A Phonetic Investigation of Vowel Variation in Lekwungen

by

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Supervisory Committee

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Abstract

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This thesis conducted the first acoustic analysis on Lekwungen (aka Songhees, Songish) (Central Salish). It studied the acoustic correlates of stress on vowels and the effects of consonantal coarticulatory effects on vowel quality. The goals of the thesis were to provide useful and usable materials and information to Lekwungen language revitalisation efforts and to provide an acoustic study of Lekwungen vowels to expand knowledge of Salishan languages and linguistics.

Duration, mean pitch, and mean amplitude were measured on vowels in various stress environments. Findings showed that there is a three-way contrast between vowels in terms of duration and only a two-way contrast in terms of pitch and amplitude.

F1, F2, and F3 were measured at vowel onset (5%), midpoint (50%), and offset (95%), as well as a mean (5%-95%), in CVC sequences for four vowels: /i/, /e/, /a/, and /ə/. Out of five places of articulation of consonants in Lekwungen (alveolar, palatal, labio-velar, uvular, glottal), uvular and glottal had the most persistent effects on F1, F2, and F3 of all vowels. Of the vowels, unstressed /ə/ was the most persistently affected by all consonants. Several effects on perception were also preliminarily documented, but future work is needed to see how persistence in acoustic effects is correlated with perception.

This thesis provides information and useful tips to help learners and teachers in writing and perceiving Lekwungen and for learners learning Lekwungen pronunciation,

as a part of language revitalisation efforts. It also contributes to the growing body of acoustic phonetic work on Salishan languages, especially on vowels.

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Chapter 1

Introduction

Language revitalisation necessarily involves creating new speakers, and in British Columbia these new speakers currently have English as their first language. In situations where fluent, first-language, speakers are non-existent or rare, documentation can help fill the gaps for language teachers and learners (Hinton, 2011). One aspect of documentation that is essential to language revitalisation is documentation of pronunciation and its variation. Pronunciation can have at least two important functions when it comes to language revitalisation. It can be important for developing a fluent speaker-like accent in the language (if this is deemed important), in particular by clarifying how a first-language speaker of a given language varies their pronunciation, and how this pronunciation might differ from a beginning learner's. Pronunciation can also be important for writing the language. Knowing what variation in pronunciation is predictable vs. what variation is not can help learners and speakers write more consistently.

People working to revitalise and learn their language in the absence of fluent speakers can be at a disadvantage when it comes to learning the specifics of pronunciation. Perceptual differences that might seem important to a learner might not be so to a fluent speaker, and in the absence of someone to point this out and guide the learner, the learner might be at a loss for what to say or write when they hear certain variation. 'Is this *this* sound, or *that* sound I'm hearing?' 'Is this an important change to pronunciation, or does it not matter?' This uncertainty is particularly relevant for vowels. Vowels are by their nature fluid, and are susceptible to considerable variation depending on surrounding speech sounds ('coarticulatory effects') (Manuel, 1987; Manuel, 1990). For example, the same 'meaningful' (underlying, phonemic) vowel /ə/ in Lekwungen (a variety of North Straits Salish, a Central Salish language, and the focus of this thesis) can sound like [ɪ] (like in English *bit*) when preceded by certain consonants, and like [ʊ] (like in English *book*) when followed by others. Complicating this, languages can have varying sets of meaningful vowel distinctions: English (Germanic Indo-European), for example, has 12 contrastive vowels, while Lekwungen, for example, has five; while the distinction between [ɪ] and [i] is meaningful (and thus fairly perceptible) to English speakers, this is not necessarily the case in Lekwungen. In the past, speakers of Lekwungen learning English likely had difficulty perceiving, and thus knowing when to produce, the distinction between [ɪ] and [i]. They might have had trouble identifying or accurately producing, e.g., the difference between *beet* (with [i]) and *bit* (with [ɪ]), causing confusion. In the present, learners of Lekwungen are all L1 (first language) English speakers. Given this, the variation they hear in Lekwungen vowels due to the effects of neighbouring sounds could be confusing and possibly discouraging, or at least impeding.

This thesis aims to provide a tool that can help: a systematic description of phonetic vowel variation in Lekwungen. The goal is to document and analyse how and why vowel quality varies, with special attention to the effects of stress and of surrounding consonants. By determining *how* the vowels in Lekwungen can vary in a fluent speaker's speech, this thesis can help provide a guide for what vowel variation to expect. By determining *why* the vowels in Lekwungen vary as they do, this thesis can help provide a guide for identifying the causes of vowel variation, and thus how to perceive, write and pronounce them.

Additionally, in the academic linguistic literature, while there are a number of descriptive works on phonetic variation in Salishan languages, acoustic studies are still relatively rare, especially for Central Salish languages, and in particular for whole vowel systems. This thesis also helps to fill in this gap, and provides a reference point and model for further studies on the same and related languages.

In order to fulfill the goals of 1) providing a tool for language learners and 2) furthering our scholarly knowledge about the language, this thesis first undertakes a review of academic literature relating to vowel variation in Lekwungen and related languages, as well as unrelated languages which exhibit similar effects (Chapter 2). From this literature review as well as observations made by the author, this thesis then presents six hypotheses to answer the research question: 'in Lekwungen, how do stress and adjacent consonants affect the quality of vowels?' The six hypotheses are:

- The length (duration), the pitch, and the relative loudness (amplitude) of a vowel will correlate with the vowel's stress (or lack thereof) in a word.
- /ə/ will be affected by consonants with **palatal** and **(labio-)velar** places of articulation, and these effects will be reflected in acoustic measurements.
- All vowels in Lekwungen will be affected by consonants with a **uvular** place of articulation, and these will be reflected in acoustic measurements.
- All vowels in Lekwungen will be affected by consonants with a **glottal** place of articulation, and these will be reflected in acoustic measurements.

- Consonants in Lekwungen which use the 'glottalic' airstream mechanism (specifically, **ejectives**), as opposed to other consonants, which are 'pulmonic', will not have effects independent of their place-of-articulation effects on vowels, and this will be reflected in acoustic measurements.

The first four hypotheses are based on a review of the literature, while the fifth hypothesis (on the effects of ejectives) is based on observation from the workshop.

In order to confirm or deny the validity of these hypotheses, the thesis will look at data from heritage recordings made in the 1960s of Sophie Misheal, a fluent first-language Lekwungen speaker, when she was in her 80s (Mitchell, 1968; Raffo, 1972). This data will come from the four most common contrastive vowels of Lekwungen, /i/, /e/, /a/ and /ə/, in *consonant – vowel – consonant* (CVC) sequences in which the vowel is either preceded by or followed by one or two of the most common consonants from each category under investigation (see hypotheses): palatal /č/ and /y/, labio-velar /w/ and /kʷ/, uvular /q/ and /qʷ/, glottal /ʔ/, ejective /t̓/ (Chapter 3). Measurements (formants one (F1), two (F2), and three (F3); vowel duration, mean pitch, and mean amplitude) will be taken from the vowels in these sequences, with the formants being measured at three time points: 5%, 50%, and 95% into the vowel, as well as averaged over the middle 90% (5% - 95%) of the vowel. The sequences are taken from words spoken in isolation.

The remainder of the thesis is structured as follows: In Chapter 2 the background literature on Lekwungen (Section 2.1) is reviewed, definitions for technical terms used in subsequent chapters are provided (Section 2.2), background literature on possible stress and consonant coarticulatory effects (Section 2.3 to 2.5) are reviewed, and hypotheses from this review and observations from the workshops made (Section 2.6). Chapter 3 discusses the methodology employed in the thesis, including the approach to ethics adopted here, situated in the Community-Based Language Research model (Czaykowska-Higgins, 2009) (Section 3.1), the recordings from which the data for the thesis is extracted (Section 3.2), and the methods used for data collection and analysis (Section 3.3). Chapter 4 presents the results of the data collection and analysis. Results for stress correlates are presented first (Section 4.1), then the results for consonant coarticulatory effects are presented vowel-by-vowel for F1 and F2 (Section 4.2.1), then for F3 (Section 4.2.2). Other coarticulatory effects of consonants are presented third (Section 4.2.3): vowel quality assimilation across glottal stops (4.2.3.1) and timing of secondary labialisation (4.2.3.2). These results are discussed in Chapter 5, which includes tips for writing/teaching/learning Lekwungen based on what we find out about vowel pronunciation. In chapter 5, the consonantal coarticulatory effects are discussed consonant-by-consonant, and the relation between the persistency of effects on vowel quality and their perceptual implications is discussed (Section 5.2). Selected results are interpreted in a Perturbation Theory framework, so as to offer clues to the possible articulatory gestures that underlie the observed formant effects. Chapter 5 ends with a summary of the observed persistent and perceptible effects of consonants on vowels and their relevant environments (Section 5.3). Chapter 6 summarizes the main findings of thesis, notes limitations and areas for future research, and reaffirms the commitment of the thesis to providing useful and useable information for Lekwungen learners.

Chapter 2

Background

This chapter goes over background information for this thesis project. Section 2.1 provides details on the sounds of Lekwungen and previous linguistic work on the language, as well as lays out the initial research questions which prompted the investigation contained in this thesis. Section 2.2 provides definitions of technical terms for readers who may not be familiar with the some of the terminology in this branch of linguistics: acoustic phonetics. Sections 2.3 to 2.5 reviews the existing academic linguistic literature relevant to answering those questions presented in Section 2.1, specifically literature on stress and stress effects; coarticulatory effects of palatal, labio-velar, uvular, glottal, and ejective consonants in Salish and other languages; as well as other possible factors which might affect pronunciation: speech rate, aging, and language environment. Chapter 2 concludes with hypotheses about what the investigation will find in answering the research questions, based on the review of the existing literature and observations from the Lekwungen language workshops (Section 2.6).

2.1 Lekwungen

Lekwungen, also called Songhees or Songish in the literature, is a Central Salish language of the Salish language family, in the sub-group of Straits Salish. It is one of six mutually intelligible varieties of North Straits Salish (the others are Malchosen, Samish, Semiahmoo, T'Sou-ke, and SENĆOŦEN). Linguists refer to the group as 'North Straits Salish' but there is no common term in the languages themselves for all the varieties/languages as a group (Montler 1999). Lekwungen is also closely related to Klallam (Central Salish), spoken on the other side of the Juan de Fuca Strait. Lekwungen has been traditionally spoken in the area of modern-day Victoria, British Columbia, and of the North Straits Salish varieties it has the greatest similarity with SENĆOŦEN (aka Saanich), spoken just north on the Saanich Peninsula and Gulf and San Juan Islands.

Figure 2.1: Some languages around the Salish Sea, with Lekwungen circled; after Thom 1996

There are no fluent speakers and very few understanders of Lekwungen today, but revitalisation efforts are underway, and one of those efforts is the ongoing Lekwungen language-learning workshops organized by the Songhees Nation. These workshops focus on transcribing Lekwungen from recordings and, as doing so, working on developing a writing system for the language (for more details on the workshops, see Chapter 3, Section 3.1 below).

Linguistic work on Lekwungen is relatively sparse. Hill-Tout (1907) complied a phrase list, a story, and a word list, but differing transcription practices have made their work difficult to decipher for modern language learners and linguists, though see Montler (1996) for a reconstruction of a Hill-Tout story text. Mitchell (1968) created a dictionary of Lekwungen words including some phrases, as well as the recordings used in this project. Raffo (1972) documented the phonology (including allophonic variation) and morphology of Lekwungen. Bouchard (2008) compiled the word lists found in Hill-Tout, Mitchell, and Raffo. For related languages, there are a greater number of works, though as I note below there are relatively few phonetic works on Central Salish languages in general. The main phonetic and phonological works for closely related languages I will reference are Montler (1986, 1998, 1999), on SENĆOŦEN phonology/phonetics, and Bird & Leonard (2009) and Bird, Czaykowska-Higgins, & Leonard (2012) on SENĆOŦEN phonetics. See section 2.4 for discussion involving these.

2.1.1 Consonant and vowel systems

This section is based on the descriptions in Raffo (1972) on Lekwungen and Montler (1986) on SENĆOŦEN. They detailed the phonemic contrasts of Lekwungen and SENĆOŦEN respectively[1] and gave a basic overview of allophonic variation, as well as phonological patterns and phonotactics.

[1] The main known difference between the sound systems of the two languages is the presence of /s/ and /c̓/ in Lekwungen for /θ/ and /t̓ᶿ/ in SENĆOŦEN, though some SENĆOŦEN speakers have /c̓/.

The consonant inventory of Lekwungen consists of six places of articulation (bilabial, alveolar, palato-alveolar, labio-velar, uvular, and glottal); and six manners of articulation (stop, affricate, fricative, nasal, glide, and lateral). Each manner, save fricatives, has both glottalized and non-glottalized counterparts. There are additionally rounded (labialized) velar and uvular stops (both glottalized and not) and fricatives. The following table shows the consonant inventory of Lekwungen in the North American Phonetic Alphabet (NAPA)[2]:

Consonant Inventory of Lekwungen		Bilabial	Alveolar	Palato-alveolar	Labio-velar	Uvular	Glottal
Stops	Plain	p	t		(k)	q	ʔ
	Ejective	p̓	t̓			q̓	
	Labialized				kʷ	qʷ	
	Labialized Ejective				k̓ʷ	q̓ʷ	
Affricates	Plain			č			
	Ejective		c̓	č̓			
	Ejective Lateral		ƛ̓				
Fricatives	Plain		s	š		x̣	h
	Labialized				xʷ	x̣ʷ	
	Lateral		ł				
Resonants	Nasal	m	n			ŋ	
	Glottalized Nasal	m̓	n̓			ŋ̓	
	Glide			y	w		
	Glottalized Glide			y̓	w̓		
	Lateral		l				
	Glottalized Lateral		l̓				

Table 2.1: Consonant inventory of Lekwungen

With regards to consonant distribution and variation, Raffo (1972) details that the plain unrounded velar stop /k/ occurs only in borrowed words, and that the nasal /ŋ/ is

2 Lekwungen is written in the NAPA, and most Salish work uses the NAPA. International Phonetic Alphabet (IPA) equivalents: c̓ = t͡s’, ƛ̓ = t͡ɬ’, ł = ɬ, č = t͡ʃ, č̓ = t͡ʃ’, š = ʃ, y = j, y̓ = j’, x̣ = χ, x̣ʷ = χʷ.

fairly far back, close to the place of articulation of the uvular stops and fricatives. Raffo further notes that all plain stops, as well as the ejectives (glottalized stops) /k̓ʷ/ and /q̓ʷ/, are aspirated prevocalically[3], syllable finally, when preceding stops, and in the case of /p/, /t/, and /q̓ʷ/ but not /k̓ʷ/, before affricates as well[4]. The glottalized resonants are realized as a resonant preceded or followed by a glottal stop or creak, the exact timing of which seems to be determined by stress or position within a word (see Caldecott 1999 on SENĆOŦEN).

There are five underlying vowels in Lekwungen: four full vowels (/a/, /e/, /i/, /u/) and schwa /ə/. This distinction is common to Salish languages, where full vowels and schwa have been found to pattern distinctively phonetically, phonologically, and morphologically. In Lekwungen, all full vowels can be long or short, and underlying /u/ is rare (discussed further below).

<table>
<tr><th></th><th>Front</th><th>Central</th><th>Back</th></tr>
<tr><td>Close</td><td>i</td><td></td><td>u</td></tr>
<tr><td>Close-mid</td><td>e</td><td rowspan="2">ə</td><td></td></tr>
<tr><td>Open-mid</td><td></td><td></td></tr>
<tr><td>Open</td><td></td><td>a</td><td></td></tr>
</table>

Table 2.2: Vowel inventory of Lekwungen

The following description of vowel variation is mainly from Raffo (1972), but also takes into consideration Montler (1986) describing SENĆOŦEN. All examples are from Raffo (1972) unless otherwise specified. Note that the examples here use Raffo's transcription system (using a mix of the NAPA and the IPA) and that this is *not* the current system used to write Lekwungen. Additionally, Raffo did not use the notion of

[3] Unlike SENĆOŦEN and like Klallam (Montler 1986).

[4] Forward slashes (/) surround phonemes, which are underlying representations of sounds. Brackets ([ ]) surround the phonetic representations of those sounds (i.e., how they're pronounced), which may differ from the phonemes, as seen here.

glottalized resonants as I (and all work on Northern Straits Salish since the 1980s) do, so their analysis of [əẏ] and [əẇ] as variants of unstressed /i/ and /u/ before glottal stops respectively is no longer canonical; this is also the case for their analysis of [o] as an unstressed /u/ (in this case[5]). Current practice is to analyse these forms as an underlying schwa plus a glottalized resonant, so 'river' is *staľəẇ*, with the final schwa-glottalized w pronounced as [əwʔ] or [oʔ].

/i/ can be [i] both when stressed and unstressed: *x^{w}íʔləm*, 'rope'[6], *lisék*, 'sack', but Raffo describes it as freely-varied [i] or [e] when stressed before velars and uvulars, /s/ and /š/: [sqəqəwés~sqəqəwís] for *sqəqəwís* 'rabbit'; and as [ɪ] between glottal stops: [q^{w}ənʔɪʔ] for *q^{w}ənʔiʔ*, 'seagull' (all transcriptions are those provided by Raffo 1972). Montler describes a retracting and lowering of /i/ neighbouring velars, uvulars, and glottals. Raffo also considers [əy] a variant of /i/ which occurs when unstressed before glottal stops: [ṗʌ́wəyʔ] for *ṗə́wiʔ* 'flounder'. /e/ freely varies between [æ] and [ɛ] when stressed or unstressed: [łǽtš~łɛ́ts] for *łéč*, 'dark', and as [ɛ] before [y] and when long: [sč̓ɛ́yn] *sč̓éyn*, 'very', [sčɛ́:nʊx^{w}] *sčé:nəx^{w}*, 'fish'. In SENĆOŦEN Montler notes that /e/ is usually [ɛ] before post-velar consonants, and that it raises to near /i/ neighbouring laterals, palatals, and velar resonants. /a/ is usually [a] in all positions: [stáʔləwʔ] *stáʔluʔ*, 'river', though Raffo notes a few varying instances of [ɒ] in a limited set of words, though this is not noted as predictable. Montler says that this backing is in the environment of post-velars. Raffo describes /ə/ as [ɔ] before /kˈ^{w}/ and /h/ and after /qˈ^{w}/: [mɔ́k̓^{wh}] *mək̓^{w}*, 'all', [mɔháyʔ] *məháyʔ*, 'basket', [q̇^{wh}ɔṗʌ́x̣^{w}] *q̓^{w}əp̓əx̣^{w}*, 'acorn' and as [ʊ] between a resonant and /x^{w}/ or /x̣^{w}/: [sčɛ́:nʊx^{w}] *sčé:nəx^{w}*, 'fish'; and otherwise as [ə]

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[5] [o] and [u] phonetic forms of /əw/, usually occurring when unstressed and stressed, respectively

[6] This may actually be an instance of a vocalised glottalized glide.

unstressed or [ʌ] stressed: [sɬəlp̓əlǽx̣ən] *sɬəlp̓əléx̣ən*, ‘bat’, [pʰʌ́q̓] *pə́q̓*, ‘white’. SENĆOŦEN schwa is similar (Montler 1986), lowering to [a] by post-velars, raising to [ɪ] after palatals and before resonants and to [ʊ] before labialized consonants, being [ə] otherwise. Raffo, describes /u/ as [u] when stressed and [o] when unstressed: [tʰu:lə] *túlə,* ‘over there’, [c̓ox̣íʔləm] *ć̓ux̣íʔləm* ‘mythical hero’. Raffo also groups [əw] as a variant of /u/ occurring when unstressed before glottal stops, freely varying with [o]: [stáʔləwʔ]~[stáʔloʔ] *stáʔluʔ*, ‘river’.

