction. First, as previously mentioned, Montana Salish only has the /ƛ̓/ phoneme, but sometimes has the [ƛ] as a phonetic realization. This non-ejective form occurs only in sequences of reduplicated /ƛ̓/, whereby only the last one is ejected, though all are released. So for the sequence [inƛƛƛ̓í], the first two are non-ejective, (but released), and the last one is ejected. Visual examination of the tongue movement through ultrasound has shown that the release of the *non-ejective* lateral affricates occurs primarily in the direction of the retracted tongue dorsum (in addition to laterally). The direction of this movement is somewhat similar to the direction for the lateral approximates (glottalized and non-glottalized). This smaller, reminiscent TD movement is a likely function of the lateral consonant production whereby in addition to the lateral movement by the sides of the tongue, volume preservation requires some minimal tongue backing. This is likely the same reason the small and variably present TD peak is apparent in some productions of the /ɬ/.

It would be phonologically unintuitive for the /ƛ̓/ to pattern with the approximants and not the fricative as the /ƛ̓/ consists of a [t̓] and a [ɬ]. In each of the /ƛ̓/ and /ɬ/, there seems to be a consistent TB and TT position, but the ultimate position and movement of the TR and TD is variable. This suggests that the /ƛ̓/ retraction is comprised of two distinct components: a small TD retraction for the release of the affricate, and a dominant TR retraction for the ejective release. Nevertheless, analysis of this segment shows that while there are inherently two underlying components to the retracted movement of the /ƛ̓/, the drastic TR movement encompasses any retraction which might occur at the TD. Moreover, it is only the TD movement of the /ƛ̓/ which could pattern with the TD gesture of the lateral approximants, but the TR movement as a phonetic byproduct completely encompasses any TD movement.[2]

If the tongue root (TR) is phonologically unspecified, the large variability by vowel context in TR positioning for the /ƛ̓/ and /ɬ/ is expected. This implies that the phonological gesture, as defined by Browman and Goldstein (1992), is specified only for

[2] It is imperative to differentiate the release of /ƛ/ glottal closure from the release of the /ƛ̓/ as an ejective.

the necessary part of the tongue but not elsewhere. In this case these are the TT and TB area (or at least the tongue constriction area). If this line of thought is correct, then the four laterals are consistent with each other for the phonological gesture, but not those tongue movements which are a byproduct of another via the tongue's interconnected set of muscles in one unit of volume. That is, the TT and TB gesture is specified for the /ƛ̓/ and /ɬ/, while the gesture specified for the /l/ and /l̓/ is the TD and TT.

Another factor differentiating the retraction of the lateral approximants from that of the lateral ejective affricate is the phonetic reality. Since the tongue is a volume preserving hydrostat, compression in one area of the tongue is always in opposition to expansion in another area. In the case of the lateral ejective affricate, the dramatic ejected release has been shown to equate with a large tongue root movement, while the remaining sections of the tongue (TB, TT) remain constant. This TR movement has been established by both acoustic and articulatory evidence to be a phonetic byproduct: an action out of necessity, rather than from phonological specification.

As demonstrated in Chapter 4, there is a biomechanical explanation for the dramatic TR retraction of the lateral ejective affricate: this distinguishes why it is not a function of the ejectives but rather sourced in ballistic volume displacement coupled during ejection. This is consistent with the TD retraction in !Xoo clicks (Traill 1985) and the TD/TR retraction gesture in the [!] in Khoekhoe (Miller-Ockhuizen 2004). Similarly, dramatic volume displacement is the likely source of the Montana Salish vowel quality change between <ko> [k̓ʷ]u and <ku> [kʷ]u (Mengarini 1877-79; Thomason p.c. 2004).

This similar action across such a diverse grouping of sounds implies that the physical motivation for the TR movement is instead sourced in the forced tongue body lowering which takes place during each of these sounds. The tongue body lowering co-occurs with a backward displacement of a large amount of tongue "flesh" which is primarily composed of the TR.

Returning to the question of differentiation in phonological retraction, it is suggested that distinction between the tongue root and tongue dorsum movements can, but does not necessarily, equate to two different types of phonological retraction. Despite two phonetically different retraction movements by the tongue, the acoustic realizations are such that the /ƛ̓/ generally patterns the same as the /l/ and /l̓/ in lowering of high vowels, and raising of low/back vowels. It seems to make no difference what the primary phonetic or phonologically dictated gesture is for the acoustic signal, but rather, it is dependent upon the entire tongue shape (and other non-connected external factors like lip rounding, etc.). Both types of retraction can be resolved gesturally either though temporal compromise (vowel transitioning), or spatial compromise (vowel laxing/lowering). Therefore, the overall outcome and effect on the vowels within a language, and similarly, one instigating foundation for phonological retraction, may not necessarily distinguish between the two different origins of their retraction.

However, distinction of TR from TD in terms of retracted gestures implies that retraction need not necessarily correlate to RTR as a feature. That is, the lateral approximants exhibit a retracted TD gesture, but this does not couple with a simultaneous TR retraction. Therefore, while these segments can be retracted consonants, (in addition to retracting consonants), this does not equate to a retracted feature of RTR.

6.2 Lateral retraction in Montana Salish phonology

Thus far, little mention has been made of how any lateral tongue retraction fits into the Montana Salish phonological system. As discussed in Chapter 1, Egesdal (1993:18) proposed two distinct lateral approximants; a retracted and non-retracted version of the plain lateral approximant /l/, and glottalized lateral approximant /l̓/. He uses this historically based stipulation to justify the vowel lowering in such otherwise unexplainable environments as the lateral approximants. However, this is done with the caveat that the amount of merger between these two distinguished (hypothetical) segments is unclear in current speakers.

While this present examination did not survey enough lateral approximants to distinguish whether two distinct retracted and non-retracted lateral approximant phonemes exist in modern day Montana Salish, some light can be shed on this matter when one recalls the choice of words used in this study. Along with Egesdal's (1993:18--19) generalization, he lists 22 words with a historically retracted /l/. Given that none of the words in Egesdal's (albeit presumably incomplete) list of retracted /l/ words were used in the current study, it can be concluded that the retraction demonstrated here is inherent in the non-retracted /l/ movement. The tongue position of the non-historically retracted consonant /l/ presents sufficient gestural conflict with the adjacent vowels such that some resolution must take place. In addition, recall that the /l/ affected the adjacent /a/ vowel such that it pulled it forward, rather than retracted it back, as it did for the /i/ vowel. This implies that all synchronic /l/s are retracted, and this retracted gesture has a specific enough target to advance the position of the low/back vowels, but retract the position of the high, front vowels. Nevertheless, this targeted position is an area in which ultimate position is dictated by coarticulatory effects.