The case of (true) /u/ is special, for it seems to mostly be found in loan words, and is described as being rare, while also having an indeterminate phonological analysis. Mitchell’s (1968) thesis gave a brief sketch of the phonemes of Lekwungen, where they described an /o/ where Raffo has /u/. Mitchell’s /o/ did not have contrastive length and was described as the ‘rarest in occurrence’ of vowels. Raffo likewise described /u/ as being ‘of limited occurrence’. Montler (1986) describes the /u/ in closely-related SENĆOŦEN as primarily being found in loan/borrowed words. Thompson, Thompson, & Efrat (1974) likewise conclude this for both Lekwungen and SENĆOŦEN, considering only /i/, /e/, /a/, and /ə/ to be historical (i.e., non-loaned) sounds of Lekwungen. They reconstruct a Proto-Straits *u, which lowered to /a/ as *a fronted to /e/ in the historical development of Lekwungen. This is in contrast to other varieties of North Straits Salish, where *u lowered to /o/, and to Klallam, which had no historical lowering of *u, and so retains it. Table 2.3 summarizes Raffo and Montler’s descriptions of vowels in Lekwungen and SENĆOŦEN, respectively.

	Lekwungen (Raffo 1972)	SENĆOŦEN (Montler 1986)
/i/	[i~e] before velars, uvulars, /s/, /š/ [ɪ] between glottals [i] elsewhere	[ɪ] neighbouring velars, uvulars, glottals [i] elsewhere
/e/	[ɛ] before /y/ and when long [æ~ɛ] otherwise	[ɛ] before uvulars, glottals [i] neighbouring resonants
/a/	[a]	[ɒ] neighbouring uvulars, glottals [a] elsewhere
/u/	[u] stressed [o] unstressed	[u]
/ə/	[ɔ] before /k̓ʷ/ and /h/, after /q̓ʷ/ [ʊ] between a resonant and /xʷ/ or /x̣ʷ/ [ʌ] elsewhere	[a] neighbouring uvulars, glottals [ɪ] after palatals, before resonants [ʊ] before labialized consonants [ʌ] elsewhere

Table 2.3: Summary of phonetic variation for Lekwungen and SENĆOŦEN vowels

Lekwungen can have up to three consonants word initially and finally. Vowels cannot start a word and they rarely end one (Raffo 1972). All consonants, save for glottalized resonants and /h/ can appear word-initially, medially, or finally. /h/ may not be in word-final position and glottalized resonants cannot be in word-initial position. Any available combination of consonant-vowel-consonant (CVC) sequence should be possible, subject only to these restrictions on glottalized resonants and /h/. Neither Mitchell nor Raffo make note of limits on syllable length; Montler (1986) states that the longest a *root* may be in SENĆOŦEN is CCVC or CVCC.

Raffo's (1972) work is a good phonological analysis and basic description of Lekwungen's sound system, but is impressionistic and makes no indication of having involved detailed phonetic study or analysis. This means that the opportunity for such a description is ripe, and this thesis so seeks to provide it.

2.1.2 Questions arising from the previous work

In addition to the descriptions of Raffo (1972) on vowel variation, detailed above, a few observations were made in the Lekwungen language workshops I attend. Participants in these workshops are working to learn about Lekwungen, and are currently working to transcribe Lekwungen from heritage recordings. In the course of working in these workshops several instances of possible effects have been observed (for more on the workshops and my involvement with them see Section 3.1). This section briefly discusses some of these observations, before turning to present the general research areas of interest in this thesis.

One effect heard in the workshops that prompted interest was the ambiguous perception of the /i/ in *t̓íləm* 'sing', which was heard as in between [i] and [e]. While it is certainly possible that ambiguity could be due to differing perceptions of /i/, /t̓/ occurs rarely enough that the prospect of vowel lowering from ejectives (independent of place of articulation) was brought up, a factor spurring interest in studying vowel variation. Another question from the workshops was about what acoustic cues are available to distinguish underlying /a/ and /ə/, given that stressed schwas often seem to lower to [a]. From this came an interest in other acoustic cues of vowels and stress, in particular duration.

These observations, in combination with the observations put forward by Raffo (and Montler for SENĆOŦEN), motivate the research question this thesis will investigate:

In Lekwungen, how do stress and consonants affect the quality of vowels?

In order to investigate this question, this thesis focuses on CVC sequences and any possible coarticulatory effects the consonants may have on the neighbouring vowel, as well as possible general stress effects on vowels. Of specific interest are the effects of stress, palatal and labialized consonants (especially on schwa), post-velar consonants (uvular and glottal consonants), and ejectives. The following sections review previous work in the academic literature on these effects.

2.2 Definitions of technical terms

Before beginning to go over the existing literature, I provide in this section definitions for technical terms I will use throughout the thesis, in order to increase accessibility and clarity.

Term	Definition
Coarticulation	Overlap between neighbouring speech gestures, due to the fact that speech is a continuous flow of sound, and articulators (tongue, lips, jaw, etc.) can only move so fast between them. I talk about two types in this thesis: • Anticipatory: the effects of a following sound on a preceding sound • Preservatory: the effects of a preceding sound on a following sound (also called 'retentive' in the literature)
Vowel quality	The properties of vowels that make them sound different from one another (e.g. [a] vs. [i]). The specific combination of different formant frequencies (see below), affected by the physical configuration of the vocal tract, make up a vowel's quality.
Pitch (F0)	The fundamental frequency (F0) or pitch of a sound, representing in speech the rate at which the vocal folds are vibrating. Measured in cycles per second (Hertz, Hz); a higher number means a higher pitch, a lower number, a lower pitch.
Amplitude	The relative loudness or intensity of a sound. Measured in decibels (dB). Greater amplitude or intensity (a higher number) means a (relatively) louder sound.
Duration	The length in time of a sound/word/phrase, etc. When dealing with individual sounds, it is measured in milliseconds (ms).
F1, F2, F3	Speech formants numbers one, two, and three. Formants are frequencies of sounds, measured in hertz. They are frequencies of a sonorous (usually vowel) sound that have greatest intensity; these frequencies change based on shape of the speaker's vocal tract. Because of this, their

	frequencies provide clues as to how the vocal tract is configured for each sound. • **F1** is inversely correlated with tongue height in the mouth. A lower F1 measurement means a higher tongue body and closer jaw, and a higher F1 measurement means a lower tongue body and more open jaw. Vowels produced with a high tongue body, like /i/, will have a relatively low F1, while a vowel produced with a low tongue body, like /a/, will have a relatively high F1. • **F2** is directly correlated with how far forward the tongue is in the mouth. Vowels more forward in the mouth, like /i/, will have a higher F2, and those further back, like /u/, will have a lower F2. • Usually F1 and F2 are all that are needed for vowel identification, but in this thesis I also investigate **F3**. The associations of F3 are less clear than the other two, but F3 usually correlates with lip rounding or constriction in the pharynx, the region behind the tongue and above the vocal folds.

Table 2.4: Summary of technical terms

To illustrate these terms/measurements, I provide an illustrative spectrogram, a tool used in linguistics to visually display information about sounds.

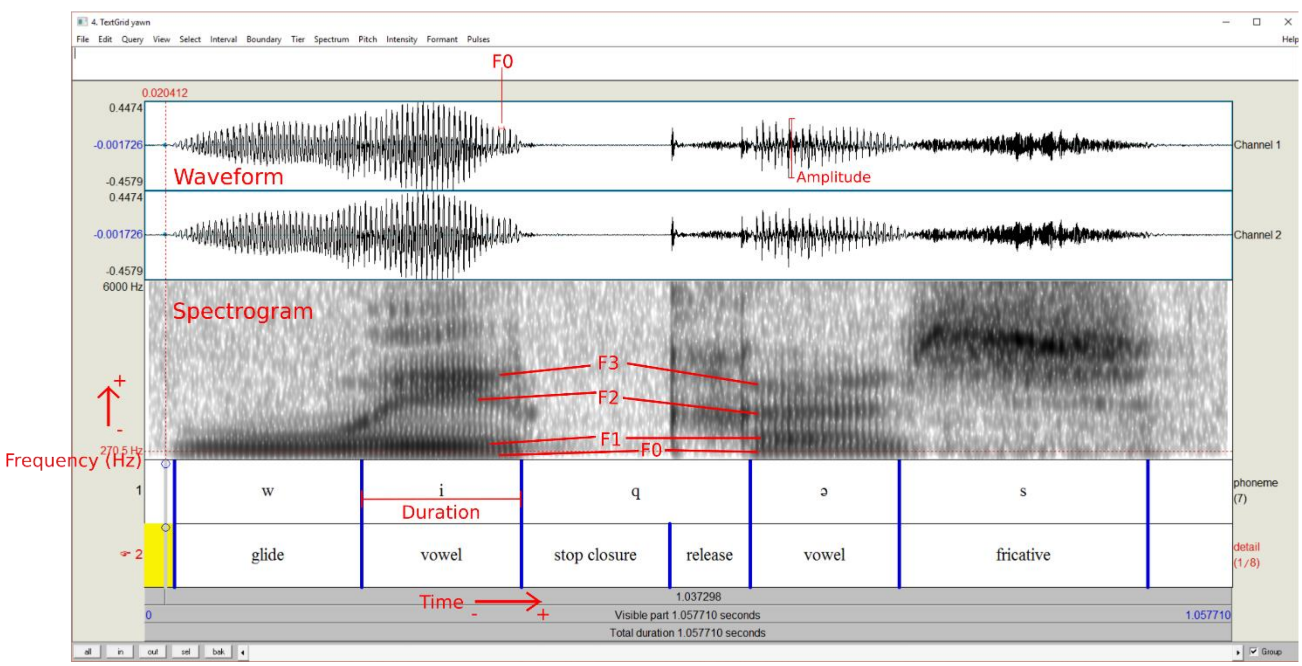

Figure 2.2: An illustrative spectrogram showing *wiqəs*, 'yawn'

In the top half of the image is a waveform, the deviations up and down from its centreline correspond to amplitude, or loudness: the greater the deviation, the louder the sound. The distance between spikes corresponds to the fundamental frequency, or pitch. The bottom half of the image is a spectrogram, and the regular vertical striations running through the parts marked 'vowel' and 'glide' are the glottal pulses: the opening and closing of the vocal folds, corresponding with the spikes in the waveform. In the same way a prism will break apart light into its component wavelengths, so does a spectrogram for sound. A single speech sound is composed of a number of different frequencies at different amplitudes over time; the spectrogram breaks these apart. Frequency increases top to bottom, time left to right, and the dark parts are higher amplitude (louder). Observe how the vowels have dark bands at certain frequencies, these are the formants. They are different between the two vowels (/i/ vs. /ə/) because the vowels are produced with different mouth configurations. F2 is higher in /i/ than in /ə/ because the tongue is further forward in the mouth for /i/ than for /ə/. The different formants make them sound different. The stop /q/ consists of a blank period with no noise (except background tape hiss), this is the closure; following is a period of turbulent noise (note the lack of regular vertical striations that represent voicing in the vowels), this is the stop release. At the end of the word is /s/, which consists of turbulent noise centred around a frequency of about 3500 Hz (cross-linguistically low for a /s/).

2.3 Stress and stress effects on vowels

In most Central Salish languages stress has an effect on the quality of vowels, as well as on their duration, amplitude, and pitch. Pitch and duration are the most common acoustic correlates of stress in Salish languages (Czaykowska-Higgins & Kinkade 1998). Additionally, in Central Salish languages, stressed or unstressed full vowels can undergo quality changes due to stress (e.g., Sḵwx̱wú7mesh close vowels lower to mid vowels when stressed, ʔayʔaǰuθəm close vowels lax when unstressed) and in a few languages can even reduce to schwa (when unstressed), including in SENĆOŦEN (Montler 1986, Leonard 2007), Klallam (Montler 1998) and hən̓q̓əmin̓əm̓ (Suttles 2004). This section first details three phonetic studies of stress in Central Salish languages: one on non-vowel quality related acoustic correlates of stress in Sḵwx̱wú7mesh (Tamburri-Watt, Alford, Cameron-Turley, Gillon, & Jacobs 2000); and two on quality-related (and other) acoustic correlates of stress in Lushootseed and ʔayʔaǰuθəm (Barthmaier,1998 and Blake & Shahin, 2008). The section then discusses three studies on languages with unstressed full vowel reduction: SENĆOŦEN (Leonard 2007), Klallam (Montler 1998), and hən̓q̓əmin̓əm̓ (aka Musqueam aka Downriver Halkomelem; Central Salish) (Suttles 2004).

Tamburri-Watt et al. (2000) investigated the acoustic properties of stressed and unstressed /a/ and /u/ in Sḵwx̱wú7mesh (aka Squamish) (Central Salish). Duration and pitch were significantly[7] longer and higher for stressed /a/ and /u/ than for their unstressed counterparts in the four conditions studied: when appearing in the stressed syllable in CV́, CV́CV, and CV́CVCV, and in words where stress is shifted to a stress-attracting suffix. The stressed vowels in the four conditions were also all statistically the same in pitch and duration relative to each other. Amplitude, however, was split. It was significantly greater for stressed /a/ compared to unstressed /a/ (as in [sł**á**n**a**y']) in all four

[7] In quantitative studies (studies which make numerical measurements), 'significant' refers to statistical significance in the analyzed results.

conditions, but for stressed /a/ in a trisyllabic word (as in [m**á**lalòs] 'racoon') it was significantly lesser than in the other three conditions. Similarly, for /u/ (realized as [o]), amplitude for stressed /u/ (as in [sh**ó**hopèt] 'rabbit') was significantly greater than unstressed /u/ (as in [ʔánʔ**o**sk]) 'two o'clock' in all four conditions, but amplitude was significantly less between stressed /u/ in a bisyllabic or monosyllabic word (as in [l**ó**ləm] 'sing' or [p**o**ʃ] 'cat') and stressed /u/ in a trisyllabic word or the stress-attracting suffix –*ulh* (as in [sh**ó**hopèt] 'rabbit' or [sèx^{w}ał**ʔɔ́**lł] 'young child'). Overall though, stressed vowels had significantly greater pitch, duration, and amplitude compared to unstressed vowels.

Barthmaier (1998), studying Lushootseed (Central Salish) found duration to be a consistent acoustic correlate of stress on vowels. With data from stories digitised from tapes, Barthmaier found that /a/ was the longest stressed vowel, with a mean duration of 218 ms, followed by /i/ at 217 ms, /u/ at 163 ms and /ə/ at 109 ms. However, when unstressed, full vowels did not collapse in duration to schwa: /a/ was 144ms, /i/ 143 ms, /u/ 117 ms, and /ə/ 75 ms. Likewise, full vowels did not collapse in vowel quality to schwa entirely, though they did centralise greatly. F2 of /i/ lowered from 2000 Hz to 1500 Hz, F2 of /u/ raised from 1000 Hz to 1200 Hz, while F1 for both remained unchanged. Schwa was unchanged, and F1 for /a/ lowered from 750 Hz to 525 Hz, and F2 lowered from 1300 Hz to 1100 Hz. Barthmaier did not analyse the changes perceptually, but inferred that visually the vowels still grouped by phoneme based on the vowels, even as they all centralised.

Similarly, Blake and Shahin (2008), studying ʔayʔaǰuθəm[8] (Sliammon dialect of Mainland Comox) (Central Salish), found that unstressed full vowels /i/, /a/, /u/ did not collapse in vowel quality to schwa, though /i/ and /a/ did centralise. All full vowels had a slightly lower average F2 when unstressed than when stressed, and this was most pronounced for /i/. /a/ and /u/ had a slightly lower F1 when unstressed, while /i/ had a more noticeably higher F1 when unstressed. Overall though, the reduced (unstressed) full vowels retained their quality, and there was no neutralization or collapse of unstressed vowels together. Additionally, save for unstressed [a], duration was not greatly affected in the unstressed variants. Unstressed [a] had a duration of 90 ms, while the other stressed and unstressed full vowels all had durations around 150 ms. As for schwa, unstressed schwa had a slightly lower F2 and a slightly higher F1 than stressed schwa (similar to unstressed vs. stressed /i/) and like the full vowels there was no collapse in quality, with the vowels and overall quality said to be retained. Additionally, unstressed [ə] had a duration of ~90 ms, while stressed [ə] had a duration of ~100 msec.

Given the fact that none of these languages had reduction of unstressed vowels to schwa, it makes sense that their acoustic correlates of stress also show no similar collapse, though they do reduce. However, the general trend that stressed vowels had greater duration and pitch than unstressed vowels (while intensity was unclear) points to a likely trend for Lekwungen. Supporting this, Leonard (2007) briefly acoustically analyzed vowels in SENĆOŦEN, finding that stressed full vowels had a longer duration than stressed schwas, which had a longer duration than unstressed schwas. Pitch was also greater for stressed vowels, both full vowels and schwas, than for unstressed vowels.

[8] Also spelled Éy7á7juuthem.

Intensity was inconsistent, and Leonard hypothesized that pitch and duration were the likely acoustic correlates of stress, but left it up to future work to do a comprehensive acoustic analysis. Furthermore, and importantly for studying Lekwungen, Leonard noted the collapse of full vowels to schwa when unstressed, or even their outright deletion, though performed no acoustic analysis of such.