The acoustic coarticulatory effects from the vowels and laterals onto each other mirror this overall retraction and general tongue position. As reflected in the formants (primarily F2), the low vowels are raised, while the high vowels are lowered when adjacent to the lateral consonants, though the total amount is variable by vowel and lateral. This occurred in both pre- and post-adjacent contexts. Furthermore, the physical tongue position of the laterals themselves also exhibits coarticulatory effects as a result of the adjacent vowels. The TR and TD are slightly more fronted in the environment of a high vowel but more retracted in the environment of the low vowel /a/. While the TD movement for the lateral approximants is a specified TD gesture, the final amount of this retraction is dictated by the coarticulatory effects of the adjacent segments. These coarticulatory effects appear to be most influential on the TR, with the TT/tongue blade and TB seeming to maintain a more constant position.[3] Here it seems that the gestural target is not specified for the TR.

[3] This claim that the TB and TT are only minimally variable is based only on observations made through tongue tracings and not through statistical measurement, since neither the TT nor TB is the focus of the current articulatory investigation.

6.3 Gestural conflict

The data presented in this study also have implications for the subject of conflicting tongue target gestural resolution within a language. The descriptions within Gick and Wilson (2002, 2003) and Wilson (2003) imply that only one strategy is operable per pre- or post-adjacent environment. Recall that the investigated data has demonstrated that all conflict is resolved via transition. The amount and length of time utilized in this resolution is variable, but spatial compromise as it equates to an ultimate laxed or lowered vowel is not demonstrated in the local environment. However, Montana Salish literature (Egesdal 1993; Bessell 1998a; Thomason 2000) presents that back consonants lower adjacent vowels. The vowels /e/, /u/, /o/, etc. lower to [ɑ], [ɔ] and [ɔ], etc. in the environment of adjacent uvulars, pharyngeals, and some laterals as well.

If this lowering is simply one method of resolving the gestural compromise between the conflicting position of the vowel and consonant, then an important generalization about gestural resolution can be made: the lateral and uvular consonants exhibit both laxing and lowering in the same environment. The lateral consonant to vowel conflict is resolved by transition, as well as laxing, and the uvular conflict for /i/ is resolved by transition (and laxing), and for the other vowels, laxing, then both processes are at work in MTS in the same environment. If one sequence can either transition, or lax, then it implies that a language does not necessarily set which type of resolution it prefers to use, but rather lets that decision be dictated by other parameters and generalizations which hold in the phonology.

However, if instead, the laxing/lowering of vowels is only a phonological phenomenon, as is implied by the current study, then rather than a language not specifying which gestural resolution is applied, the language differs as to which method of resolution is used in the phonology and which is used in the phonetics. In this case, all the investigated sequences exhibited vowel transition as the method of gestural compromise. However, this was expected, as the selected word list specifically was designed not to contain vowels which were known to be phonologically lowered. Therefore, no truly conclusive claims about specified gestural resolution can be made. Nevertheless, it seems probable that the vowel lowering in Montana Salish is phonological, but at least for the lateral consonants and the plain uvular stop, the phonetic realization is vowel transitioning.

6.4 The relation of gestural conflict to phonological transparency

If correct, this local gestural conflict has important ramifications for the phonetic and phonological descriptions of retraction or faucal harmony in the Salish languages. Recall that Egesdal (1993) and Bessell (1994, 1998a) claim that /i/ in Montana Salish is "transparent" (i.e. it does not pattern with the other vowels by lowering/laxing in a retraction-triggering context). In this same context, and in the case of both progressive and regressive retraction, /u/ lowers to [ɔ], and /e/ laxes to [ɑ], which, according to

Egesdal (1993:4) are not "audibly" distinct from phonemic /o/ and /a/.[4] Other phonemic /o/ and /a/ are already low and/or back, they do not participate in this process. However, the investigation here has shown that /i/ preceding or following a lateral or uvular stop is not inert. It is not phonetically unaffected. The realization of /i/ in these contexts clearly exemplifies vowel transitioning to or from the retracting consonant. What is significant, however, is that the articulation of /i/ even in these retracting environments always resolves to that of a neutral /i/. In some cases the amount of transition is resolved by the midpoint of the vowel, while in others full [i] formant values are established only at the 05%/95% point of the transition (i.e. at the measure point of the vowel that is maximally distant from the triggering consonant. Phonetically /i/ is subject to the same gestural conflicts that all other vowels are. This suggests that the resolution to this conflict is simply a temporal compromise, rather than a spatial one.

This is, in fact, also consistent with the acoustic evidence on /i/ lowering presented in Bessell (1998b) for two languages in which /i/ is documented as participating in phonological retraction effects as well as local coarticulatory retraction, specifically Moses Columbian Salish and Coeur d'Alene Salish. In Moses-Columbian, the local phonetic interaction of /i/ with uvulars and pharyngeals yields [ɪ, ɪe, e], while regressive harmony yields [ɛ] (Bessell 1998b:5). In Coeur d'Alene /i/ preceding a uvular yields [ɛ], /e/ yields [ɑ], and /u/ yields [ɔ] while for regressive harmony interactions /i/ is transparent. Bessell (1998b) claims that this adjacent lowering is coupled with some form of transition as well. The lowered /i/ in fact does transition as well but rather than specifying amount, she lays the onus on the timing of the /iQ/ shift. For Nxaʔamxcin (Moses-Columbian) the /i/ lowering is based on a transitory change, gradual throughout, whereas for Snchitsuʔumshtsn, (Coeur d'Alene) there is less transition, but it occurs at an earlier moment and is quickly stabilized for the rest of the vowel production (Bessell 1998b:23--25). The implication here is that the transition part of the vowel is the phonetic result of gestural compromise, whereas the maintenance of a lowered vowel is dictated by the phonology. Here, the languages demonstrate the phonetic and phonological retraction working jointly to produce the final outcome.

One further implication of the coarticulatory evidence presented for the lateral consonants in Montana Salish concerns retracted tongue root (RTR) harmony and segment transparency. If phonological harmony is phonetically grounded (Archangeli and Pulleyblank 1994) and further, if harmony is grounded in some local effect, then transparent segments of any kind present a problem. Not only has /i/ been considered a transparent segment for Montana Salish, it is implicitly implied in most literature discussing these vowel harmony systems in the Salish languages, that the consonants are transparent as well. That is, harmony can pass through these consonants, but does not affect them directly.

While the current study has not compared the lateral positions in RTR contexts to non-RTR contexts, it has clearly shown that there is TR variability as a function of the adjacent vowel. Recall from Chapters 4 and 5, that l / _a has more TR retraction that l /_i, though this is only visible at the very first measurement at the base of the TR.

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[4] The current analysis documents a difference between a/l_ and neutral /a/ as well as other such pairs. If there is a distinct difference between /l/, a non-retracted consonant, and /a/, then there is predicted to be an even greater difference between /q/ and /a/. The same implication applies to other V/C_ and V/_C sequences.

Similarly, /ɬ/ and /ƛ̓/ both have more TR and TD retraction in the /a/ context as compared with the /i/ context. It is plausible to hypothesize that since the laterals have parts of the tongue (generally the TR and sometimes the TD as well) which vary by vowel, it is possible that RTR harmony does in fact influence the consonant as well. Currently this can only be attributed to pure coarticulatory effects, but nevertheless, it implies that if an adjacent segment is effected, then it is further possible for RTR harmony to pass through at least some consonants on to other non-adjacent segments. This, in fact, is consistent with preliminary articulatory results by Archangeli and Kennedy (2004) who demonstrated with ultrasound that putatively transparent segments in Wolof and Hungarian are not phonetically transparent to retraction effects. A further articulatory study of consonant position in the environment of low or back vowels, or retracted consonants, would test these predictions.

6.5 Implications on the class of "laterals"

In addition to the valuable descriptive nature of the articulatory discussion on Montana Salish lateral consonants, this study has far-reaching implications into the area of phonological theory, specifically in the phonologically based categorization of lateral consonants as one class. Bessell (1998a) briefly addresses this issue of series unification versus subset differentiation for the coronal segments. She concludes that both in Salish and Arabic, all coronals do not always pattern as a class in terms of retraction (Bessell 1998a:141). However, the specific issue of unified lateral action is not approached. Montana Salish's rich phonemic inventory with four lateral consonants allows for a greater look into this grouping. Recall that only three of the four lateral consonants exhibit tongue retraction. On the surface, then, these consonants do not act uniformly as one class ought to. However, a closer look within these "retracted" laterals, must distinguish the tongue dorsum retraction of the two approximants from the tongue root retraction of the lateral ejective affricate. At an even deeper level, the /l/ and /l̓/ act slightly differently as retraction for the /l/ is a factor of its overall shape and less of its movement, while the glottalized lateral demonstrates a more distinct movement. The latter generalization being a caveat of the adjacent consonant and vowel environment such that if any of the laterals are initiated from a high front sound, then by nature of their targeted position, they have to retract, but if they are initiated from a retracted consonant or vowel, then this movement does not show up independently on the /l/, but does on the /l̓/ (and ƛ̓).

In her 1997 dissertation, Walsh Dickey claims that liquids differ from each other by place features, not manner features. She states "Corono-Dorsal place structure defines a lateral segment. . . the manner feature [lateral] is not phonologically valid" (Walsh Dickey 1997:68-69). She further claims that obstruent and sonorant laterals can only be grouped together based on place features, but not with "lateral" as a manner feature. Her motivation for such a claim is based on trends within a number of surveyed languages which have laterals but where the lateral "does not define a phonological class observed in rules or co-occurrence restrictions...and laterality...never spreads independent of the whole segment" (Walsh Dickey 1997:19).

Since the claim is that the lateral (approximants), are made up of a complex of both coronal and dorsal gestures, for Walsh Dickey (1997) the term "lateral" is redundant in terms of its reference to gestural movement. She specifically defines the coronal gesture as a "movement of the tongue blade to the alveolar ridge. The dorsal gesture is a retraction of the tongue body away from the palate" (Walsh Dickey 1997:49). However, the definition of the TD gesture away from the palate seems incomplete when the Montana Salish laterals are taken into account. Here the ultrasound imaging clearly shows the TD making a movement backward in the pharynx with no movement in relation to the palate being relevant. If this movement is taken to be the dorsal movement for the lateral, then it is still not common across all the four MTS laterals, thus requiring that the coronal movement must be the primary gesture for the lateral fricative.

Furthermore, the articulatory data presented here has clearly shown that there is a lateral movement in each of the four examined consonants, that is, at least in terms of a movement made by the sides of the tongue. This movement is variable, but common to each lateral consonant is the raising and/or lowering of the sides of the tongue such that peaks and troughs are created in the tongue, as viewed in the coronal cross-section images, regardless of airflow direction and movement. The ultrasound data here has presented evidence for lateral unification based on the lateral movement by the sides of the tongue, also implied through mid-sagittal lateral compression, as well as a continued basis for the feature "lateral". While specification seems to be variable in terms of RTR, this does not necessarily imply that the laterals are not a class, simply that they do not pattern together in all areas.

6.6 Gestural Proposal

Based on the establishment of the physical tongue movement during lateral consonant production, a proposal of the phonological status is possible. Following Browman and Goldstein (1992), gestures are phonological and could therefore be proposed to correspond to features in a feature system. In light of the articulatory documentation for the Montana Salish lateral consonants, two main proposals are presented.

First, consistency in direction, shape, and function of the TD movement beyond physical necessity in the lateral approximants points toward its classification as a phonological gesture, and not just a movement. This is in complete opposition to the TR movement observed in the /ƛ̓/ which has been explained as a physical by-product of tongue volume preservation. The TD gesture of the lateral approximants is also viewed distinctly from the sporadic and minimal TD peak that is variably apparent on the lateral fricative.

Second, coronal cross-sectional imaging, which has documented the lowering of the tongue sides common to all the investigated laterals, in addition to the mid-sagittal measurement of medial expansion which reflects lateral compression, both support the proposition of a common feature "lateral". Importantly, the proposed notion of a unifying lateral movement, termed "lateral compression", is not making reference to airflow. Lateral airflow and the feature "lateral" are distinct.

In addition, in terms of phonological gestures, using both lateral compression and TT would be redundant, (since lateral compression entails TT) and therefore TT is excluded from the analysis below. Similarly, because TB movement was not the focus of the present investigation, phonological status for this subsection of the tongue is not discussed. Lastly, glottal closure is presented as an equally distinguishing gesture. These propositions are summarized in Table 6.2 below.