Montler (1998) provides acoustic information (F1 and F2 measurements) on the reduction of unstressed vowels, but does not distinguish it from the formant measurements of stressed vowels in their chart. Montler also details that Klallam stressed vowels were longer than unstressed vowels, but that stressed schwa was only about half the length of the stressed full vowels, not significantly different from the unstressed vowels. Suttles (2004) does not provide acoustic information on the reduction of unstressed vowels but they do discuss that hən̓q̓əmin̓əm̓ has reduction of unstressed full vowels to schwa.

Given that Central Salish languages can have some centralisation of vowel quality when unstressed, as well as a corresponding decrease in duration and pitch (and possibly intensity), it is likely that Lekwungen will have similar acoustic correlates of stress, especially given the patterns in closely related languages. Furthermore, since SENĆOŦEN is mutually intelligible with Lekwungen, has reduction of unstressed full vowels to schwa and a decrease in pitch and duration, it is likely that Lekwungen does as well.

2.4 Consonantal coarticulatory effects on vowels

This section looks at literature that has impressionistically or experimentally investigated the coarticulatory effects of the consonants under investigation in this thesis.

The first three subsections look at place of articulation effects, while the fourth subsection looks at airstream mechanism effects. The first subsection gives some impressionistic accounts of Central Salish phonetic variation, including coarticulation, which demonstrate the types of effects that may be present in Lekwungen and that will be investigated in further detail as the section progresses. The second subsection looks at coarticulation and uvular consonants, finding that vowel quality effects, namely lowering and/or retraction, are well-attested and widespread in uvular consonant contexts. The third subsection looks at coarticulation and glottal stops, where we see that languages vary on whether or not vowel lowering is associated with glottal environments. Finally, the fourth subsection looks at coarticulation with ejective consonants, finding that, while ejective consonants vary widely in their properties among languages and speakers, vowel quality effects are relatively rare with ejective consonants, and voice quality effects are more common[9].

In this section specifically, ‘coarticulatory effects’ will refer (unless otherwise specified) to ‘persistent’ coarticulatory effects. All consonants (and vowels) will have some degree of coarticulatory effect on neighbouring vowels (and consonants) in the few milliseconds at their boundaries, and in this thesis these are referred to as ‘transitory’ or ‘peripheral’ coarticulatory effects. These effects are more so the involuntary/universal result of physical constraints in moving from one speech segment gesture to another. Unless every sound was said in isolation, such effects would be impossible to avoid. Persistent coarticulatory effects, on the other hand, are changes to vowel quality that persist across all or most of the vowel, that don’t alter the meaning of the word (i.e., are

[9] Voice quality refers to the acoustic components that give information about the phonation that the glottis (the vocal folds and surrounding structures) is producing (e.g., voicing, creaky voice, etc.). Measurements such as jitter, shimmer, pitch, amplitude, can all be important correlates of a certain phonation type.

allophonic), and are language-specific effects, dependent on a variety of factors (Manuel & Krakow, 1984; Manuel, 1987).

Especially relevant to the investigation of Lekwungen here is the language's relatively sparse vowel space. Manuel (1990) found that Sotho (Southern Bantu), a language with a more crowded phonemic vowel space was likely to have fewer persistent perception-altering coarticulatory effects on their vowel quality than Ndebele (Southern Bantu) or Shona (Southern Bantu), languages with fewer vowels, because the crowded state of the Sotho vowel space means that each vowel has a limited target space, that is, a limited range of formant values it can have before it crosses a meaningful perceptual boundary. A speaker could not diverge too widely from the target space, or else the vowel would sound like a different (meaningful) vowel. A language with a smaller vowel inventory (e.g., Ndebele) could allow greater persistent coarticulatory effects on vowels by having a larger target space for each vowel, where a bigger change in vowel quality would be less likely to cross a perceptual boundary and affect meaning and comprehension.

In Central Salish languages, which have relatively sparse phonemic vowel inventories, the vowel most affected by consonantal coarticulatory effects is schwa. It is possible that schwa would have a relatively large target space for its output, allowing a variety of persistent coarticulatory effects to alter schwa, and to a Lekwungen speaker it would still remain within the range of possible schwas. Full vowels in Central Salish languages are not affected as dramatically as schwa (as we'll see below), but a relatively sparse vowel space means that they could experience relatively persistent coarticulatory effects without being perceived as a different vowel.

2.4.1 Impressionistic descriptions/accounts

Acoustic phonetic studies of Central Salish languages are relatively few, but there exist some impressionistic descriptions. The following table (Table 2.5) details information from four studies (chosen for availability), focusing on consonantal coarticulation but also including notes on stress effects.

	ʔayʔaǰuθəm (Blake 2000)	hən̓q̓əmin̓əm̓ (Suttles 2004)	SENĆOŦEN (Montler 1986)	Sḵwx̱wú7mesh (Kuipers 1967)
/i/	[ɛ] post-velars, glottalized [i] palato-alveolars, velars [e] stressed elsewhere [ɪ] unstressed palato-alveolars, velars [ɛ] unstressed elsewhere	[ɪʲ] before uvulars [e] after uvulars low [i] ~ high [e] elsewhere	[ɪ] neighbouring velars, uvulars, glottals [i] elsewhere	[ɛ] before uvulars [ɛy] between uvulars and non-uvulars [e] stressed [i] unstressed
/e/		[ɛ]~[æ]	[ɛ] before uvulars, glottals [i] neighbouring resonants	
/a/	[ɑ] post-velars [ɛ] palato-alveolars, palatals [a~æ] non-sonorant laterals [a~ʌ] coronals, labials [ɑ] elsewhere	[ɑ]	[ɒ] neighbouring uvulars, glottals [a] elsewhere	[ɛ]~[æ] palatals (not /y/) [ɔ] labialized C (not /w/) [a] elsewhere
/u/	[ɔ] post-velars, glottalized [u] palato-alveolars, velars [o] stressed elsewhere [ʊ] unstressed palato-alveolars, velars [ɔ] unstressed elsewhere	[u]~[o]	[u]	[o] stressed [u] unstressed
/ə/	[ʌ] uvulars [ɪ]palato-alveolars, palatals [ɨ~ï] velars [ɑ] laryngeals [ʊ] labialized velars [ɔ] labialized uvulars	Unstressed: [ɪ]~[i] before /x/, /y/ [o] before /w/ and labialized velars Stressed: [ɪ] before /x/ [ɛ] before /y/ [ɑ] before /w/ [o] labialized velars	[a] neighbouring uvulars, glottals [ɪ] after palatals, before resonants [ʊ] before labialized consonants [ʌ] elsewhere	

Table 2.5: Some Central Salish languages' vowel quality variation

In these descriptions we see similar effects on vowel quality as those detailed in Raffo (1972): stress effects; effects of /w/ and /y/, especially on schwa; effects of glottal stops; and effect of uvulars.   Blake (2000)'s description of ʔayʔaǰuθəm shows several patterns: fronting/raising in the environment of palatals, backing/lowering in the environment of uvulars and glottals, and for schwa backing in the environment of labialized consonants and raising in the environment of velars. For schwa, Suttles (2004) describes similar effects in hən̓q̓əmin̓əm̓: a fronting before palatals and velars, and a backing and raising before /w/ and labialized consonants. Montler (1986) describes retraction of /i/, /e/, /a/ with uvulars and glottal stops, as well as the lowering of schwa with uvulars and glottals, and the raising and fronting or backing of schwas with coronals or labialized consonants. Finally, Kuipers (1967) describes stress effects on vowel quality in Sḵwx̱wú7mesh, where close vowels /i/ and /u/ lower to [e] and [o] respectively when stressed.

In the following sections I go into each of these effects, save palatals and labio-velars, in more detail. I do not include palatals or labio-velars due to an overall lack of acoustic work done on their effects in Salish languages. The one work that does investigate their effects though, Bessell (1997), found that alveolars and velars in St'át'imcets (aka Lillooet; Interior Salish), did not greatly affect F1 or F2 of schwa (or /i/, /a/, and /u/) relative to a mean; and in this did not differ from the effects of /p/ or /ʔ/. Despite these findings, I include palatals and labio-velars for analysis because of their documented perceptible effects in Central Salish languages (see Table 2.5). The following sections detail effects for which more works are available, warranting sections of their own.

2.4.2 Coarticulatory effects of uvular consonants

Uvular consonants have a strongly attested lowering and/or retracting effect on neighbouring vowels, an effect most notably seen with close vowels (Rose, 1997). These are associated with a variety of compensatory strategies different languages make use of to resolve the universal articulatory conflict between close front vowels, which require a tongue relatively forward and high in the mouth, and uvular (and similar) consonants, which require a tongue far back (and possibly low) in the mouth (Gick & Wilson, 2006). This subsection looks first at a broad range of effects from different languages, not only limited to uvular consonants. It then discusses two acoustic studies of close vowels neighbouring uvular stops from St'át'imcets, before looking at the variation in compensatory strategies found in Central Salish languages, including the closely related SENĆOŦEN.

Rose (1997) described coarticulatory effects of uvulars in a number of Salish, Afroasiatic, and other languages. In Nłeʔkepmxcín (aka Thompson; Interior Salish), close vowels /i/ and /u/ are realized as [e] and [o] in the environment of uvular /q/ (order unspecified). In Snchitsu'umshtsn (aka Coeur d'Alene; Interior Salish), close vowels /i/ and /u/ and open vowel /a/ are lowed and retracted, appearing as [ɛ], [ɔ], and [ɑ], respectively, preceding uvulars. In Arabic, uvulars, emphatics (pharyngealized), and pharyngeals lower and retract both preceding and following vowels, though often vowels lower less with uvulars than with pharyngeals. For example, /i/ and /e/ in Palestinian and Syrian Arabic (Central Semitic) both lower to [a]; /i/, /u/, and /a/ in Moroccan Arabic (Central Semitic) appear as [ɪ], [ʊ], and [ɑ] respectively. Tamazight (Berber) has lowering of /i/, /u/, and /a/ for a number of post-velar consonants as well as emphatic coronal consonants. The below table summarises these findings:

	Nłeʔkepmxcín	Snchitsu'umshtsn	Palestinian and Syrian Arabic (pharyngeals)	Moroccan Arabic	Tamazight	ʔayʔaǰuθəm	hən̓q̓əmin̓əm̓	Sḵwx̱wú7mesh
/i/	[e]	[ɛ]	[a]	[ɪ]	[ɪ]	[ɛ]	[ɪʲ]/_C [ɛ]/C_	[ɛ] [ɛy]
/u/	[o]	[ɔ]		[ʊ]	[ʊ]	[ɔ]		
/a/		[ɑ]		[ɑ]	[ɑ]	[ɑ]		

Table 2.6: Effects of post-velars on vowel quality

Moving to an acoustic study of this lowering, in investigating St’át’imcets, Bessell (1997) and Namdaran (2006) found that uvular stop /q/ consistently raised F1 and lowered F2 (relative to baseline mean value for the vowel) of a preceding or following vowel (i.e., lowering and retracting the vowel). For Bessell, F1 was raised more when preceding /q/ than when following /q/ for all four vowels, while F2 was lowered more for /i/ and /ə/ preceding /q/ than following, and more for /u/ and /a/ following /q/ than preceding. For Namdaran, who only looked at close vowels /i/ and /u/, F1 was also consistently raised before and after /q/. For /i/ F1 was not considerably higher depending on context, but F1 was higher for /u/ following /q/ than preceding it. F2 effects were more complex: /i/ when preceding /q/ and /u/ when following /q/ had rapid and persistent lowering of F2, but /i/ following /q/ did not have that initial rapid lowering, instead it lowered consistently as the vowel progressed away from /q/. F2 in /u/ preceding /q/ was initially higher than a base /u/ F2, but by offset at the consonant it had lowered. The magnitude though, like for Bessell, was less than for /i/. Namdaran (2006) also investigated F3. Preceding /q/, F3 was lowered for /i/ and /u/, but for /u/ it raised closer to /q/. Following /q/, F3 was consistently raised for /i/ and lowered for /u/.

The vowel lowering and raising detailed in Bessell (1997) and Namdaran (2006) is one of a number of compensatory strategies languages use to resolve articulatory conflict between close vowels and uvular (and post-velar in general) consonants. Bird & Leonard (2009) investigated the instantiation of a number of strategies in SENĆOŦEN. They found that for both stressed and unstressed /qi/ and /iq/ sequences produced by two fluent speakers, three main strategies were used: vowel retraction, e.g., /qi/ to [qɪ]; transitional vowel, e.g., /qi/ to [qᵊi]; and transitional frication, e.g., /qi/ to [qˣi].

	Speaker 1	Speaker 2
/qi/	[qᵊi], [qɪ]	[qɪ]
/iq/	[ɪq], [iˣq]	[iˣq]

Table 2.7: Most commonly used strategies for the two SENĆOŦEN speakers in Bird & Leonard (2009)

For acoustic analysis, only Speaker 2's productions were analysed, as Speaker 1's acoustic measurements did not pattern consistently with what the auditory analysis suggested. For the vowel retraction cases, higher F1 measures (compared to baseline /i/) were consistent with retraction, but higher F2 measures were not. F1 and F2 did remain stable across the retracted vowel. Slightly higher F1 measures and lower F2 measures which were unstable across the vowel indicate that the transitional frication also seemed to have some retraction, as well as a transitional vowel. Overall, strategies and their acoustic properties were mixed, and no single strategy was exclusively used by either speaker.

As seen above in Section 2.3.1 with hən̓q̓əmin̓əm̓ and Sḵwx̱wú7mesh, and as seen here with SENĆOŦEN, compensatory strategies and/or vowel quality effects can be asymmetrical depending on context. In fact, this seems to be fairly common in Central Salish languages. Bird & Leonard provide a table summarizing the pronunciation of /qi/ and /iq/ sequences in a number Central Salish languages, reproduced here:

Language	/qi/	/iq/	/i/ elsewhere
SENĆOŦEN (Bird & Leonard 2009)	[qɪ]	[iˣq]	[i]
SENĆOŦEN (Montler 1986)	[qɪ]	[ɪq]	[i]
hən̓q̓əmin̓əm̓ (Suttles 2004)	[qe]	[iᵊq]	‘low [i] or high [e]’
Hul’q’umi’num’ (Kava 1967)	[qɪ]~[qe]	[iᵊq]	[i]~[ɪ]
ʔayʔaǰuθəm (Davis 1978)	[qe]	[iᵊq]	[ɪ]
ʔayʔaǰuθəm (Blake 2000)	[qɛ]	[ɛq][10]	[i] ~ [ɛ] ~ [e]
Sḵwx̱wú7mesh (Dyck 2004)	[qey]	[eq]	[i] unstressed [e] stressed

Table 2.8: Compensatory strategies in Central Salish languages; from Bird & Leonard (2009)

Overall, the lowering and/or retracting effects of uvular consonants on vowels is robustly attested, and is likely to be universal to languages with uvular consonants. Unlike ejective consonants, where effects can vary from speaker to speaker and from language to language, or glottal consonants which seem to divide languages on whether they involve lowering or not, the variety of languages with uvular consonants all have either lowering or retracting of vowels, especially close vowels. In looking at coarticulatory effects for Lekwungen then, persistent formant effects on vowels neighbouring uvular consonants are very likely to be present.

[10] Bird & Leonard attribute the lack of asymmetry in ʔayʔaǰuθəm and Sḵwx̱wú7mesh to these languages’ proximity to Interior Salish languages, which, as seen earlier with St’át’imcets, have relative symmetry in resolutions between /qi/ and /iq/.

2.4.3 Coarticulatory effects of glottal stops

The literature is mixed with regards to the coarticulatory effects of glottal stops. Languages studied have differed on whether or not they have some type of lowering in the environment of glottal stops, most prominently with variation on whether or not /ə/ is realized as [ə] or [a].

For non-Salish languages, Rose (1997) describes phonological lowering of /ə/ to /a/ in Tigrinya, Tigre (North Ethio-Semitic), and Nisga'a (Tsimshianic), with an adjacent[11] (preceding and following) glottal stop. Rose, though, also found other languages where there was no phonological lowering of /ə/ to /a/, e.g. Amharic and Gafat (South Ethio-Semitic). For other vowels, the effect of glottal stop is likewise divided. Rose (1997) found that for most languages studied there was no phonological lowering of non-schwa vowels with glottal stop, but the East Circassian language Besleney did have glottal stop lowering /e/ to [a].Though glottal stop was not studied in detail, Wilson (2007) found that it patterned with non-post-velar consonants (bilabials, alveolars, laterals, post-alveolars, palatals, velars, labio-velars) in average F1 and F3[12] of /i/, /a/ and /u/ for Nuučaan̓uł (aka Nuu-chah-nulth aka Nootka) (Southern Wakashan). Wilson also remarked that the other Southern Wakashan languages had a similar absence of lowering. Conversely to Southern Wakashan, Howe (2000) found that in 'Uik'ala/Oowekyala (Northern Wakashan) close vowels /i/ and /u/ lower to [e] and [o] following glottal stop; additionally, lowering of /i/, /u/, and /ə/ also occurs in other Northern Wakashan languages, namely Kwak'wala and Hailhzaqvla (aka Heiltsuk aka Bella Bella).

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[11] When I leave if an effect was found before or after a consonant unspecified, this is because the authors being cited did not specify themselves.

[12] F2 was considered to be a poor correlate of vowel retraction and was not included in results.

As for Salish languages, Bessell (1997) found no considerable effects of glottal stop on neighbouring full vowels in St'át'imcets, where it patterned near /p/, /t/, and /k/ in average F1 and F2 measures, as well as no lowering for /ə/ after a glottal stop, but there is a phonological lowering process where /ə/ lowers to /a/ before glottal stops. Blake (2000) found that for ʔayʔaǰuθəm, /ə/ lowers to [a] before a glottal stop. Montler (1998) found two effects of glottal stops on vowels in Klallam: close vowels are lowered before a glottal stop: /i/ lowers to [ɛ] and /u/ to [o]. Close vowels did not, however, lower/back before uvular consonants. Neither of these effects are found in SENĆOŦEN (and perhaps also not in Lekwungen), but an additional effect is: the lowering of /ə/ to [a] before glottals.

In regards to SENĆOŦEN specifically, Bird, Czaykowska-Higgins, & Leonard (2012) found that, for a single speaker of SENĆOŦEN storytelling, a sequence of /Vʔə/ (vowel-glottal stop-schwa), like in /leʔə/ 'there', /netʃtiʔəs/ 'different', or /qʷɑʔəŋ/ 'to fetch water', most often reduced to [V:] (long vowel), and /VʔV/ (vowel-glottal stop-vowel) sequences, like in /tʃeʔi/ 'work', /jeʔu/ 'went', or /tiʔe/ 'this', usually were realized as [VʔV] (examples in the IPA as presented in Bird, Czaykowska-Higgins, & Leonard 2012). They acoustically compared the /eʔə/ sequences (like in /leʔə/) and /e/ (e.g., in /məqsten/ 'everything'), which had been realized as [e:] and [e] respectively. /eʔə/ was significantly longer than /e/, almost twice so. F2 was also significantly lower and F1 significantly higher in /eʔə/ than /e/. Pitch and amplitude dip was also significantly greater in /eʔə/ than /e/ in word-final position.

Overall, the literature suggests that languages are split on coarticulatory effects of glottal stops on vowel quality. There are languages that exhibit no vowel quality effects with glottals and those that have lowering (especially of schwa). Ultimately, it is likely that we might see effects in Lekwungen similar to those in closely related SENĆOŦEN: lowering of schwa preceding glottal stop, but no lowering of full vowels.

2.4.4 Coarticulatory effects of ejective consonants

One detail heard in the Lekwungen workshops is the possible vowel quality effect of ejectives, introduced in Section 2.1.2 above. This motivates investigation, though contrary to what might be being heard, phonetic work done on the coarticulatory effects of ejective consonants has found that vowel quality effects are unlikely. The effects most commonly found are voice quality effects related to the type of ejective consonant produced. This suggests that Lekwungen would also be unlikely to have ejective-specific vowel quality effects.

There are two types of ejectives: ‘strong’/’stiff’ and ‘weak’/’slack’ (Lindau 1984, Kingston 1985). The difference between the two types can be seen in their acoustic correlates. The ‘strong’ type is the more distinctive ‘pop’ type of ejective, with a relatively strong burst, a silent period between consonant release and vowel onset (and a long VOT), a fast rise in vowel amplitude, high F0 at vowel onset, and modal or tense voice at onset. The ‘weak’ type is harder to discern from non-ejectives (even sometimes for L1 speakers, see Wright, Hargus, & Davis 2002); weak ejectives have a similar burst to non-ejectives, but compared to strong ejectives have a shorter VOT, a dip in F0, a slower rise in amplitude, and creaky voice at vowel onset.

Studies of the acoustic correlates of ejectives have shown that these voice quality effects are relatively consistent with different types, but these studies have not reported vowel quality correlates (Lindau 1984; Kingston 1985; Ingram & Rigsby 1987; Warner

1996; Grossblatt 1997; Wright, Hargus, & Davis 2002; Hajek & Stevens 2005; Ham 2007; Nelson 2010) in a variety of languages: Tigrinya (North Ethio-Semitic); Niimiipuutímt (aka Nez Perce) and Sħáptənəxw (aka Sahaptin) (both Sahaptian); Montana Salish (Interior Salish); Diné bizaad (aka Navajo), Witsuwit'en, and Tsilhqut'in (aka Chilcotin) (all Dene); Hausa (West Chadic); Quiché (Eastern Mayan); Gitsenimx̱ (aka Gitxsan) (Tsimshianic); Ingush (Northeast Caucasian); and Waima'a (Malayo-Polynesian). For the one attestation of possible formant effects, McDowell (2004) found that Montana Salish ejective lateral affricate /ƛ̓/ had a lowering effect on F2 in a following /i/ of ~450 Hz at vowel onset (compared to a neutral /i/), decreasing to ~50 Hz by offset, with no effect on F1 or F3. /a/ was affected with a ~170 Hz lowering in F1 and a ~150 Hz rise in F2. /e/ had a ~200 Hz lowering in F3, and /u/ had a ~50 Hz lowering of F1. However, this pattern is not only found with /ƛ̓/, but also with lateral non-glottalized /l/ and lateral glottalized /l̓/. This suggests that these differences were not because of the ejective status of the consonant, but because of the place of articulation.

In summary, in the literature there is little attestation to vowel quality coarticulatory effects of ejective consonants specifically, and it seems that any effect on vowels in Lekwungen is most likely going to be an effect just on voice quality. This suggests that the likelihood of finding vowel quality effects from ejectives in Lekwungen is low.

2.4.5 Timing of secondary articulation

One final consonantal coarticulatory feature that might be present in Lekwungen involves the nature of the timing of secondary articulations, specifically, secondary labialisation. Ladefoged & Maddieson (1996) in *Sounds of the World's Languages* discuss secondary articulations. Secondary labialisation, specifically, is accompanied by a dramatic lowering of F2 in neighbouring (usually following) vowels, along with a lowering in F1. Though the lip rounding is theoretically simultaneous with the stop consonant, it can start and end at any point before, during, or after the stop closure and release, because the articulators, the lips and tongue, are independent (though this is not the case with a rounded labial consonant, e.g., /p^w/). Often, cross-linguistically, secondary labialisation on stop consonants is more commonly realized during and following the stop burst, not before the stop closure (Ladefoged & Maddieson, 1996). Lip rounding in these cases would therefore begin during the stop closure and end after the stop release. This is evident in the burst and frication spectra of the stop release and, if present, as a transitional [w]-like portion (a low F1 and F2) before the following vowel, as the lips unround and the tongue moves to articulate the vowel. It can also, however, begin before the stop closure, where, if preceded by a vowel, it appears as a lowering of F2 and F1 before the stop closure. It may or may not be present following the stop release.

Specific phonetic literature on secondary articulation timing seems to be fairly sparse, especially when dealing with stop consonants. Kochetov (2006) documented acoustic differences in Russian plain /t/ and palatalized /t^j/ in the environment of /a_#k/, /a_#n/, and /a_#s/. Not only did the stop releases differ, the releases of /t^j/ being longer and quieter than those of /t/, but the second formants of the preceding /a/ differed as well. F2 was higher at both the midpoint and offset of the /a/ before /t^j/ than before /t/. This would suggest the anticipation or presence of the palatal gesture before the stop closure. Work on other types of consonants also shows variation in timing. Bird & Caldecott

(2004) and Bird, Caldecott, Campbell, Gick, & Shaw (2008) document the variability of glottalization (laryngealization) in St'át'imcets glottalized resonants, finding that glottalization can occur both before and after the resonant, as well as throughout the resonant, with the exact timing dependent on the language. Kochetov (2005) describes the variability in timing of secondary palatalization in Russian /l, l^j, r, r^j/, using corpus electromagnetic articulometer (EMA) data. The raising of the tongue body associated with palatalization was nearly simultaneous with the constriction at the tongue tip, associated with the consonant production as a whole, in /l^j/ for all speakers; but there was considerable lag between the constrictions at the tongue tip and the tongue body in /r^j/ for all speakers.

Additionally, variation in the timing of secondary labialisation has been attested in SENĆOŦEN, where the [w]-like sound and associated acoustic features has been heard/seen on the vowel preceding the stop consonant closure, as well as following it (Bird, 2016). Given that timing in secondary articulations, especially with stops, is fairly variable cross-linguistically, and that variability is found in SENĆOŦEN, it is likely that variability could be found in Lekwungen.

2.5 Other factors possibly affecting speech

It is possible that other factors might affect the speech in the recordings. Considered here are three factors: speech rate/style and its effects on coarticulation (Sophie Misheal spoke with both story-telling naturalistic speech and elicitation clear speech), the effects of aging on speech (Sophie Misheal was in her 80s when the recordings were made), and the effects of language transfer (Sophie Misheal learned

Hul’q’umi’num’ from a young age and spent much of her life in a Hul’q’umi’num’ speaking environment).

An effect of speech rate on coarticulation that could be present in the data is one outlined in Lindblom’s (1990) Hyper- & Hypospeech Theory (H&H Theory). In this theory, speakers’ pronunciation varies on a continuum depending on production constraints (physiological, cognitive) and reception constraints (social, communicative). ‘Hyperforms’ will be produced when output (reception) constraints dominate, and ‘hypoforms’ when system (production) constraints dominate. System constraints will favour more economical productions, that is, those that involve the least amount of work while still being understandable to a listener. Coarticulation effects would be expected to be the most observable in hypoforms; here the consonants would have the greatest allowable coarticulatory effect on vowels, consonant-vowel coarticulation being a low-cost behaviour. Output constraints on the other hand will favour clarity to the listener over more economical productions. Coarticulation in hyperforms could be more minimal, producing vowels with fewer coarticulatory effects, as the need for clarity to a listener outweighs the economical production of coarticulation. Sophie Misheal’s isolated words would be more likely to demonstrate hyperforms, given that she is speaking for a very communicative purpose: the elicitation of words and their transcriptions, and so clarity of her speech is of importance to ensure details are not missed by a non-speaker of Lekwungen. Vowel quality effects could be lessened in those productions. In contrast, her storytelling speech would be more likely to produce hypoforms, given that, while she is still telling them in order to be recorded, story-telling is a more natural style of speaking than saying single, isolated words. This could increase (relatively) the vowel quality effects in these productions.

Aging is marked by a number of acoustic correlates, though considerable variation has been observed between individual speakers and across studies (Ramig & Ringel 1983). Those most associated with the effects of age are F0, jitter (change in F0 from glottal pulse to glottal pulse), and shimmer (change in amplitude pulse to pulse). Xue and Deliyski (2001) investigated a range of acoustic correlates in elderly men and women, comparing them to younger men and women. They found that elderly (70 – 80 years) women had significantly lower mean F0, greater jitter and shimmer percent, and greater variation in pitch than younger women. Awan (2006) investigated difference in F0, jitter, shimmer, signal-to-noise ratio, and a number of physiological measures in English-speaking women age 18 to 80. Mean pitch significantly decreased with age. The older groups also had significantly greater pitch variability than the younger groups. There was, however, no significant difference found between age groups for jitter, shimmer, or signal-to-noise ratio. Age can thus have a number of common, if variable, correlates, and in general greater jitter and shimmer are associated with aging, as is a decrease in pitch for women. Of importance to this study is the fact that age can correlate with a number of features associated with glottalization, namely pitch perturbation, jitter, and shimmer and Sophie Misheal was ‘around 80’ (Raffo, 1972) at the time the recordings were made. The effects these features could have on voice quality could interfere with identifying or analysing instances of glottalization, as the effects could resemble the voice quality effects of glottalization. This could confound findings about coarticulatory effects associated with glottal consonants, and would need to be taken into account.

Finally, it is possible that language environment and language contact may have an effect on overall pronunciation as well, and would be useful to keep in mind. Of the studies cited in the background literature section, for those which mentioned language background of their speakers, all were old enough that they had been raised speaking their language, but a number had an interruption of use in childhood, and all were highly proficient or bilingual in English from a relatively young age. Sophie Misheal shares a similar background. She learned English at age seven at a residential school, where she also acquired Hul'q'umi'num', the language of most of her classmates (Mitchell, 1968; Raffo, 1972). She also had contact with SENĆOŦEN speakers at the school and at home (Mitchell 1968). Sophie Misheal's husband was a Hul'q'umi'num' speaker, and her children grew up only speaking Hul'q'umi'num'. Mitchell and Raffo both describe how later in life Sophie Misheal had few chances to converse in Lekwungen, most of her interactions being in Hul'q'umi'num' or English. Given this linguistic environment, Sophie Misheal might have some influence from Hul'q'umi'num' in her speech. Mitchell notes that every so often Sophie Misheal would produce [θ] for Lekwungen /s/, likely from Hul'q'umi'num' influence. Sophie Misheal would usually comment on and correct these 'mistakes' (Mitchell 1968). As for influence on vowels, Elmendorf & Suttles (1960), in describing vowel variation in Hul'q'umi'num', do not note any variation that differs greatly from that described for Lekwungen. Their speakers were from a similar age range as Sophie Misheal, and so are likely to be representative of a speech like her classmates, husband, and neighbours would have. They described how palatals raise and front neighbouring /ə/ and labialized consonants raise and back neighbouring /ə/, uvulars have a retraction effect on vowels, with the possible use of a transitional vowel between /i/ and /q/, and didn't note variation with glottal stops. Thus, it seems unlikely that influences from Hul'q'umi'num' would influence the vowel variation she would present for Lekwungen.

2.6 Hypotheses for the current work

This chapter began with detailed background information on Lekwungen and the research question motivating this thesis. It then reviewed literature discussing similar questions and phenomena related to the questions in distantly and closely related languages. It reviewed correlates of stress, vowel quality effects of stress, vowel quality effects of glottal/glottalized consonants (including ejectives), labio-velar and palatal consonants, and uvular consonants. Vowel quality effects are well attested with uvular consonants, and are likely to be present in Lekwungen. Glottal consonants have a language-variable lowering effect: a number of Central Salish languages have lowering of schwa in this environment, and it is possible Lekwungen might as well. Vowel quality effects are seldom attributed solely to ejectives in environments with ejectives, but it could be possible that Lekwungen might have some. Finally, stress has been found in Central Salish languages to have an effect on vowel quality.

Based upon the review in the current chapter and the observations made in the language workshops, I propose the following predictions to answering the research question (Section 2.1.2), in Table 2.11:

Environment	Prediction of vowel quality effects?	Justification
Stress	Duration, pitch, and amplitude will be correlated with stress in Lekwungen	Basis/Prediction: Literature (Section 2.3)
Palatals and Labio-velars	Lekwungen /ə/ will exhibit persistent effects of palatal and labio-velar consonants	Basis/Prediction: Literature (Section 2.4.1)
Uvular consonants	Lekwungen vowels will exhibit persistent backing/lowering effects of uvular consonants	Basis/Prediction: Literature (Section 2.4.2) and observations in workshops
Glottal consonants	Lekwungen vowels will exhibit persistent lowering effects of glottal consonants	Basis/Prediction: Literature (Section 2.4.3) and observations in workshops
Ejective consonants	Lekwungen vowels will **not** exhibit persistent place-independent effects of ejective consonants	Basis: observation in workshops Prediction: Literature (Section 2.4.4)

Table 2.9: Predictions of vowel quality effects in Lekwungen

In investigating these hypotheses, I hope to learn enough about Lekwungen vowels to provide a guide for learners of Lekwungen for both writing the language and learning the pronunciation of the language. I will provide a guide based on the results to help with accurate interpretation of vowel variation in Lekwungen. Learners could know that when they hear a certain vowel sound or another, they are hearing a variant of a certain phonemic vowel, and would then be able to make the necessary connections between their knowledge of the phonemes of the language and the actual variants they would hear. Should a phonemic orthography be chosen for Lekwungen, this guide would also help in writing the language. In reverse, this knowledge of variation would help learners in speaking the language ‘with a more Lekwungen accent’ by informing them how, when, and how much, they might vary the vowels they would say. Additionally, for academic linguists and linguistics, this thesis contributes to phonetic typology, by providing a detailed acoustic phonetic study of the vowels of Lekwungen, and, more generally, of a Central Salish language, an area relatively under-investigated. The following chapter, Chapter 3, details the methodology, the steps and methods I undertook, to investigate these predictions.

Chapter 3

Methodology

In order to examine what may be affecting vowel quality in Lekwungen, it is necessary to undertake an acoustic analysis to measure and quantify the various phenomena discussed above, found in both the existing literature and heard in the workshops. This chapter describes the methodology employed in obtaining and analysing the data presented in this thesis.

The chapter begins with a discussion of the ethical considerations that bear upon linguistic work done in the context of Indigenous languages and their revitalisation in British Columbia (Section 3.1). This was a necessary first step before any data collection, let alone measurements or analyses, could be undertaken. This is followed by a description of the available data and the process of selecting the environments and sounds analysed (Section 2.2). Finally, the chapter concludes with a discussion of the data analysis, both acoustic and statistical (Section 3.3), and a summary.

3.1 Ethical considerations

Researchers working in Indigenous language revitalisation settings must pay extra attention to the research ethics they utilise, owing to historically exploitative practices of research done with Indigenous people. One set of research ethics that works to achieve this is that of participatory research (also termed community-engaged, community-participatory, community-based, collaborative, and cooperative; Ferreira & Gendron 2011). Participatory research sees application in a wide range of fields, from those focused on education, to resource management, to social sciences (Polfus, Manseau, Simmons, Neyelle, Bayha, Andrew, Klütsch, Rice, & Wilson, 2016). In this thesis I chose to frame my research in the model put forth by Czaykowska-Higgins (2009) for participatory research in linguistics.

Czaykowska-Higgins (2009) outlines a model for undertaking research with language communities, based on the context of work done in Canada with minority Indigenous language communities: the Community-Based Language Research (CBLR) model. The focus of the model is on '[r]esearch that is on a language, and that is constructed for, with, and by the language-speaking community within which the research takes place and which it affects'; according to the model, the research should not be primarily for the satisfaction of needs for the linguist, and should not be primarily done by linguists. This represents a goal to work towards for all community research, where the research goals of the linguists may be present, but are not the primary goals of the overall research itself, for the goals of the community often differ from those of the linguist. Whereas linguists may have goals to answer theoretical questions, for language communities, especially Indigenous language communities, the goal is often the documentation and revival of their languages.

In a community-based model of linguistic research the goals of language speakers and learners should take precedence over those of the linguist. Research ought to be focused on and created by/for/with the language community, and, specifically, linguistic theoretical questions of interest to the linguist should not be the main focus. In the full realisation of this model, members of the language community working on the research are researchers in their own right, not just participants or informants of information for the linguist to take away.

Czaykowska-Higgins' model is built upon three increasingly involved models (from Cameron, Frazer, Harvey, Rampton, & Richardson, 1992), involving gradual increases in community (or members of a community) involvement and agency in the research undertaken. The first is research done 'on a language', with minimal involvement of the community in a collaborative role at all. This is the 'Ethical (Linguist-focused) Research' model. In this model there is a clear line between needs and goals of the researcher and researched, and the community falls to the 'researched' side, while the needs of the researcher remain predominant. The researcher sets the goals and pace of research, and while they treat their consultants in an ethical manner and give them due acknowledgment, the researched has no power of the direction of research. Following this is research done 'on a language and for a community', the 'Advocacy Research' model. The researcher and their goals remain the focus, the work is done to the researcher's priorities and in their perspectives, but the goals of the researcher take into account some of those of the community, and the researcher's work advocates for the community's goals and needs. The next step adds 'with a community', the 'Empowering Research' model. Here the researcher works in dialogue with the community, working to satisfy the community's needs and fulfil the community's goals. They work with the community to empower the community with the results of the research (e.g., through training or creating materials) but the researcher remains the focal point of the research and holder of formalised knowledge. The last component goes beyond either the Advocacy or the Empowerment models, and is at the opposite end of a spectrum from the

Ethical Research model. This step adds ‘by a community’, and here members of the community are realized as researchers and experts in their own and full right, equal to the academic linguistics researcher. This model could include efforts to train members of the community to conduct their own community-based research, being able to eventually supersede the need for outside academic researchers.