Table 6. 2 Classification of Phonetic and Phonological Status for Tongue Movements: Gestural Proposal

	TR	TD	Lat-comp	Glot-closure
q	+	+		
l		+	+	
lʼ		+	+	+
ɬ			+	
ƛʼ			+	+

Specification of a back gesture for what have been traditionally considered non-"retracted" consonants (i.e. non-uvular and non-pharyngeal consonants) is not a new proposition. In an investigation of palatal and post alveolar clicks in Khoekhoe, Miller-Ockhuizen (2004a:1) states "Ultrasound images and EPG contact patterns confirm that the post-alveolar [!] click type has a uvular gesture produced with the tongue body to form the posterior constriction of this click type". Traill (1985) also notes a TD retraction for the same click in !Xoo and Thomas-Vilakati (1999) notes a TB retraction for IsiZulu. This is important since it is a relevant question among Salishanists whether it is the consonants that are retracted, or the vowels that retract these consonants. The evidence presented in this study has shown that while vowel context influences the total amount of tongue retraction, the movements involved are specified gestures made toward phonological targets. The TD retraction on the two lateral approximants /l/, /lʼ/, occurs independent of vowel environment.

Lastly, one further contribution to the articulatory investigation of retraction is provided by the methods established in this study. Interspeech rest, as defined by Gick et al. (2004) has been shown to occupy a medial place in the Montana Salish vowel inventory with respect to the tongue root and tongue dorsum positions. It lies near the average position for the /e/ [ɛ] vowel in the first three measurement positions. Even though the areas of the tongue farther forward than the TD do not resemble any other vowel, the TR and TD positions are medial with respect to tongue retraction. It is likely that within the relevant physiological constraints, this interspeech rest position will also sit medially in additional languages.

From the multiple above discussions, the implications of this study have been presented. New methods of investigation into the tongue articulators involved in consonant and vowel retractions have been demonstrated. Not only does this study contribute to the typological knowledge of lateral consonant behavior for some little-studied laterals, as well as to the documentation of a little-studied language, the results are relevant for many areas of phonological theory. Implications from this study have given insight to the issues of phonological transparency, lateral class legitimacy, language specification of gestural conflict resolution, and most importantly, the issue of consonant retraction in the Salishan languages.

References

Alwan, Abeer. 1986. Acoustic and perceptual correlates of pharyngeal and uvular consonants. MA thesis, Massachusetts Institute of Technology.

Alwan, Abeer. 1989. Perceptual cues for place of articulation for the voiced pharyngeal and uvular consonants. *Journal of the Acoustical Society of America* 86 (2):549-556.

Archangeli, Diana, and Douglas Pulleyblank. 1994. *Grounded Phonology.* Cambridge: MIT Press.

Archangeli, Diana, and Bob Kennedy. 2004. Transparency in Wolof and Hungarian. Paper presented at Ultrafest II, University of British Columbia, Vancouver.

Bessell, Nicola J. 1991. Vowel effects of uvular and pharyngeal consonants in Nxaʔamxčin (Interior Salish). Paper presented at the 121st Acoustical Society of America, Baltimore.

Bessell, Nicola J. 1992. Towards a phonetic and phonological typology of post-velar articulation. Doctoral dissertation, University of British Columbia.

Bessell, Nicola J. 1994. Interior Salish progressive and regressive harmonies. Paper presented at the 29th International Conference on Salish and Neighbouring Languages, Pablo, MT.

Bessell, Nicola J. 1998a. Phonetic aspects of retraction in Interior Salish. In *Salish languages and linguistics: Theoretical and descriptive perspectives,* eds. Ewa Czaykowska Higgins and M. Dale Kinkade, 125-152. Berlin: Mouton de Gruyter.

Bessell, Nicola J. 1998b. Local and nonlocal consonant-vowel interaction in Interior Salish. *Phonology* 15:140.

Borden, Gloria J., Katherine Harris and Lawrence Raphael. 1994. *Speech science primer: Physiology, acoustics, and perception of speech.* 3rd ed. Baltimore: Williams and Williams.

Browman, Catherine, and Louis Goldstein. 1986. Towards an articulatory phonology. *Phonology Yearbook* 3:219-252.

Browman, Catherine, and Louis Goldstein. 1992. Articulatory phonology: An overview. *Phonetica* 49:155-180.

Carlson, Barry F. 1972. A grammar of Spokan: A Salish language of eastern Washington. Doctoral dissertation, University of Hawaii.

Cole, Jennifer S. 1987. Planar phonology and morphology. Doctoral dissertation, Massachusetts Institute of Technology.

Czaykowska-Higgins, Ewa. 1990. Retraction in Moses-Columbia Salish. In *Papers for the 25th*

International Conference on Salish and Neighbouring Languages. 8196. Vancouver, BC.

Doak, Ivy G. 1987. Coeur d'Alene vowel harmony. Paper presented at the 22nd International Conference on Salish and Neighbouring Languages, Victoria, B.C.

Doak, Ivy G. 1992. Another look at Coeur D'Alene harmony. *International Journal of American Linguistics* 58 (1):1-35.

Egesdal, Stevan M. 1993. Retracted vowels in Selish (Flathead). Ms., Salish Kootenai College, Pablo, Montana.

Flemming, Edward, Peter Ladefoged, and Sarah G. Thomason. 1994. The phonetic structures of Montana Salish. *UCLA Working Papers in Phonetics* 87:1-34.

Gick, Bryan. 2002. The use of ultrasound for linguistic fieldwork. *Journal of the International Phonetic Association* 32 (2):113-122.

Gick, Bryan. 2002. An X-ray investigation of pharyngeal constriction in American English schwa. *Phonetica* 50:38-48.

Gick, Bryan, and Ian Wilson. 2003. To appear. Excrescent schwa and vowel laxing: Cross linguistic responses to conflicting articulatory gestures. In *Papers in Laboratory Phonology VIII.*

Gick, Bryan, and Sonya Bird. 2004a. To appear. Techniques for field application of lingual ultrasound imaging. *Clinical Linguistics and Phonetics.*

Gick, Bryan, Fiona Campbell, Sunyung Oh, and Linda Tamburri-Watt. 2004b. Under review. Toward universals in the gestural organizations of syllables: A cross-linguistic study of liquids.

Gick, Bryan, Ian Wilson, Karsten Koch, and Clare Cook. 2004c. Under review. Language specific articulatory settings: Evidence from inter-utterance rest position.

Johnson, Robert E. 1975. The role of phonetic detail in Coeur d'Alene phonology. Doctoral dissertation, Washington State University.

Kent, Ray, and C. Read. 1992. *The acoustic analysis of speech.* San Diego: Singular Publishing Group, Inc.

Kinkade, M. Dale. 1967. Uvular-pharyngeal resonants in Interior Salish. *International Journal of American Linguistics* 33 (3):228-234.

Kuipers, Aert. 1974. *The Shuswap language.* The Hague: Mouton.

Ladefoged, Peter, and Ian Maddieson. 1996. *Sounds of the world's languages.* Cambridge: Blackwell.

Ladefoged, Peter, A. Cochran and S. Disner. 1977. Laterals and trills. *Journal of the*

International Phonetic Association 7:46-54.

Mengarini, Gregory, Joseph Giorda, Leopold van Gorp, Joseph Bandini, and Joseph Guidi. 1877–79. *A Dictionary of the Kalispel or Flathead Indian language*. St. Ignatius, MT: St. Ignatius Print.

Miller-Ockhuizen, Amanda. 2004a. Posterior tongue body constriction location differences in click types. Paper presented at the 9th Conference on Laboratory Phonology, Urbana Champaign.

Miller-Ockhuizen, Amanda. 2004b. Postvelar TB constriction location differences in clicks. Paper presented at Ultrafest II, Vancouver.

Miller-Ockhuizen, Amanda. 2004c. Postvelar TB constriction location differences in clicks. Paper presented at the Annual Conference of African Linguistics, Boston.

Munhall, Kevin G., Eric Vatikiotis-Bateson, and Yoh'ichi Tohkura. 1995. X-ray film database for speech research. *Journal of the Acoustical Society of America* 98 (2):1222-1224.

Peterson, Gordon, and Harold Barney. 1952. Control methods used in a study of vowels. *Journal of the Acoustical Society of America* 24:175-184.

Shahin, Kimary. 1997. Post-velar harmony. Doctoral dissertation, University of British Columbia.

Shahin, Kimary. 2002. Post-velar harmony. Philadelphia: John Benjamin.

Shank, Scott, and Ian Wilson. 2000a. Acoustic evidence for /ʔ/ as a glottalized pharyngeal glide in Nuu-chah-nulth. In *UBC Working Papers in Linguistics 3: Proceedings of 35th International Conference on Salish and Neighbouring Languages*. eds. Suzanne Gessner and Sunyoung Oh, 185-197.

Shank, Scott, and Ian Wilson. 2000b. An acoustic analysis of vowel formants in pharyngeal and glottal contexts in Nuu-chah-nulth. *University of Washington Working Papers in Linguistics* 19:75-84.

Shaw, Patricia. 1992.Templatic Evidence for the Syllable Nucleus. Paper presented at the 23rd North East Linguistics Society, Université d' Ottawa. Ottawa, ON.

Shaw, Patricia. 2004. To appear. Inside access: The prosodic role of internal morphological constituency. In T*he nature of the Word: essays in honor of Paul Kiparsky*. eds. Kristin Hanson and Sharon Inkelas. Cambridge: MIT Press.

Stone, Maureen. 1997. Laboratory techniques for investigating speech articulation. In *Handbook of Phonetic Sciences*. eds. William Hardcastle and John Laver, 11-32. Oxford: Blackwell Publishers.

Thomas-Vilakati, Kimberly. 1999. Co-production and co-articulation in Isizulu clicks. Doctoral dissertation, University of California, Los Angeles.

Thomason, Sarah G. 1992. The Flathead word. Ms., University of Pittsburgh.

Thomason, Sarah G. 1996. Irregular velar developments in Montana Salish. In *Papers for the 31st International Conference on Salish and Neighbouring Languages,* ed. M. Dale Kinkade, 311-319. Vancouver: B.C.: University of British Columbia.

Thomason, Sarah G. 2000. Montana Salish dictionary. Ms., University of Michigan.

Thomason, Sarah G. 2002. On Montana Salish /h/. In *UBC Working Papers in Linguistics 9: Papers for the 37th International Conference on Salish and Neighbouring Languages*, eds. Rachel Wojdak, Niomi Sawoi and Carrie Gillon, 335-356.

Thomason, Sarah G. In preparation. A sketch of Montana Salish structure. Ms., University of Michigan.

Thompson, Lawrence C. and M.Terry Thompson. 1990. *Thompson Dictionary.* Ms., University of Hawai'i.

Thompson, Lawrence C. and M.Terry Thompson. 1992. *The Thompson Language.* University of Montana Occasional Papers in Linguistics, No. 8, Missoula, MT.

Traill, Anthony. 1985. Phonetic and phonological studies of !Xoo Bushman. Hamburg: H. Buske Berlag Quellen zur Khoisan Forschung.

Van Eijk, Jan. 1997. *The Lillooet Language: Phonology, Morphology, and Syntax.* Vancouver: University of British Columbia Press.

Vogt, Hans. 1940. *The Kalispel Language.* Oslo: Det Norske Videnskaps-Akademi.

Walsh Dickey, Laura. 1997. The phonology of liquids. Doctoral dissertation, University of Massachusetts, Amherst.

Wilson, Ian. 2002. Ultrasound database of Nuu-chah-nulth. University of British Columbia.

Wilson, Ian. 2003. *Post-velar CV interactions in Nuu-chah-nulth: Phonology or phonetics?* Doctoral generals paper. University of British Columbia.

Appendix A

List of Elicited of Montana Salish Words

Some initial comments: Pronunciations in [ ] brackets represent the elicited pronunciations which were used in data analysis. All words without additional transcription information were elicited as written. Words are written in the standard orthography with the exception of the vowel /e/ which is written as its phonetic pronunciation of [ɛ]. Note that schwa has been transcribed as either [ə] or [ᵊ] corresponding to variability in its phonetic realization. Status of this vowel as either nucleic or not is yet undetermined. -Parentheses ( ) indicate that what occurred inside was sometimes said and sometimes not included at all. Often this changes the meaning of the English gloss. Many times, something in parentheses was said once, and then the word or phrase was repeated without it.