Given that this thesis is only the third ever to focus exclusively on Lekwungen (the other two being Mitchell 1968 and Raffo 1972), it might be useful to analyse how the previous two would fit in the CBLR model, as a way to help observe how linguistic research practices with Indigenous languages and communities has changed in the past half century in this specific context. Neither Mitchell nor Raffo make note or mention of their work involving a community of language learners or speakers (other than Sophie Misheal, obviously): they mention no community concerns or involvement, nor any possible benefits they may have provided them during/as a result of their research. Their research was not taken on the initiative of a community, nor were their investigations based on fulfilling goals a community had. Mitchell does note that they hoped that their work (a dictionary) would be useful to a future Lekwungen-speaking community[13], but makes no note as to any provisions they might have taken to ensure this. Mitchell and Raffo’s work falls decidedly into the Ethical (Linguist-focused) Research model, where research is done ‘on a language’. Although they took care to conduct their research by ethical standards, had contact with the community, fostered good relations with Sophie Misheal, and acknowledged and thanked her (their participant), they did not appear to actively involve the speakers or community in creating benefits of their research,

[13] Which it has been.

deciding the goals of their research, or conducting their research (as fellow researchers). The community and language remained an object of research.

In contrast, while this thesis project does not correspond with a fully-realized community-based language revitalisation model, it does fall more into the 'Empowerment' model, where the research here is being done on, for, and with a community, but not by them. It goes beyond the 'Ethical Research' model, as while the research is on the acoustic properties of Lekwungen vowels and due care has been taken to comply with university ethics requirements, the project seeks to engage equally with, and give back to the community. Situating the project in the 'Advocacy' model does not fit with the aims of the project, given that the project does not immediately aim to *advocate* for needs and goals of the community (though this is not ruled out entirely, just that the main intent of the project is not to take the results and campaign on behalf of the community for some goal of the community). The best fit then is the 'Empowerment' model. This is emphasised by the facts that the research topic comes out of the language workshops, i.e., out of the needs of community members learning Lekwungen; that I signed a research agreement with the community (see below); and that one of the goals of the research is to provide language learners with useful and usable information and materials on the pronunciation (and so on the writing) of Lekwungen. It does not fit the fully realized model because of the fact that, owing to the requirements of a thesis (timely completion of the project and authorship constraints[14]), I am the only researcher working on the project, and the fact that I also remain the only person in the relationship with the formalised technical knowledge and specialized skills (specifically in terms of acoustic

[14] Theses can only have a single author.

analysis) critical to the completion of the project. In the below paragraphs I describe how I arrived at this situation for my project.

Since October 2015 I have attended and participated in weekly Lekwungen language-learning workshops initiated by members of the Songhees Nation, made possible through the connection provided by my co-supervisor (Dr. Suzanne Urbanczyk), who leads the workshop meetings. I became introduced to these workshops in late summer / early fall of 2015, while on the look-out for a topic for a thesis. Knowing that I wanted to do work with a local Indigenous language, and wanted to do work in as collaborative a manner as possible, my co-supervisor, Dr. Sonya Bird, connected me with Dr. Urbanczyk, who had been requested to lead the Lekwungen language workshops. With the approval of the workshop group, I began attending and participating in the workshops, learning (and learning about) Lekwungen through them.

The workshops' goal is 'writing the Lekwungen language'. To help accomplish the goal, workshop participants listen to the digitisations of Mitchell's recordings, and practice writing (transcribing) the words and phrases heard. The writing system used is based upon Dr. Timothy Montler's transcription system for North Straits Salish, using characters from the Northern American Phonetic Alphabet. Usually, a number of transcriptions will be revised over the course of a workshop meeting, as collective ears hear details that might escape one pair alone. The subject of this thesis comes from these collective ears and the desire to write Lekwungen accurate to Sophie Misheal's speech/knowledge.

This thesis seeks to study the phonetic vowel and consonant interactions in Lekwungen because one of the main issues that comes up during the workshops is figuring out what to write when a vowel is heard. In some cases the transcription is generally transparent (e.g., for *snét*, 'night'; or *ƚéč*, 'dark'), but in other cases it can be difficult to tell what a vowel should be written as (e.g., *qʷə́l̓*, 'soft'), especially in the case of schwa, whose perception to English-speaking ears can vary considerably. I reasoned that materials resulting from a systematic phonetic study of the vowels of Lekwungen and their quality variation could help learners write the language, by laying out what types of variation in vowel quality might be expected where and when, so people writing the language would know what to write. It would have additional benefit by serving as a guide to pronunciation when reading the written language, as a learner would know when to change the quality of a certain vowel. This subject was presented to officials at the Songhees Nation and approved.

In doing research involving Indigenous communities, not only are there the personal ethical considerations and choices of the project and its aims to consider, but there are also official/institutional ethical guidelines and requirements to work within. In order to begin work on data collection, even with second-hand data, I needed to obtain official approval from the University of Victoria's Human Research Ethics Board (HREB). I also wanted to obtain official approval from Songhees Nation (under whose auspices the language workshops and materials are held). The two necessities dovetailed nicely, as in the course of acquiring university approval, several issues arose that I could not unilaterally decide, including issues of consent, anonymity, and data storage. None of these issues could be decided only by myself, so an agreement with Songhees Nation for official permission to undertake the project would need to address them.

To get this official permission, a formal written and signed research agreement between myself and Songhees Nation was created. My co-supervisors and I met with Songhees Nation officials to discuss the project and to present agreement templates for them to choose from that had been developed in other similar contexts, including the template from the *Guidelines for Ethical Research in Manitoba First Nations* (Manitoba First Nations Education Resource Centre) and the CURA Research Contract template from the Language Revitalization in Vancouver Island Salish Communities Project. The CURA template was chosen, and the research agreement with Songhees Nation was based on it. The agreement specified the decisions on the issues laid out above (consent, confidentiality, ownership), as well as provided for the transmission of findings to the language community. The agreement gave consent from Songhees Nation on behalf of Sophie Misheal's family. They had allowed for use of the recordings in Lekwungen language revitalisation efforts, which this thesis was determined to be doing. Additionally, it was decided that Sophie Misheal would be acknowledged in publications/presentations stemming from this thesis project[15]. The finalised agreement was also sent to the University of Victoria HREB, as a component of the university's ethics approval process.

3.2 Data

The data comes from recordings made in the late 1960s of Sophie Misheal, Lekwungen speaker, containing information taught to and recorded by linguist Marjorie Mitchell. Mitchell and Raffo, who also learned from and recorded Sophie Misheal for their dissertation on Lekwungen, but to whose recordings I did not have access for this

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[15] As you might have guessed by this point.

thesis, provide details about Sophie Misheal's linguistic background[16] (Mitchell, 1968; Raffo, 1972). She was 'around 80' in 1969 (Raffo, 1972), so it is likely that she was born in the late 1880s or early 1890s, and grew up speaking Lekwungen, in a Lekwungen speaking environment. She learned English as a child at a residential school. At the school she also learned Hul'q'umi'num', the language of most of her classmates and her husband, who she married at 17. Sophie Misheal's speech on the recordings is therefore likely to be that of a fluent L1 speaker speaking a style of the language acquired before more intense language change could have begun with the loss of most fluent speakers and a language community. However, in the ten years before Mitchell and Raffo studied Lekwungen from her, Sophie Misheal 'had had little chance to use her native language…' (Raffo, 1972). Additionally, given that she is (at the moment) the only Lekwungen speaker whose speech has been acoustically analysed, there is likely to still be an amount of uncertainty as to whether certain features are characteristic of the language in general or just to her speech.

The recordings consist of two primary types of spoken material: there are words spoken in isolation, interspersed with phrases, and there are stories of varying length. The isolated words and phrases are associated with an English word or phrase (a translation), but the stories have no translation given on the recordings. Most of the tapes consist of isolated words or phrases, but there is at least an hour and a half of stories recorded out of approximately 14.5 hours of recordings. The recordings were made in a quiet room in Sophie Misheal's house on a Sony TC-801A portable tape-recorder onto Magnetophon or Scotch brand five-inch magnetic tapes (Mitchell, 1968), and were

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[16] Also detailed in Section 2.5.

digitised in 2015. The digital sound files used in the research are in AIFF-C format at a 44.1kHz sample rate of 16 bits.

Through the Lekwungen workshop, a number of the isolated words and phrases have been transcribed. Mitchell's dictionary also contains entries on a number of the words heard in the recordings. The workshop's transcriptions are phonemic and use the current orthography for Lekwungen, based on the NAPA. They are based primarily on what participants in the workshop hear, with additional reference to how Mitchell transcribed the words, or how they are written in SENĆOŦEN if clarification is needed. It is when sources conflict, or the workshop group is divided on transcription, that the need for a more detailed analysis on variation becomes clear; this thesis seeks to address this need.

The focus of this thesis was the vowel system of Lekwungen and the variation in those vowels. To this end, data consisted of vowels in CVC sequences such that the four most common vowels were paired with consonants from the categories discussed in Chapter 2. Ten consonants were selected to be investigated in CVC sequences: /p/, /kʷ/, /qʷ/, /q/, /y/, /č/, /ʔ/, /t̓/, /t/, and /w/. Sounds were selected based partly on frequency of appearance and partly on membership in a category under investigation. The vowels investigated were based the literature discussed in Chapter 2, and consisted of three categories; full vowels /i, e, a, u/, stressed schwa, and unstressed schwa, all of which have different qualities depending on stress and consonantal environment. The consonant categories investigated were those detailed in Chapter 2 that had been found to have co-articulatory effects in the literature, or heard to have possible effects in the language workshop: palatal consonants, labio-velar consonants, uvular consonants, glottal consonants, and ejective consonants. For ease of data collection, usually the most common member of a target category (see below) was selected so as to provide the greatest possibility of finding tokens. For example, out of the uvular consonants /q, qʷ, q̓, q̓ʷ, x̣, x̣ʷ/, /q/ and /qʷ/ were selected because they were the most frequently appearing uvular sounds. When a less common sound was selected, this was due to cross-category membership ruling out the more common possibilities, as in the case of selecting /t̓/ over /q̓/ (as the ejective /q̓/ is also a uvular). The choice of which sound to investigate from a category was based on a frequency ranking of the sounds of Lekwungen, detailed in the following paragraph.

Recall from Section 2.1 that Lekwungen has five vowels and 35 consonants. 29 may appear initially and 34 finally (the six glottalized resonants may not appear initially, and /h/ may not appear finally). To create a frequency ranking of these sounds, I created a frequency listing of my own for Lekwungen, where I noted all CVC and CV# sequences transcribed in the Lekwungen workshop so far (as of September 2016, 2818 sequences), tallied up all instances of each sound, and sorted them by frequency[17]. Relative to overall frequency, six consonants investigated in this thesis were in the more-frequently occurring half of the ranking, and the remaining four were in the less-frequently occurring half. The accuracy of the ranking made is corroborated by its consistency with a ranking of closely-related SENĆOŦEN sounds that Montler (1986) created from a random search of SENĆOŦEN utterances[18]. While the ordering in the

[17] That ranking is: /ə, ʔ, e, n, s, i, l, t, a, ŋ, ɬ, č, c̓, kʷ, l̓, q, w̓, n̓, y, x̣, m, ƛ̓, qʷ, xʷ, q̓, y̓, k̓ʷ, č̓, q̓ʷ, ŋ̓, w, m̓, p̓, p, x̣ʷ, š, t̓, h, u/.

[18] Montler's ranking, from most to least frequent, is: /ə, s, ʔ, n, t, e, ɬ, l, xʷ, kʷ, ŋ, č, i, a, q, l̓, w̓, x̣, y, š, w, k̓ʷ, t̓ᶿ, θ, m, n̓, q̓, qʷ, ƛ̓, t̓, m̓, p, y̓, č̓, ŋ̓, x̣ʷ, q̓ʷ, h, p̓/.

Lekwungen ranking may not accurately represent the frequency seen in natural speech or stories, the general picture it presents broadly matches Montler's ranking of frequency.

As stated above, the specific sounds were chosen for both their membership in a category under investigation and their frequency rank. /q/ and /qʷ/ are the most frequent uvular sounds, and /kʷ/ is included for comparison, especially as the differences between rounded uvulars and velars are considered difficult by learners. /ʔ/ satisfies the category of glottals (the [ʔ] of glottalized resonants was not included). /t̓/ is the most frequent non-uvular, non-velar ejective stop, and /t/ serves as a comparison. /w/, /y/, and /č/ have clear effects on schwa colouration (phonetically the sequence /əw/ is realized often as [u] or [o]). /p/ serves as a baseline environment to compare other environments to, as it does not involve any lingual articulation.

While ideally data would be taken from CVC sequences consisting of the target vowel and the target consonant along with a neutral (ideally labial) consonant, limits to available tokens meant that most CVC sequences collected consisted of a target vowel and target consonant with the other consonant being simply a non-target consonant (i.e., none of /p/, /kʷ/, /qʷ/, /q/, /y/, /č/, /ʔ/, /t̓/, /t/, nor /w/). These consonants were /ɬ, s, š, l, m, n, ŋ, l̓, m̓, n̓, ŋ̓/. In most cases the consonant was coronal (the most frequent type of consonant other than a glottal stop in the language), either /ɬ, s, l, l̓, n, or n̓/.

This thesis being a first look at vowel quality variation in Lekwungen, it was natural to begin by looking at tokens from the isolated words, so as to get 'clear speech' measurements of vowels and variation. These could then serve as a baseline for values when investigating the continuous, spontaneous speech. Tokens analyzed were located in two ways: 1) relevant tokens were identified in the transcriptions, located on the corresponding recordings, and extracted; 2) relevant tokens were listened for in the recordings directly and extracted when found.

3.3 Data collection and analysis

Data consisted of vowels in CV# (a CV sequence at the end of a word) and CVC syllables, from stressed and unstressed syllables. In the recordings, isolated words were repeated twice, and data was usually collected from the second of the two productions, given that that was usually where Sophie Misheal corrected any errors she had made and was likely to be the more natural of the productions. One hundred and forty-three tokens were located on the recordings and extracted manually through Praat (Boersma & Weenink, 2016; version 6.0.22). They were saved as individual files and opened again in Praat. There they were segmented with a textgrid and labelled manually. The determination of a vowel's category (full vowel, stressed or unstressed schwa) was based primarily on the work done by Mitchell (1968), the phonological analysis of Raffo (1972) and Montler (1986), and transcriptions done in the workshop (themselves primarily informed by the information in these works). Determination was aided by knowledge of likely processes affecting quality and knowledge of morphology when needed.

The measurements taken from vowels and consonants were based on those found in the literature, and strategically included to answer the research questions. For observing acoustic correlates of stress effects, duration, mean fundamental frequency (pitch) and mean intensity (amplitude) were measured from vowels, as all had been found to be acoustic correlates of stress by Tamburri-Watt et al. (2000) in Sḵwx̱wú7mesh, and Leonard (2007) in SENĆOŦEN. To observe the interaction of stress and consonant lengthening (a phenomenon first observed in the workshop), duration was also measured for the consonant following the target vowel. To measure coarticulatory effects of consonants and vowels, F1, F2, and F3 were measured at three time points during the target vowel: 5% into the vowel, 50% into the vowel, and 95% into the vowel. In addition, mean F1, F2, and F3 measurements were extracted over the middle 90% of the vowel (between 5% and 95%). F1 and F2 have been found to be affected by glottal and uvular stops in a number of Salish and other geographically-local languages (Bessell, 1997; Montler, 1998; Wilson, 2007; Bird, Czaykowska-Higgins, & Leonard, 2012; for glottal stops; and Bessell, 1997, Namdaran, 2006; Bird & Leonard, 2009; for uvular stops). Bessell (1997) also reported effects on F1 and F2 by the other consonants under investigation here, and the fact that Blake (2000) and Suttles (2004) heard quality variation of schwa related to coronal (alveolar and palatal), labialized, and velar consonants suggests that these too have effects on F1 and F2. F3 has been found to correlate with uvular coarticulatory effects (particularly specifics of pharyngeal articulation) and lip rounding (Namdaran, 2006; Eek & Meister, 1994; Fant, 1973). Measuring formants at various points in the vowel is a common strategy for quantitatively studying the overall contour of vowels, and measuring at the 5% and 95% time points (the onset and offset of vowels) ensures formant measurements capture effects of neighbouring consonants, while measuring at the 50% time point and measuring a mean value over the middle 90% of the vowel provide a token-specific baseline to study how exactly coarticulatory effects are altering vowel formants (see Namdaran, 2006, for a use of this in measuring the effects of uvulars and pharyngeals) .

The below figure demonstrates how words were segmented for measuring. Two textgrid tiers were used. Duration, pitch, and amplitude measurements were taken from the first 'phoneme' tier, used to track overall duration of the target vowels and consonants. Vowels were measured over areas of regular pitch pulses with multiple formants present, usually dependent upon the presence of at least a second formant. Resonants were measured as vowel-like areas of voicing, but with a lower amplitude and/or fewer to no formants visible. Affricates and stops were measured from closure, signalled by the cessation of formants of the preceding vowel, to the onset of voicing of the following vowel/resonant or noise of the following fricative or, when word-final, to the end of burst, frication, or aspiration. Fricatives were measured from the beginning of aperiodic noise to its cessation. In the below image, the second segment shows a vowel, labelled 'e' and the third segment shows an affricate labelled 't', these were the segments measured. The first segment, 'n' was not measured.