Words with Lateral Consonants used in Articulatory and Acoustic Analysis	
Montana Salish Words	English Gloss
1. ččɛčɛɬɛ́	three people
2. ččl̓ɛ́xʷ	muskrat
3. čmíƛ̓mn [čmíƛ̓ᵊmən]	butter (something that spreads)
4. čn ɛsnxam̓pcí [ɛsᵊnxam̓pcí]	I'm getting thirsty
5. ɛsƛ̓ɛʔɛm̓scu	getting into trouble
6. ɛsčmíƛ̓	it's already spread on
7. ɛsk̓ʷúl̓l̓i	it is being born
8. ɛsnqamɛ́lsi **	he/she feels calm (safe)
9. i ƛ̓áx	it's stiff
10. i čn č̓úcn	I'm quiet
11. iɛsslím	I'm setting out a bunch of stuff
12. i kʷkʷl̓íl̓ [kʷkʷlíl̥]	the sun is shining
13. i nƛ̓ƛ̓ƛ̓í / i nɬƛ̓ƛ̓í [inλλƛ̓í]/[inɬλƛ̓í]	it's a sharp point
14. i nmál̓ [inmál̥]	it is warm
15. čn kʷɛ́ɬ [čᵊn kʷɛ́ɬ]	I'm nervous, scared
16. k̓ʷiƛ̓t	others
17. líkʷlɛxʷ	prairie, bare ground
18. lamús	(woman's name) Lamus
19. ƛ̓čƛ̓á	blackbird
20. ƛ̓ɛ́	already
21. ɬɛ́cn [ɬɛ́cᵊn]	smooth it down
22. ɬkʷɬákʷɬš	slapping sound of wet moccasins
23. ɬtxtá	pepper
24. ɬɬú [ɬú]	less, few
25. malí	Mary
26. makalí	Margaret

27. maľúkʷ	out of joint
28. (sc)ntúcuʔs [scᵊntúcus]/[ntúcus]	(dough) mix, knead
29. nťíɬkʷ	dirty water
30. nčlátkʷ	it's cold water
31. nmɛ́x̌	mix
32. npx̌á	take it off
33. nšx̌á	all kinds of things
34. ľľác	red raspberry
35. p(ə)ľíp	it drifted away
36. i čn ṕúx̌ [ṕúx̌]	I'm greasy
37. sx̌úk̓ʷm [sx̌úk̓ʷᵊm]	'Indian' carrot
38. šx̌úsm [šx̌úsᵊm]	look all around
39. sčkʷx̌ús	eye
40. scúɬm [scúɬᵊm]	bull
41. scɬcúɬm [scɬcúɬᵊm]	several bulls
42. skʷx̌ús	face
43. smúľmn [smúľᵊmən]	war spear, lance
44. snčľɛ́	coyote
45. splim̓cm [splím̓cᵊm]	lip, mouth
46. sťlťlá	thunder
47. talíp	it got untied
48. čn ɛsšáľľi	I'm bored
	in addition to those listed above:
Word Used in Acoustic Analysis: for Laterals, Uvular /q/, and 'neutral' Vowels	
Word with 'neutral' vowels also used in articulatory analysis	
49. ʔáṅṅ [aʔn]	magpie, or a reference to someone who talks too much
50. čn čc'nám	I won't let go, I hold it tight.
51. čn c̓χʷóm či qsxʷú č̓ nɬʔay	I made plans to go to Missoula
52. čmíx̌mn [čmíx̌ᵊmᵊn]	butter, something that spreads
53. čn ɛɬtá	I say no, I take it back again
54. čsáxm [čsáxᵊm]	near
55. čč̓čɛ́ľšč̓n [cč'ɛ́l'ščən]	woodtick
56. i c'án [c'án]	it's tight
57. cíq	dig
58. ckʷúnt	pull it!
59. cúnc	he told him
60. qɛ cúntm [cúntᵊm]	we told someone
61. ɛsʔiʔaʔ	they gathered together e.g. birds getting ready to go south
62. ɛsɬíp̓	stripe, marker
63. ɛsc'ánm [ɛsc'ánᵊm]	its being tightened, squeezed
64. pút u ɛsc'ɛk̓ʷomí	the flowers have bloomed

65. ʔɛspčmá	it (fly) is laying eggs, fly blow
66. ɛspmpmá [ɛspᵊmpᵊmá]	he's going faster
67. ɛstaqí ***	waving at someone
68. ɛswamísti	he hurrying, walking fast
69. ɛspáť	something that is soft, like mud, diarrhea
70. (čn) ɛsnxam̓pcí	(I'm) getting thirsty
71. ha šɛ́	is that right? is that correct?
72. isčuáxxn i ƛ̓ax [isčuáxxən i ƛ̓áx]	My arm is stiff
73. i nás	It's wet
74. i túkʷ	It's rotten, (or if clothes are ragged, threadbare)
75. i ťás	It is hard
76. išíl'š incítxʷ	My house settled low
77. qʷo kʷúpntxʷ [kʷúpᵊntxʷ]	You pushed me
78. k̓ʷúl̓m [k̓ʷú'l̓]	work, labor
79. kʷtkʷtuʷnšn [kʷtkʷtuʷnšᵊn]	big feet
80. łm̓łam̓á [łəmła:m̓á]	frog
81. łíčntxʷ [łíčᵊntxʷ]	You whipped him/her
82. iɛsłínm [iɛsłínəm]	I'm sprinkling it
83. łínm [łínəm]	she/he sprinkled something
84. łqqaʔsqɛ́	petite, thin
85. mił čťa łu malí	Mary is too skinny
86. malí čxʷiʔcútmntm (t nq̓ʷiq̓ʷsm̓í) [čxʷiʔcútᵊmᵊntᵊm t nq̓ʷiq̓ʷosᵊm̓i]	Mary got attacked (by dogs)
87. mił	too much
88. ṅɛ́m	maybe (future)
89. nłapá	absolutely, darn right!
90. nťam̓cán	kiss
91. nkʷtnáqs čoni	Johnny has a big nose
92. nk̓ʷuʔsťapsqɛ́	one shot (at a person)
93. nkʷk̓ʷá	yarrow, milfoil
94. nmɛƛ̓	mix
95. (sqʷóʔł) nsúťkʷ	honey (Bitterroot Salish, *cf.* lamná 'honey' which DF says is Pend d'Oreille)
96. płił	thick
97. (i) piq	(it's) white
98. spupusɛ́nč	sorrow, sadness
99. pťať	spill something over
100. p̓ačnt	press something, squeeze it!
101. p̓l'ásuwɛ	Frank
102. p̓l'ɛsuwɛ́	Francis
103. qáxɛʔ	aunt (mother's sister)
104. qɛ	we (tr. subj.), us (obj.)
105. qɛ cúntm [cúntᵊm]	we told someone

106. qɛ ɛsq̓ɛymu	our tipi
107. qɛ qsk̓ʷisq̓q̓mɛ́	We're going to go fishing
108. sčm̓čmác̓s [sčᵊmčmác̓s]	eye matter, eyes got ditry
109. sc'mqín [sc'əmqᵋín]	brain
110. scuɬúɬm/scɬúɬm [scɬúɬᵊm]	several bulls
111. skʷƛ̓ús	face
112. smamáʔ	uncle
113. sn̓sá	tame
114. snsót̓qən [sᵊnsót̓qən]	stocking cap
115. šmiɬú	least
116. ssal̓ú	hailstones
117. st̓ša	huckleberry
118. sxʷɬɛ́psm [sxʷɬɛ́psᵊm]	firefighter
119. čn sp̓sqɛ́ [sp̓sqɛ́]	I was hitting people
120. t̓ɛ́c	touch
121. tqtqɛ́nɛ	deaf
122. tspisc'ɛ́	yesterday
123. tcáp	slap! sound of impact when someone falls and hits the ground
124. xa nɛxʷɬ̓ícn [xaʔ nɛxʷɬ̓icᵊn]	
125. čn yakʷoqɛ́ynšn [yakʷoqɛ́ynšᵊn]	I skinned my knee
126. y̓ay̓am̓m̓ín̓ [yaməmi]	farm hay rake
127. yapcín	to be in need

Words Used in Articulatory Examination of Lateral Consonants (also used in acoustic evaluation)	
Montana Salish Words	**English Gloss**
l̓	
ččl̓ɛ́xʷ	muskrat
ɛsk̓ʷúl̓l̓i	it is being born
i nmál̓	it is warm
mal̓úkʷ	out of joint
l̓l̓ác	red raspberry
p(ə)l̓íp	it drifted away
smúl̓mn [smúl̓ᵊmən]	war spear, lance
snč̓l̓ɛ́ [sᵊnč̓l̓ɛ́]	coyote
k̓ʷúl̓m [k̓ʷúˀl̓]	work, labor
p̓l'ásuwɛ [p̓ᵊl'ásuwɛ]	Frank
išíl'š incítxʷ	My house settled low
čn ɛššál̓l̓i	I'm bored
ƛ̓	
čmíƛ̓mn [čmíƛ̓ᵊmən]	butter (something that spreads)

εsƛ̓εʔεṁscú *	getting into trouble
εsčmíƛ̓	it's already spread on
i ƛ̓áx	it's stiff
i nƛ̓ƛ̓ƛ̓í / i nɬƛ̓ƛ̓í [inƛƛƛ̓í]/[inɬƛƛ̓í]	it's a sharp point
isčuáxxn (i ƛ̓ax) [isčuáxxən i ƛ̓áx]	my arm is stiff
k̓ʷiƛ̓t	others
ƛ̓čƛ̓á	blackbird
ƛ̓έ	already
nmέƛ̓	mix
npƛ̓á	take it off
nšƛ̓á	all kinds of things
i čn p̓úƛ̓ [p̓úƛ̓]	I'm greasy
sƛ̓úk̓ʷm [sƛ̓úk̓ʷᵊm]	'Indian' carrot
šƛ̓úsm [šƛ̓úsᵊm]	look all around
sčkʷƛ̓ús	eye
skʷƛ̓ús	face
l	
iεsslím	I'm setting out a bunch of stuff
Lamús *	(woman's name) Lamus
líkʷlεxʷ	prairie, bare ground
Malí	Mary
Makalí	Margaret
splim̓cm [splím̓cᵊm]	lip, mouth
sl̓tl̓á	thunder
talíp	it got untied
i kʷkʷl̓íl̓ [kʷkʷlíl̥]	the sun is shining
nc̓látkʷ	it's cold water
c̓ált	it's cold
ɬ	
εsɬíp̓	stripe, marker
míɬ	too much
čn kʷέɬ	I'm nervous, scared
čn mέɬ	I'm recovered, I'm no longer in pain
ɬέcn [ɬέcᵊn]	smooth it down
ɬíc̓ntxʷ [ɬíc̓ᵊntxʷ]	You whipped him/her
iεsɬínm [iεsɬínəm]	I'm sprinkling it
ɬínm [ɬínəm]	she/he sprinkled it
ɬkʷɬákʷɬš	slapping sound of wet moccasins
ɬmɬam̓á * [ɬəmɬa:m̓á]	frog
ɬtxtá	pepper
ɬɬú [ɬú]	less, few
(sc)nɬúcuʔs [nɬúcus]	(dough) mix, knead
nɬ̓íɬkʷ	dirty water

nɬaʔpá *	absolutely, darn right
scúɬm [scúɬ^{ə}m]	bull
šmiɬú	least
ččɛčɛɬɛ́	three people
scɬcúɬm [scɬcúɬ^{ə}m]	several bulls
sx^{w}ɬɛ́psm [sx^{w}ɬɛ́ps^{ə}m]	firefighter
q	
cíq	it's dug
ɛstaqí ***	waving at someone
čn c̓χ^{w}óm či qsx^{w}ú č̓ nɬʔay	I made plans to go to Missoula
ɬqqasqɛ́	petite, thin
(i) piq	(it's) white
čn sp̓sqɛ́ [sp̓sqɛ́]	I was hitting people
sc'mqín [sc'əmq^{ɛ}ín]	brain
snsót̓qən [s^{ə}nsót̓qən]	stocking cap
tqtqɛ́nɛ	deaf
qáxɛʔ	aunt (mother's sister)
qɛ	we, (tr. subj.) us (obj.)
qɛ cúntm [qɛ cúnt^{ə}m]	we told someone
qɛ ɛsq̓ɛymu	our tipi
qɛ qsk̓^{w}isqq̓mɛ́	We're going to go fishing
(čn) yak$^{'w}$oqɛ́ynšn [yak$^{'w}$oqɛ́ynš^{ə}n]	I skinned my knee

*Note that in these three words the stress is not on the vowel adjacent to the lateral consonant. However, to maintain a sufficient number of sequences investigated, these were still incorporated into the statistical evaluation for each environment.

** This word was used only in the tongue tracings for a sequence of segments as illustrated in Chapter 4, not in statistical analysis.