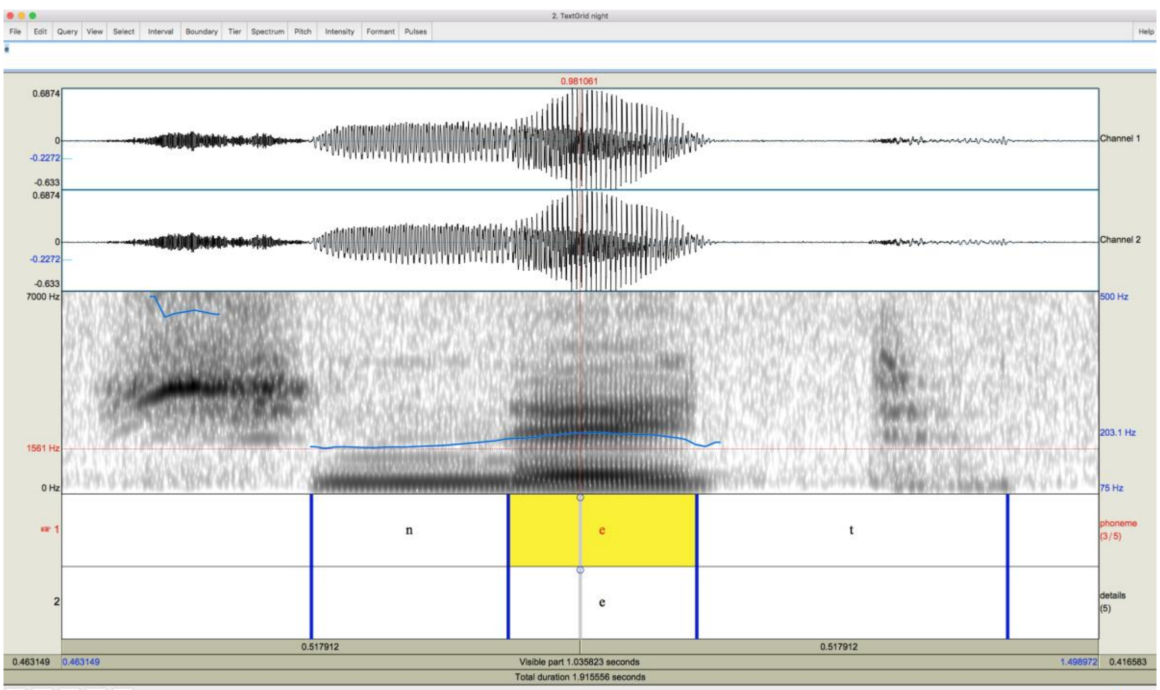

Figure 3.1: Tiers and segmentation of the word *snét*, 'night'

The second tier duplicated the first and was for notes and/or adjustments to be made for the measurement of formants. Formant measurements were taken automatically through Praat. In several cases the formant tracking function registered chaotic measurements at the edges of vowels that were not reflective of the actual vowel formants. In these cases the boundaries on the second tier were shifted into the vowel in order to ensure that the Praat script reading from the automatic measurement would take accurate data. Additionally, results were double checked manually whenever a result was produced that was wildly different from others produced for the same vowel. Each target vowel was phonetically transcribed by the author (a native speaker of Utah English), to give a sense of the perceptual coarticulatory effects that might be heard by English speakers learning Lekwungen.

Measurement data was exported to Microsoft Excel (2016) via the Praat script, and then imported to R (R Core Team, 2016), where analysis and plotting was done. Data was imported to R via the ‘gdata’ package (Warnes et al., 2015), and vowel plotting was done using the ‘phonR’ package (McCloy, 2016). Vowels were plotted in Hertz on a series of two-axis F1 by F2 plots with measurements from the three time points and means on a separate plot each; F3 was plotted in Hertz on a single axis, organised alphabetically (see Chapter 4). Finally, duration, pitch, and amplitude data were plotted in box-and-whisker plots in milliseconds, Hertz, or decibels, respectively. Statistical significance (at the $p<.05$ level) was calculated for these acoustic correlates of stress, to help in determining the significance of variation in correlate measurements. The choice of a physical scale (Hertz) over an auditory scale (e.g., Bark scale) for formant measurements was made because previous acoustic research on Salish languages has used Hertz, so the same scale would be useful for comparison. Although an auditory scale could be more useful for learners, as it would more clearly show change in perceptible properties of vowels, it was thought that this study, being a foundational study on the acoustic properties of Lekwungen vowels and consonantal coarticulatory effects, should approach the presentation of results with a physical scale. This would provide an established baseline of measurements and would serve as a useful reference point for future research, which may utilise auditory scales as part of their presentation.

3.4 Summary

This chapter has laid out the methodology used in this thesis to answer the research questions and test the hypotheses laid out in Chapter 2, including specific choices in ethics approach and topic choice (Section 3.1) and token environment and selection (Section 3.2). It also detailed the process of acoustic analysis of the measured data (Section 3.3). The following chapter, Chapter 4, reports the results of the data collection and analysis.

Chapter 4

Results

This chapter presents the results of the data collection and analysis process described in Chapter 3. Broadly, it is divided into two parts: the first focuses on vowel variation as a function of stress, and the second focuses on vowel quality variation as a functioning of surrounding consonantal co-articulation. In Section 4.1 I show that duration, pitch, and amplitude are all acoustic indicators of word-level stress in Lekwungen. In Section 4.2 I show that uvulars, glottal stops, and labialized consonants have persistent strong effects on most vowels, that palatal and alveolar consonants have strong but usually only local effects on most vowels, and that /i/ is the vowel least affected by all consonant coarticulatory effects while unstressed schwa is the most. Additionally, I show that F3 effects are relatively consistent but less so than F1 and F2 effects, that unstressed schwas seem to match the quality of a neighbouring full vowel when separated by a glottal stop, and that secondary labialisation has variable timing.

4.1 Correlates of Stress

As discussed above in Chapter 2, Salish languages exhibit differences in duration, pitch, and amplitude between stressed and unstressed vowels (Tamburri-Watt et al., 2000; Barthmaier, 1998; Leonard, 2007). In general, stressed vowels would have longer duration, higher pitch, and greater amplitude than unstressed vowels. This section presents the results from investigating those factors in Lekwungen for the three vowel categories detailed above. It is divided into two subsections, the first dealing with duration, the second with pitch and amplitude.

4.2.1 Duration

One possible correlate of stress that has been found in Salish languages is that of duration (Czaykowska-Higgins & Kinkade, 1998; Tamburri-Watt et al., 2000; Barthmaier, 1998; Leonard, 2007). Full vowels have been found to be longer than stressed or unstressed schwas, and stressed schwas longer than unstressed schwas. Data from Lekwungen seems to bear this out. In the below box-and-whisker plot (usually just called ‘box plot’), durations of full vowels, stressed schwas, and unstressed schwas are plotted together. The dark line through the middle of the box represents the median of the data, that is, where 50% of measurements are above the line and 50% below. The top and bottom edges of the actual boxes represent the 25% marks, so 25% of the measurements are above the top of the box, and 25% below (and thus 50% of the measurements are contained within the box itself). The whiskers (the lines extending from the ends of the box) go to the minimum and maximum measurements. Any dots are outliers, so extreme in their variation from the other measurements that they aren’t factored into the box and whiskers (which are showing quartiles). Duration in milliseconds is on the y-axis, and on the bottom (x-axis) are the three categories of vowels whose duration measurements are shown: from left to right they are full vowels, stressed schwas, and unstressed schwas.

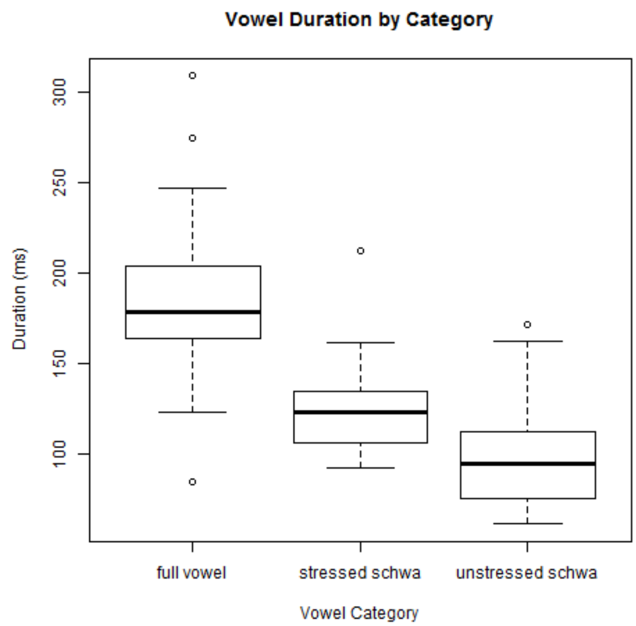

Figure 4.1: Duration of vowels by vowel category

We see in the above plot that full vowels[19] (N (Number) = 44) have the longest duration[20]. They have a median of 179 ms, with an average of 190 ms, a standard deviation (SD) of 41.5, and they range from 110 ms to 283 ms normally (with shorter and longer outliers). Between the two types of schwa, those categorized as stressed schwa (N = 26) had a longer duration than those categorized as unstressed (N = 34), though stressed schwas were still shorter in duration than full vowels. Stressed schwas had a median of 123 ms and an average of 124 ms (SD = 27.2), ranging normally between 100 to 140 ms, with a few outliers. Unstressed schwas were shorter, with a median of 95 ms and an average of 98 ms (SD = 27.7), ranging between 70 to 110 ms, with tokens both

[19] All full vowels included here are stressed, but sometimes [iʔ] can be an unstressed realisation of an underlying /əy̓/, or [uʔ] and unstressed realisation of /əw̓/; though phonologically one may not consider these actual full vowels (see Leonard (Forthcoming) for a phonological analysis of this in SENĆOŦEN).

[20] ‘N’ refers to the number of tokens the statistics are derived from. Here there are 38 tokens of full vowels, 26 of stressed schwas, and 44 of unstressed schwas.

shorter and longer, with the upper quartile of measurements overlapping the range of stressed schwa. This distinction between the stressed and unstressed vowels is also statistically significant. A Welch's one-way analysis of variance (ANOVA) found a statistically significant difference at the $p<.05$ level among all the vowels ($F[2, 56.6] = 59.5$, $p<.001$), and a post-hoc Games-Howell test showed that the averages of the three types of vowels are statistically significant from each other. Thus we can see that there is a three-way distinction in length between stressed full vowels, stressed schwa, and unstressed schwa.

An additional feature of duration related to stress observed in the Lekwungen language workshops is the lengthening of post-vocalic consonants that come after a stressed schwa (see Figure 4.2), for example in *ʔə́sə*, 'I'. Usually in these cases the preceding or following syllable contains an unstressed schwa. If this is a general trend, consonant length might also be an indicative factor of vowel stress, further helping distinguish stressed and unstressed schwas. To explore this possibility, the following paragraphs report on durations of resonants, fricatives, and stops across positions.[21]

Post-vocalic consonant lengthening has been casually observed in the workshop. Most often occurring with resonants and fricatives, sounds whose apparent lengths are most noticeable at a glance and whose lengthening is relatively straightforward to observe and measure. The data seems to corroborate these observations, with resonants and fricatives lengthening after stressed schwas. Stops additionally lengthen after stressed schwas. Interestingly, this appears to be the case with both intervocalic and word-final resonants and stops. The figure below (Figure 4.2) provides the duration of

[21] Affricates were not included due to a low token count.

intervocalic resonants based on the preceding vowel. Like with the vowel duration plot, duration in milliseconds is on the left, and the categories on the bottom refer to the vowel categories under consideration.

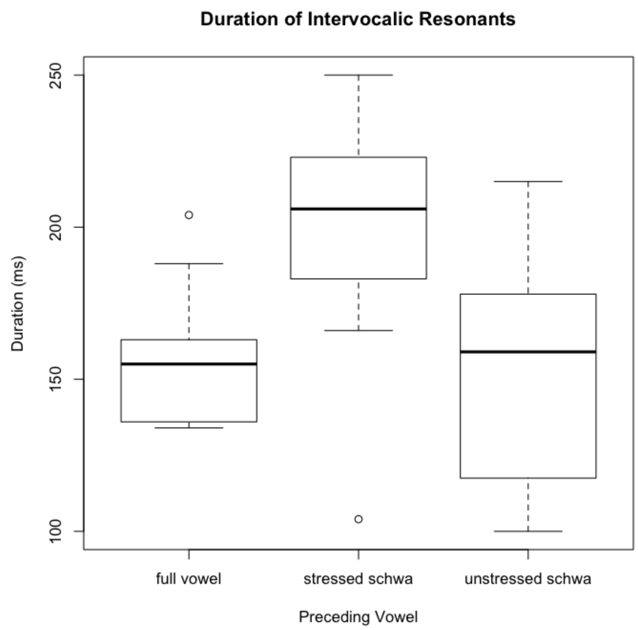

Figure 4.2: Duration of intervocalic resonants

The data for intervocalic resonants shows that those which follow stressed schwa (middle category) are longer than those which follow both full vowels (left) and unstressed schwa (right). Their median is 206 ms and their average is 200 ms (N = 13). All resonants in Lekwungen are included in the data, with /l/ constituting the majority of tokens. In the case of glottalized resonants, the glottal closure (most often as a glottal stop) is included in the duration of the resonant[22]. Resonants following unstressed schwas and full vowels are roughly equal in terms of average length, but unstressed

[22] Glottalized resonants (/l̓/) were distributed evenly across the vowel environments (two following full vowels, 3 following stressed schwa, one following unstressed schwa) and did not, as measured here, differ from their non-glottalized counterparts in terms of length

schwas have considerably more variability of measurement. While the post-unstressed schwa average is 152 ms and the median is 159 ms, it ranges normally from 110 to 190 ms (N = 7), while post-full vowels range from 134 to 188 ms with an average of 158 ms and a median of 155 ms (N = 9).[23]

Word-final resonants also appear to lengthen after stressed schwas, though if this is the case the effect is less distinctive. Figure 4.3 shows the length of resonants which are at the ends of words, with duration on the left, and the category of the preceding vowel on the bottom.

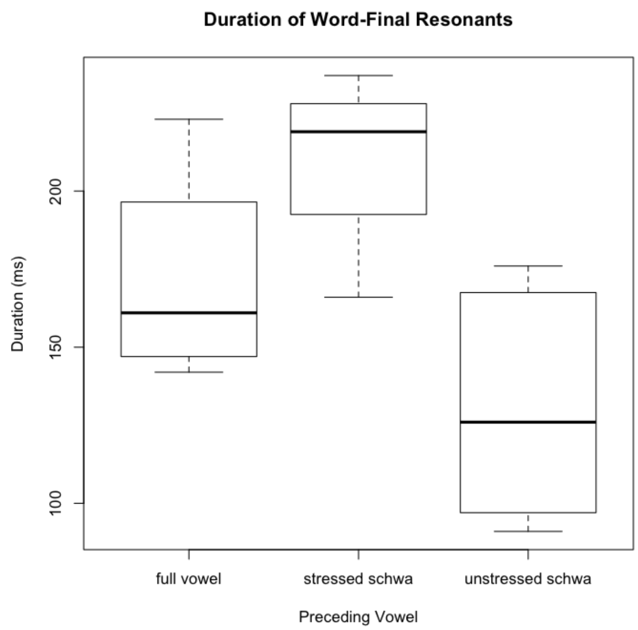

Figure 4.3: Duration of word-final resonants

Post-full vowel resonants (left category) have a median of 161 ms and an average of 172 ms, ranging from 142 to 223 ms (N = 4). Post-unstressed schwas have a median of 126 ms and an average of 131 ms, ranging from 91 to 176 ms (N = 8). In this

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[23] Owing to the small Ns, statistical tests were not run on the consonant length data

environment the post-unstressed schwas are considerably shorter than the post-full vowels. Both though are shorter than the post-stressed schwas, which have a median of 219 ms and an average of 207ms, ranging from 166 to 237 ms (N = 3). However, while the length distinction seems to be borne out in this environment, the low Ns (4 for the full vowels, 3 for the stressed schwas) cast uncertainty upon the patterns seen. More tokens would be needed for a more robust assessment. This lack of tokens also plagues the analysis of the post-vocalic fricatives in this environment, shown below in Figure 4.4. The setup of the plot is the same as for the resonants.

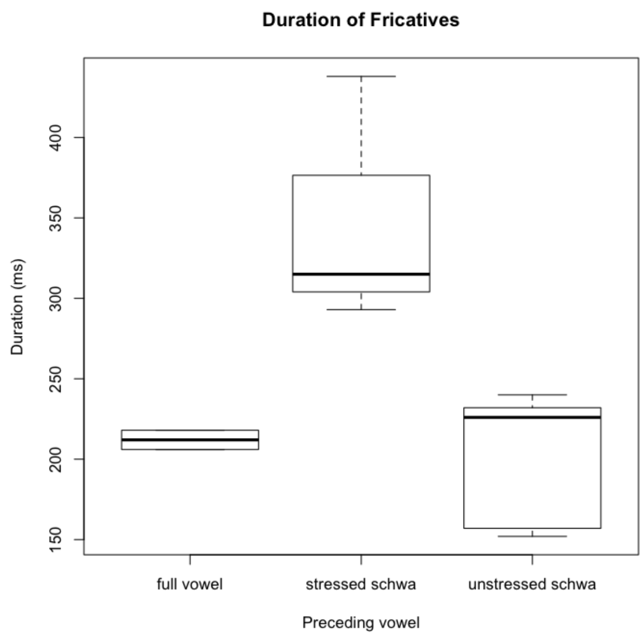

Figure 4.4: Duration of post-vocalic fricatives

The pattern seems to be supported with fricatives as well, attested to through observation from the workshops. Only two fricatives, /ɬ/ and /s/, were found and measured in this environment. Post-full vowel fricatives have a median and an average of 212 ms, post-stressed schwas a median of 315 ms and an average of 349 ms, and post-unstressed schwas a median of 226 ms and an average of 206ms. Despite the consistency of the pattern with that for resonants, low Ns (2 for full vowels, 3 for stressed schwas, 6 for unstressed schwas) hamper faith in the findings. However, given the results found for resonants discussed above, and for stops, which will be discussed below, it is likely that more tokens of post-vocalic fricatives would bear out the findings seen here, similar to the patterns found for the other consonants.

Stops show a similar pattern to that found for resonants and fricatives. All plain stops, save /k/, (/ʔ, k^w, p, q, q^w, t/) were measured. Those following stressed schwas are longer than those following unstressed schwas and full vowels, though the results are less distinctive and clear-cut than for resonants. Figure 4.5 follows the same layout as those for resonants and fricatives. For these, duration was measured as the whole stop, including the closure and the release/aspiration.

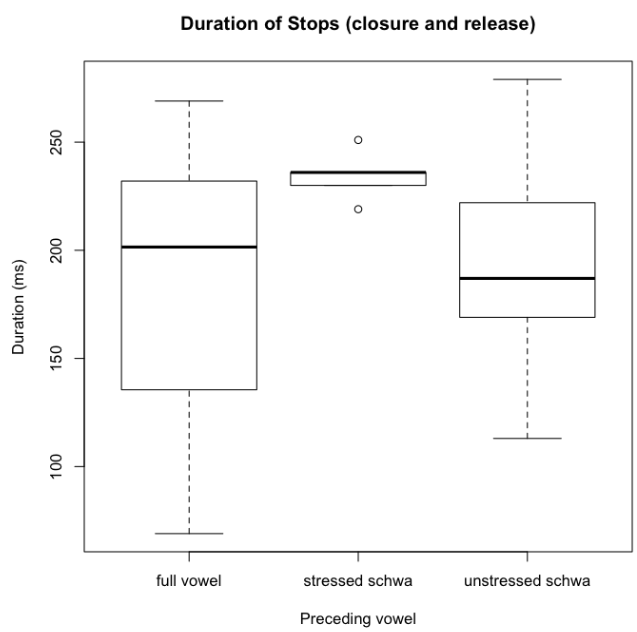

Figure 4.5: Duration of post-vocalic stops

Post-stressed schwas (N = 5) are tightly clustered, with an average of 234 ms but only ranging from 219 to 251 ms. Conversely, post-full vowels (N = 20) are shorter but have a dramatic range, from 69 to 269 ms, with an average of 181 ms. Unstressed schwas (N = 17) also are on average shorter but also have a large range, from 113 ms to 279 ms, with an average of 191 ms. This spread though seems to be partly an effect of variability in burst/frication/affrication duration, for when only stop closure durations are plotted (Figure 4.6), the pattern seen in other consonants appears more distinctly:

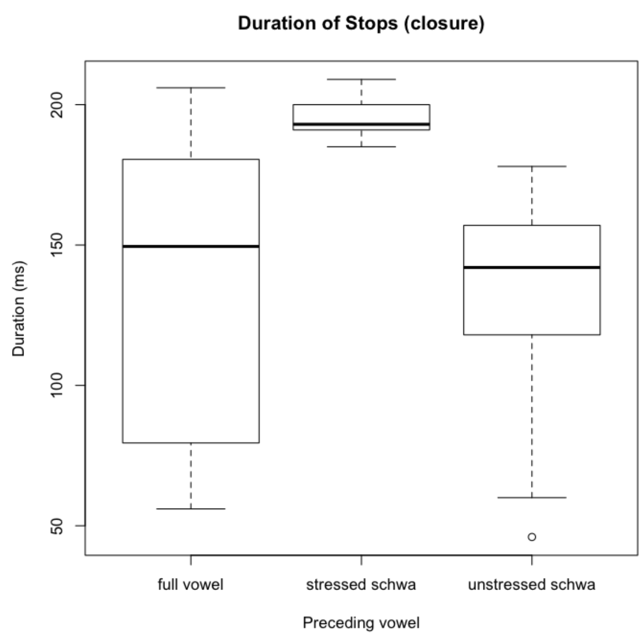

Figure 4.6: Duration of post-vocalic stop closures

For stop closure durations, variability in the duration of post-full vowels and post-unstressed schwas is still present, but the range has been reduced, from 56 ms to 206 ms and 46 ms to 178 ms respectively, and post-stressed schwas range from 185 to 209 ms, overlapping with the upper quartile of the post-full vowels. The pattern is more discernable as well, for although there is considerable range in the durations of stop closure, those following stressed schwas are still greater than the majority of post-full vowels and post-unstressed schwas.

Finally, affricates (all /č/) show the same pattern, though with an N of 3 they were not plotted. Two intervocalic tokens following stressed schwa have a duration (closure plus fricative) of 233 and 245 milliseconds, while one token following a full vowel has a duration of 205 milliseconds. The same pattern is found for their closure durations alone: 116 and 120 ms vs. 90 ms. Though no tokens following unstressed schwas have been found, the pattern appears to repeat, and given the robustness of the pattern for other consonants, it is likely to be present with affricates as well.

4.2.2 Pitch and amplitude

The two other acoustic correlates of stress discussed in Chapter 2 were pitch and amplitude. Lekwungen follows the patterns described by Tamburri-Watt et al. (2000) and Leonard (2007) and has both higher pitch and greater amplitude in stressed vowels than in unstressed vowels.

The following box plot shows pitch (fundamental frequency) of the three vowel categories. On the y-axis on the left side of the image is the frequency in Hz, and along the bottom are the three categories of vowels.

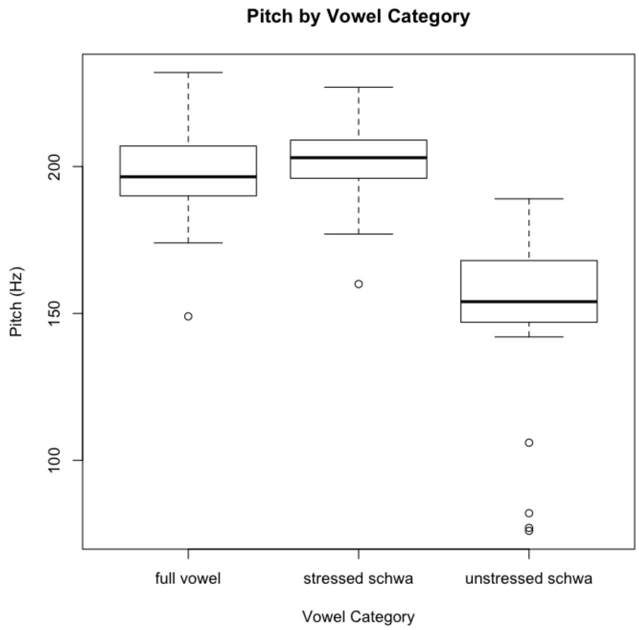

Figure 4.7: Pitch of vowels by category

As we see, pitch for full vowels had an average measure of 199 Hz (SD = 15.6). For the two types of schwas, those classified as 'stressed' had an average pitch of 201 Hz (SD = 14.2), and those classified as 'unstressed' had an average pitch of 152 Hz (SD = 28.5). Several extremely low pitch measures for unstressed schwas are due to the presence of creak from glottal stops. Ranges for the three vowels types are similar, a range of 58 Hz for the full vowels, 50 Hz for the stressed schwas, and 47 Hz for the unstressed schwas. The two stressed vowel types had near-identical average pitches, and the unstressed vowel type had a considerably lower average pitch. As we can see in Figure 4.7, with pitch there appears to be only a two-way distinction between the stressed and unstressed vowels, and this is supported by statistical tests. A Welch's one-way ANOVA found a statistically significant difference at the $p<.05$ level among all the vowels ($F[2, 52.5] = 41.1$, $p<.001$), and a post-hoc Games-Howell test showed that the averages of unstressed schwas are significantly different from the averages of both full vowels and stressed schwas, but full vowels and stressed schwas are not statistically significant from each other. Thus we can see that there is a two-way distinction in pitch between stressed full vowels/stressed schwa and unstressed schwa.

The amplitude results are similar to those for pitch. Figure 4.8 shows amplitude results for the three vowel categories, with intensity in decibels as the y-axis:

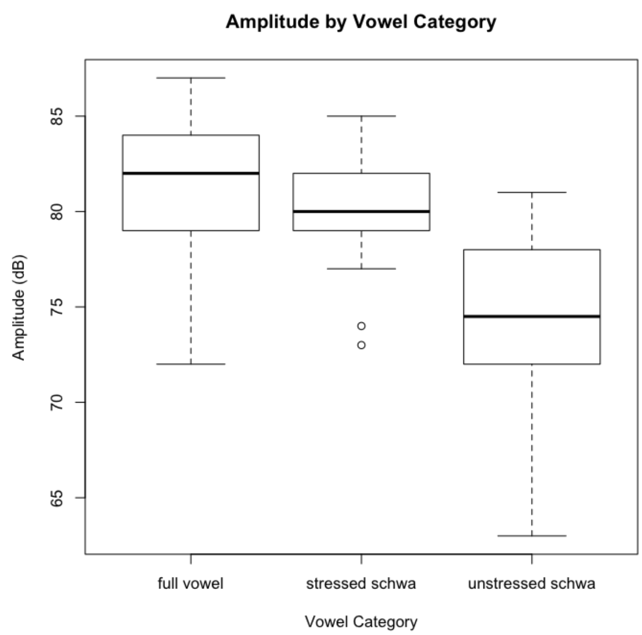

Figure 4.8: Amplitude of vowels by category

Though the overall range of the measurements was not as great as that of pitch or duration, the grouping of the stressed vowels and the unstressed vowels reflects the pattern seen with pitch. Average amplitude of full vowels was 82 dB (SD = 3.06), that of stressed schwas 80 dB (SD = 3.05), and of unstressed schwas 74 dB (SD = 4.27). Unstressed schwas also had a lower quartile of measurements from 63 to 72 dB, below the minimums of full vowels and stressed schwas. The upper quartile of 78 to 81 dB overlapped with the averages of full vowels and stressed schwas as well. As with pitch, Figure 4.8 shows that there appears to be a two-way distinction between the stressed and unstressed vowels. This is supported by statistical tests. A Welch's one-way ANOVA found a statistically significant difference at the $p<.05$ level among all the vowels ($F[2, 51.7] = 34.9$, $p<.001$), and a post-hoc Games-Howell test showed that the averages of unstressed schwas are significantly different from both full vowels and stressed schwas, but that full vowels and stressed schwas are not statistically significant from each other, while. Thus we can see that there is a two-way distinction in amplitude (like with pitch) between stressed full vowels/stressed schwa and unstressed schwa.

Overall, three acoustic correlates to stress were investigated in Lekwungen, and all three were found to correlate with stress. In terms of duration, there is a three-way distinction in vowel length, with full vowels being considerably longer than stressed or unstressed schwas, with the schwas being closer together in measurements to each other than to the full vowels. For pitch, there is a two-way patterning of fundamental frequency, with full vowels and stressed schwas having near-identical pitch measures, and unstressed schwas being considerably lower than both. For intensity, the same two-way pattern is repeated, with full vowels and stressed schwas grouping together in average intensity, and unstressed schwas having lesser intensity than the other two. Additionally, consonants following stressed schwa, whether in intervocalic or word-final position, lengthen relative to consonants of the same type (resonant, fricative, stop) that follow full vowels or unstressed schwa. Finally, when unstressed vowels reduce to schwa, and as we'll see upcoming in Section 4.2, for any unstressed schwa in general, vowel quality differs from stressed schwa, and stressed schwa behaves more like the stressed full vowels than unstressed schwa.

4.2 Consonant coarticulatory effects

This section is divided into a number of smaller sub-sections. It starts with an overview of the whole F1 by F2 vowel space of Lekwungen, detailing the overall plotting of the vowels at the four time points measured, making note of the nature of consonant coarticulatory effects. It moves on to then detail effects vowel-by-vowel, going from /i/ to /e/ to /a/ to stressed and unstressed schwas. Following this are the effects on F3 of preceding and following consonants, and finally a short section on other effects of consonants found.

Before moving on to discussing the overall vowel space of Lekwungen, first a note on gaps in the data. There are several target CVC sequences that have not been discovered in the recordings so far: /a/ both preceding and following /q/ and /w/ and preceding /t̓/; /e/ following /w/; /i/ preceding and following /y/; and stressed schwa preceding and following /p/ and /t̓/. For all vowels, /p/, /w/, /t̓/, and /y/ have limited occurrences, with only a handful of tokens for the sequences where they do appear. This is not unexpected, as they are among some of the most infrequent of the target consonants, as found in the frequency count I conducted (see Section 3.2), and so tokens would be correspondingly hard to come by for a range of vowels and environments, especially when working with already existing recordings.

4.2.1 Effects on F1 and F2

This first sub-section details the effects on F1 and F2 of preceding and following consonants, in other words, contexts which are preservatory (where the vowel is altered due to the articulation of the preceding consonant) or anticipatory (where the vowel is altered in expectation of the articulation of the following consonant). The magnitude of the anticipatory or preservatory effects can be seen by the speed with which they appear or disappear in the measurements, meaning if the effects only appear at the 5% or 95% time points in the vowel, or if they are also present at the 50% mark. A longer-lasting effect (carrying into the 50% time point) indicates a more persistent, less peripheral effect, and might be more likely to be salient enough to alter the perception of the vowel (though this is not always the case).

Figure 4.9 below shows four scatter plots of the F1 and F2 values in Hertz of all the collected tokens of full vowels and stressed and unstressed schwa at four time points: 5% into the vowel (upper left), 50% (upper right), 95% (lower left), and an average over the middle 90% of the vowel (lower right). Each data point corresponds to an individual token, indicated with the vowel that it represents, 'i' for /i/, 'e' for /e/, and 'a' for /a/. Schwa is divided into stressed schwas, indicated by a 'ʌ', and unstressed schwas, indicated by a 'ə'. The larger vowel symbols represent the means of the data points for a given vowel in a specific plot. The ellipses represent confidence intervals (that is, at least 2/3rds of all data points for a specific vowel fall within that vowel's ellipse). F2 is the x-axis (along the top) and F1 is the y-axis (along the right side). The axes are inversed (as per convention) so that the plots correspond with the configuration of the mouth for vowel production. Thus points at the top of each plot correspond with relatively closer vowels tokens and those at the bottom with relatively more open tokens, and those on the left side of the plot with more front tokens, those on the right side with more back tokens.

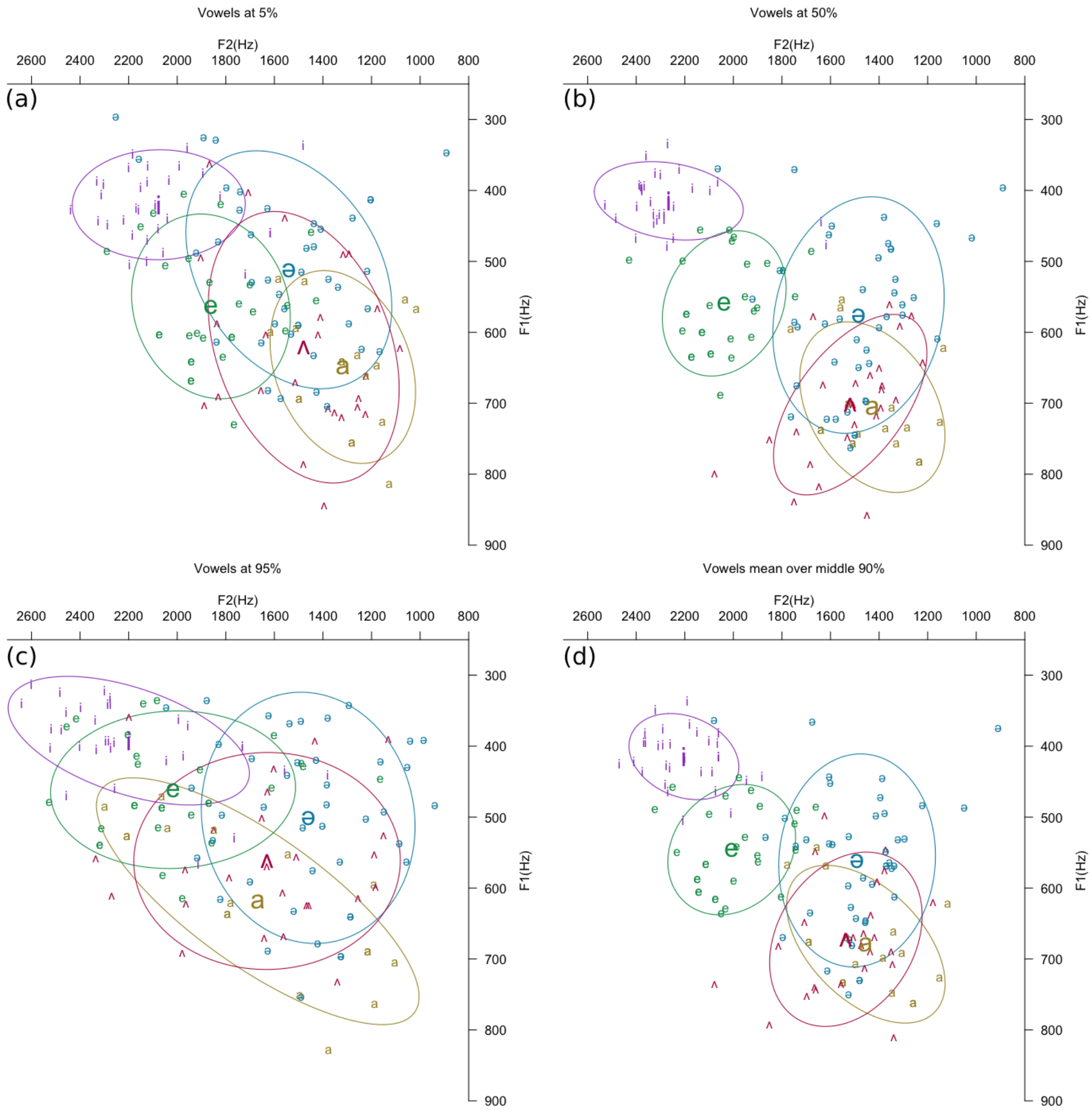

Figure 4.9: Lekwungen vowel space across three time points and a mean measure

Throughout all the time points, a relatively clear differentiation between the vowels does persist, although [a], stressed schwa, and some cases of unstressed schwa have general overlap throughout the time points, as we can see by the proximity of their means (the larger symbols) and the overlaps of their confidence intervals (the ellipses). The measurements plotted in Figure 4.9 include those from both preservatory (upper left, (a)) and anticipatory (lower left (c)) contexts. A brief observation about the locality of coarticulatory effects may be made from observing the distribution of vowels over the space of plot in (a) and (c) (the two plots on the left) vs. (b) and (d) (the two plots on the right), by looking at the spread of the individual data points and the size of the ellipses. At least in the isolated word context under study here, the stronger coarticulatory effects seem to be limited to the peripheries of the vowels: Figure 4.9(a) and Figure 4.9(c) have plots of vowels which are considerably overlapping, whereas the two plots on the right ((b) and (d)) have relatively well separated vowel spaces. The amount of change that is brought about by coarticulatory effects on the peripheries of vowels is best seen with [i] and [e], which are relatively well separated and have compact vowel spaces at the midpoint (b) and middle-average (d), but expand and loosen considerably at the onset (a) and offset (c). This can also be seen with [a] and stressed schwa (indicated by [ʌ]), which are generally compact and tightly clustered in (b) and (d) (though still highly overlapping), but spread profusely in (a) and especially in (c), where they occupy a great range of the vowel space. Similarly, unstressed schwa has a wide range at all time points, but becomes even more diffuse at the 5% and 95% time points. In general, unstressed schwa (indicated by [ə]) is looser over a wider range than the other vowels, and it is more diffuse at all time points than the other vowels. Stressed schwa is also fairly diffuse at 5% and 95%, more than the full vowels, but is more compact in (b) and (d) than unstressed schwa. The full vowels are tightly compact at (b) and (d), and though diffuse in (a) and (c), are less so than stressed and unstressed schwa.