***Stress on this word was difficult to determine. Thomason (p.c. 2004) cites Mengarini and Giorda (1877-1879) who place the stress on the /a/ vowel.

-Number of repetitions for each word varies: minimum 3, maximum 12.

Appendix B

Supporting Statistics and Comparisons

The following information is presented to supplement the discussion of the uvular vowel interaction with the preceding /i/ vowel (Chapter 3.3). Resolution of the gestural conflict for the /i/ preceding the uvular is variable. For example, preliminary acoustic measurements for within word i/_q tokens yield formant values much closer to [i] than the formants for the vowel-uvular sequence across a morphological boundary. It is interesting to note that i/+_q adjacency *across* a word or particle boundary, consistently results in /i/ audibly lowering to the /ɪ/ vowel range. However, this could a function of single word citation versus (non-) phrasal utterances. This is illustrated in Table B.1 below.

Table B.1 Additional comparison for i/_q sequences

i/_q Context	# Reps	F1 5%	F1 50%	F1 95%	F2 5%	F2 50%	F2 95%	F3 5%	F3 50%	F3 95%
/piq/ & /ciq/	19	395	420	396	2532	2624	2495	3120	3242	3368
čn ċχʷóm či qsχʷú č̓ nłaẏ	4	571	570	566	2210	2136	2006	3156	3168	3066

Fisher's PLSD for TR (Measurement #1)
Effect: Production
Significance Level: 5 %

	Mean Diff.	Crit. Diff.	P-Value	
independent l', non-independent l'	.238	.175	.0088	S
independent l', rest	-.108	.156	.1696	
non-independent l', rest	-.346	.152	<.0001	S

Means Table for TR (Measurement #1)
Effect: Production

	Count	Mean	Std. Dev.	Std. Err.
independent l'	11	2.686	.089	.027
non-independent l'	12	2.448	.281	.081
rest	21	2.794	.202	.044

Fisher's PLSD for TR 2cm up (Measurement #2)
Effect: Production
Significance Level: 5 %

	Mean Diff.	Crit. Diff.	P-Value	
independent l', non-independent l'	.464	.191	<.0001	S
independent l', rest	.478	.170	<.0001	S
non-independent l', rest	.013	.165	.8715	

Means Table for TR 2cm up (Measurement #2)
Effect: Production

	Count	Mean	Std. Dev.	Std. Err.
independent l'	11	4.101	.103	.031
non-independent l'	12	3.637	.368	.106
rest	21	3.623	.159	.035

Fisher's PLSD for 4cm up (Measurement #3)
Effect: Production
Significance Level: 5 %

	Mean Diff.	Crit. Diff.	P-Value	
independent l', non-independent l'	.072	.235	.5422	
independent l', rest	.536	.210	<.0001	S
non-independent l', rest	.465	.204	<.0001	S

Means Table for 4cm up (Measurement #3)
Effect: Production

	Count	Mean	Std. Dev.	Std. Err.
independent l'	11	4.408	.321	.097
non-independent l'	12	4.337	.374	.108
rest	21	3.872	.176	.038

Fisher's PLSD for 6cm up (Measurement #4)
Effect: Production
Significance Level: 5 %

	Mean Diff.	Crit. Diff.	P-Value	
independent l', non-independent l'	.104	.168	.2177	
independent l', rest	.610	.150	<.0001	S
non-independent l', rest	.505	.146	<.0001	S

Means Table for 6cm up (Measurement #4)
Effect: Production

	Count	Mean	Std. Dev.	Std. Err.
independent l'	11	4.650	.260	.078
non-independent l'	12	4.546	.208	.060
rest	21	4.040	.154	.034

Fisher's PLSD for TT (Measurement #5)
Effect: Production
Significance Level: 5 %

	Mean Diff.	Crit. Diff.	P-Value	
independent l', non-independent l'	.069	.155	.3757	
independent l', rest	.841	.139	<.0001	S
non-independent l', rest	.773	.131	<.0001	S

Means Table for TT (Measurement #5)
Effect: Production

	Count	Mean	Std. Dev.	Std. Err.
independent l'	10	4.671	.148	.047
non-independent l'	12	4.603	.148	.043
rest	21	3.830	.205	.045

Figure B. 1 Statistics for independent (syllabic) vs. non-independent /l'/

Fisher's PLSD for Measurement Point #1 TR
Effect: Segment
Significance Level: 5 %

	Mean Diff.	Crit. Diff.	P-Value	
a, i	1.244	.137	<.0001	S
a, l'	.504	.131	<.0001	S
a, rest	.272	.132	.0001	S
i, l'	-.740	.124	<.0001	S
i, rest	-.972	.126	<.0001	S
l', rest	-.232	.119	.0002	S

Fisher's PLSD for Measurement Poioint #2
Effect: Segment
Significance Level: 5 %

	Mean Diff.	Crit. Diff.	P-Value	
a, i	.746	.162	<.0001	S
a, l'	-.101	.155	.2005	
a, rest	.127	.157	.1100	
i, l'	-.846	.147	<.0001	S
i, rest	-.618	.149	<.0001	S
l', rest	.228	.142	.0020	S

Fisher's PLSD for Measurement Point #3
Effect: Segment
Significance Level: 5 %

	Mean Diff.	Crit. Diff.	P-Value	
a, i	-.010	.164	.9048	
a, l'	-.329	.157	<.0001	S
a, rest	.189	.159	.0205	S
i, l'	-.319	.149	<.0001	S
i, rest	.199	.151	.0106	S
l', rest	.518	.143	<.0001	S

Fisher's PLSD for Measurement Point #4
Effect: Segment
Significance Level: 5 %

	Mean Diff.	Crit. Diff.	P-Value	
a, i	-.882	.118	<.0001	S
a, l'	-.753	.113	<.0001	S
a, rest	-.183	.114	.0021	S
i, l'	.128	.108	.0199	S
i, rest	.698	.109	<.0001	S
l', rest	.570	.103	<.0001	S

Fisher's PLSD for Measurement Point #5 TT
Effect: Segment
Significance Level: 5 %

	Mean Diff.	Crit. Diff.	P-Value	
a, i	-.962	.118	<.0001	S
a, l'	-1.253	.113	<.0001	S
a, rest	-.449	.114	<.0001	S
i, l'	-.291	.107	<.0001	S
i, rest	.513	.108	<.0001	S
l', rest	.804	.103	<.0001	S

Figure B. 2 Statistics for Interspeech Rest as compared with /l'/, /a/, /e/, and /i/