Figure 4.9 suggests that most strong effects of co-articulation seem to be limited to the temporal peripheries of the vowels, but are not always. Let’s now turn to the individual vowels themselves, and see how the pattern appears across them. The following sections will explore the effects seen on each vowel, staring with /i/, moving to /e/, /a/, and stressed and unstressed schwa.

4.2.1.1 Effects on /i/

Figure 4.10 below shows the data points for /i/ (N=30). In this plot the data points are represented by their IPA symbol, based on my perception of them. The purpose of these types of plots (given for all the vowels) is to show the possible perceptual boundaries for an English speaker (as a perceptual study was not part of this thesis), and thus indicate what learners might expect to hear in Lekwungen vowel variation, as well as indicate to them what they could expect to pronounce.

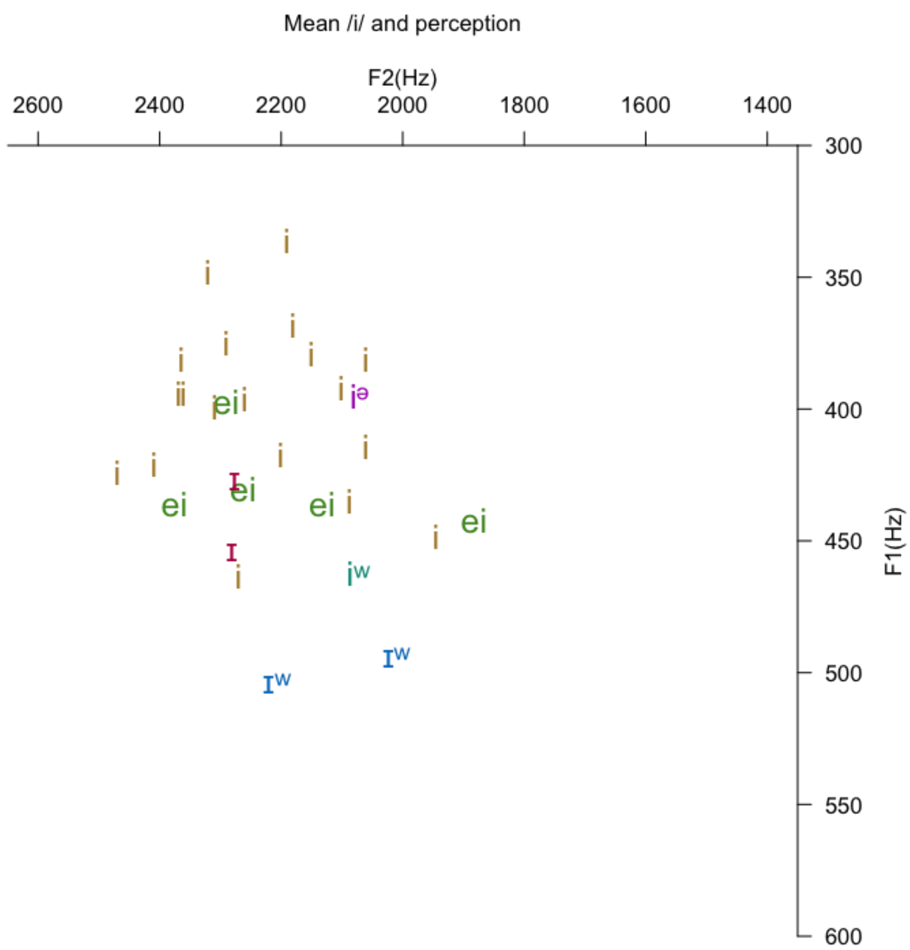

Figure 4.10: Mean measures of /i/

Figure 4.10 shows data points for the mean measures (in Hz) of F1 and F2 for /i/. The points are labelled and coloured relative to my perception of them. I include this plot to help better show the nature of vowel quality variation (e.g., that these aren't all productions of [i], but rather some cross a perceptual boundary for an English speaker, and are thus important to be aware of when writing/learning Lekwungen if one is an English speaker, as all current Lekwungen learners are). Of key interest are the three tokens in the lower right corner of the plots. These represent the /i/s heard as [i^{w}] and [ɪ^{w}], that is, with labialization following. Other groups include those heard as [i] and those heard as [ei], two heard as [ɪ] that, in their mean measurements do not stand out from the main group, and one heard as [i$^{\text{ə}}$], that is, an [i] with a following schwa-like sound. The main separation between the types is that between the labialized and the others. For the tokens heard as [ei], it should be noted that, as they were heard as diphthongs, their positions in Figure 4.10 are non-indicative of their relevant values, as they represent an arbitrary point between the two vowels they actually consist of.

For a fuller picture of vowel variation with regards to coarticulatory effects, let us turn to the plots showing variation across time points over the vowel. Figure 4.11 below shows the same tokens as in Figure 4.10, but the data points are coded by the consonant that **precedes** the vowel in the token; colours vary by perception, as in Figure 4.10 above (yellow for [i], yellow-green for [ei], purple for [i$^{\text{ə}}$], red for [ɪ], blue-green for [i^{w}] and dark blue for [ɪ^{w}]). There are two plots in the figure: one on the left showing the data measurements at 5% into the vowel, and one on the right showing the measurements at 50% in to the vowel. 95% is not included here because at the 95% mark the coarticulatory effects we would expect to see are those of the following consonant, not the preceding one. These plots show the magnitude of the coarticulatory effects and their temporal peripheralness. We saw in Figure 4.10 that the data points are relatively clustered at their mean measurements, the majority of the points are between 350 Hz to 450 Hz for F1 and 2000 Hz to 2400 Hz for F2; therefore, in Figure 4.11 if we see that a certain consonantal data point is far away from the area of the cluster, we can conclude that the consonantal coarticulatory effect is fairly strong, and if at the 50% mark it is still distanced from the cluster, then the effect is likely to be fairly persistent as well.[24]

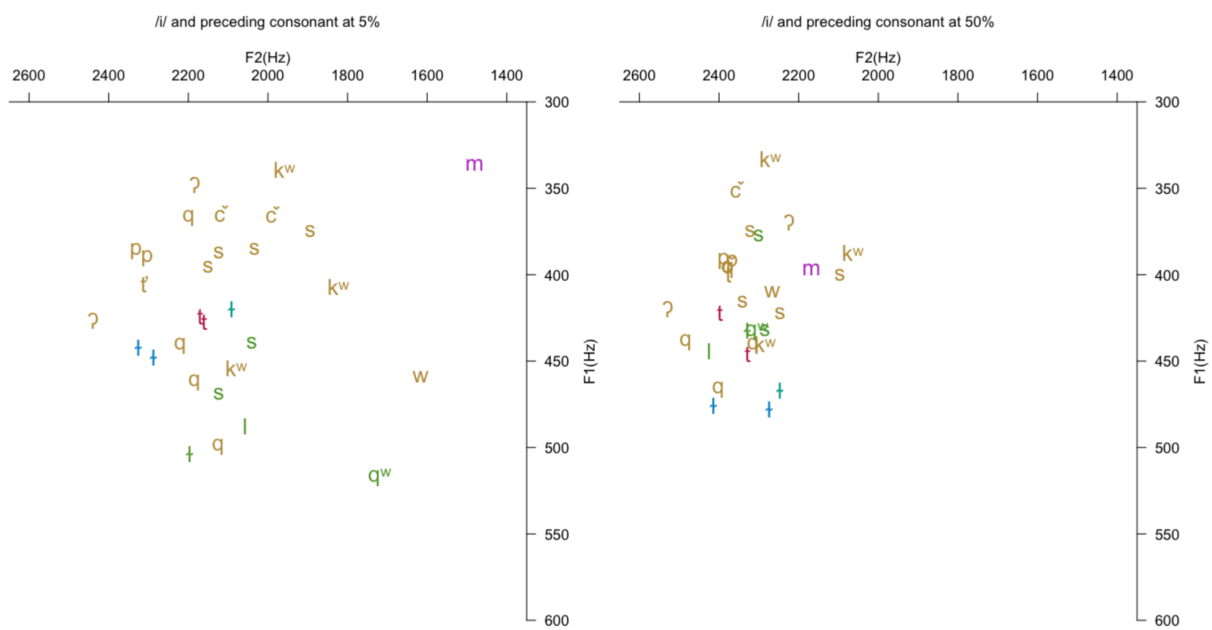

Figure 4.11: /i/ with preceding consonant at 5% and 50%

Figure 4.11 shows that the coarticulatory effects on /i/ of the preceding consonant are relatively small and peripheral (only at 5%). In the 5% plot, data points are more diffuse, but large deviations from the cluster seen in the 50% mark are few. As we saw in

[24] For the full discussion of the persistence of certain types of consonants and effects, see Chapter 5.

Figure 4.9 and as discussed in Chapter 5, this is line with /i/ being the least affected vowel. Vowels following coronals (alveolar /t/ and palatal /č/ and /y/) have a lower F2 at 5% relative to 50%, going from between 2000~2200 Hz to 2200~2400 Hz. Their F1 measurements are likewise small in difference, simply growing more compact around 400 Hz by 50%. Vowels following labial /p/ and glottal /ʔ/ have very little quality change between the time points. Preceding /q/ has a slight raising effect on F1 at 5%, but this is lost at 50%, with vowels following /q/ centralizing to the cluster. Several labial/labialized (/w/, /k^w/, /q^w/) preceding consonants have an immediate effect on the following vowel quality, reducing F2 and increasing F1 (such as the two points just past 1600 Hz F2), but as seen in the 50% plot this effect does not persist to the midpoint of the vowel. Additionally, these effects are inconsistent across labialized consonants, with two instances of [k^w] involving a rising F2 from 5% to 50% but no F1 change, but another instance involving only a slight rise in F1 and F2. The one token of preceding [q^w] involves a considerable raising and fronting from 5% to 50%, going from 1719 Hz to 2305 Hz for F2, and from 517 Hz to 433 Hz for F1. Additionally, it is important to point out that preceding ejective /t̓/ does not have any lowering or backing effects on /i/, rather it patterns with plain /t/ in raising and fronting /i/, though like /t/ this is only peripheral.

Somewhat-more persistent coarticulatory effects are seen in Figure 4.12 below, showing effects of the following consonant.

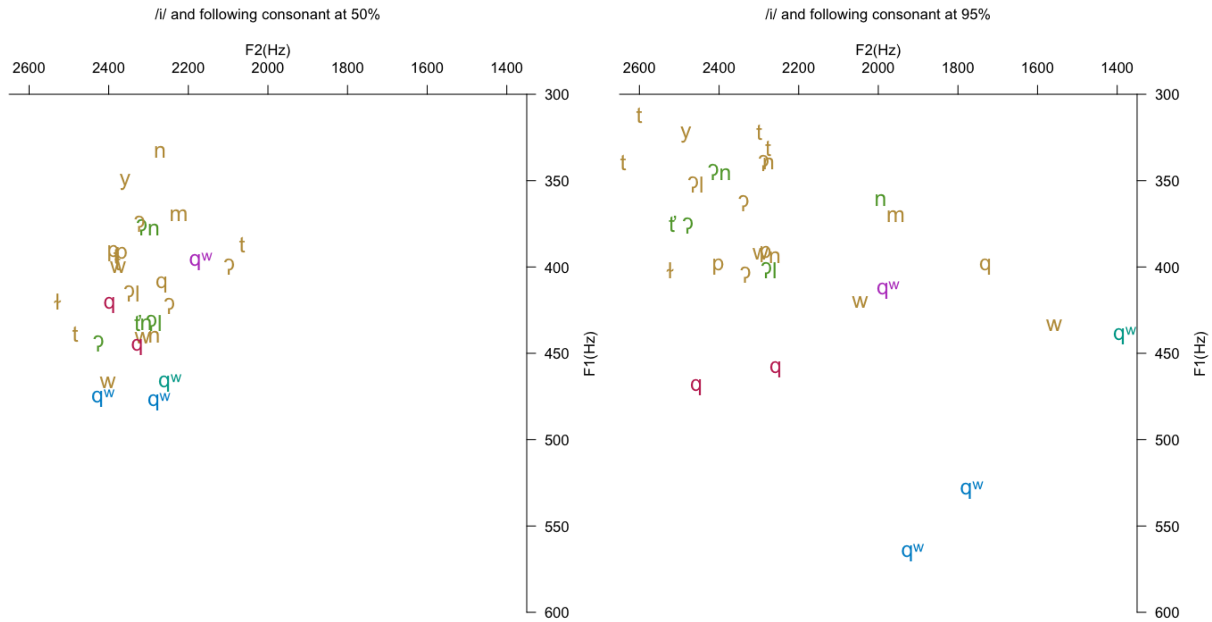

Figure 4.12: /i/ and following consonant at 50 % and 95%

In Figure 4.12 the main somewhat-persistent effect we see is that of following [qʷ], reflected by the fact that auditorily they follow [ɪʷ], [iʷ], and [iᵊ] (as indicated by their dark blue, light blue, and purple colour). These vowels are in general lowered consistently relative to the main grouping seen at 50%. At 95% the main peripheral effects are lowering and retracting seen with [q], [qʷ], and [w], and the fronting and raising with [t]. At 50% F2 preceding [q] was between 2200 and 2400 Hz and F1 was between 400 and 450 Hz; F2 was unchanged at 95%, though F1 was raised to between 450 and 500 Hz. Preceding a [qʷ], there are several effects: one token dramatically retracts to ~1750 Hz (F2) (while not lowering much), while two others lowered to between 500 and 600 Hz (F1) and retracted to 1800 to 2000 Hz (F2). Another token did not retract or lower greatly, retracting only around 200 Hz and lowering only slightly. Tokens preceding [w] resemble those preceding [qʷ]: they are within the main cluster of F1/F2 at 50%, but both considerably retracted at 95%, with F2s of ~2000 Hz and ~1600

Hz. The dramatic lowering preceding [qʷ] is likely partly due to the fact that three of the tokens have secondary labialisation from the [qʷ] present, while the one token that lowers less does not (but it does have a compensatory schwa). Compare the lowering and/or retracting preceding [qʷ] with that preceding [w]. Additionally, compare it to the lowering preceding [q], where, though there is a perceptible effect, the magnitude is lesser. [t] and [y] have the opposite effect on preceding vowels: fronting and raising. At 95% the preceding vowels have raised to have F1s between 250 and 350 Hz from ~400 Hz at 50%. As at 5%, [p] and glottal stop have little if any effect.

4.2.1.2 Effects on /e/

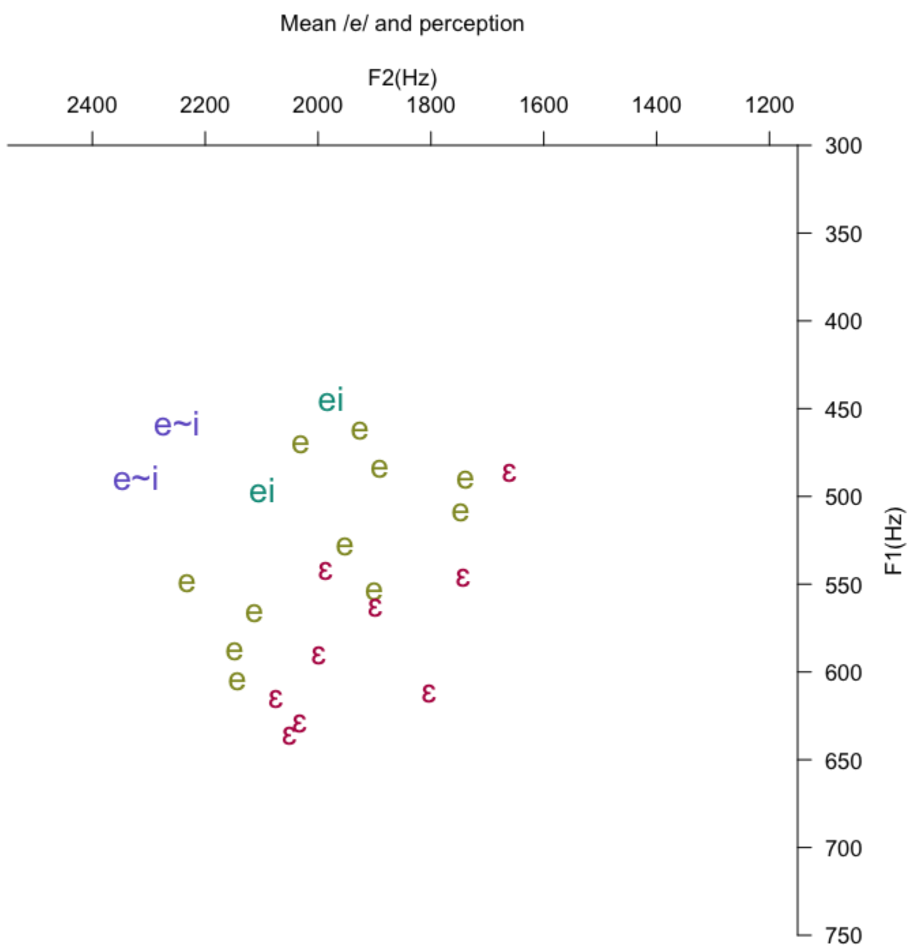

Figure 4.13: Mean measures of /e/

Figure 4.13 shows the mean measures of /e/ (N=24), and corresponding perception. There are two main groups: those heard as [e] (in yellow), and those heard as [ɛ] (in red), as well as two tokens which were perceived as marginal [e~i] (in purple) and two which were perceived as diphthongs [ei] (in teal). [e] and [ɛ] are bisected, with [ɛ] consistently having a lower F2 and/or higher F1 than [e] of similar F1/F2 measures.

When investigating the effects of preceding consonants, two major features stand out: that tokens of /e/ pronounced as [ɛ] (in red) are never preceded by a labialized consonant or a glottal stop, and that /q/ precedes only them, and not [e]. As with the plots for /i/, in the figures below the colour coding corresponds to my perception and the symbol represents the adjacent consonant. Figure 4.14, provides the data points for /e/ at 5% and 50%.

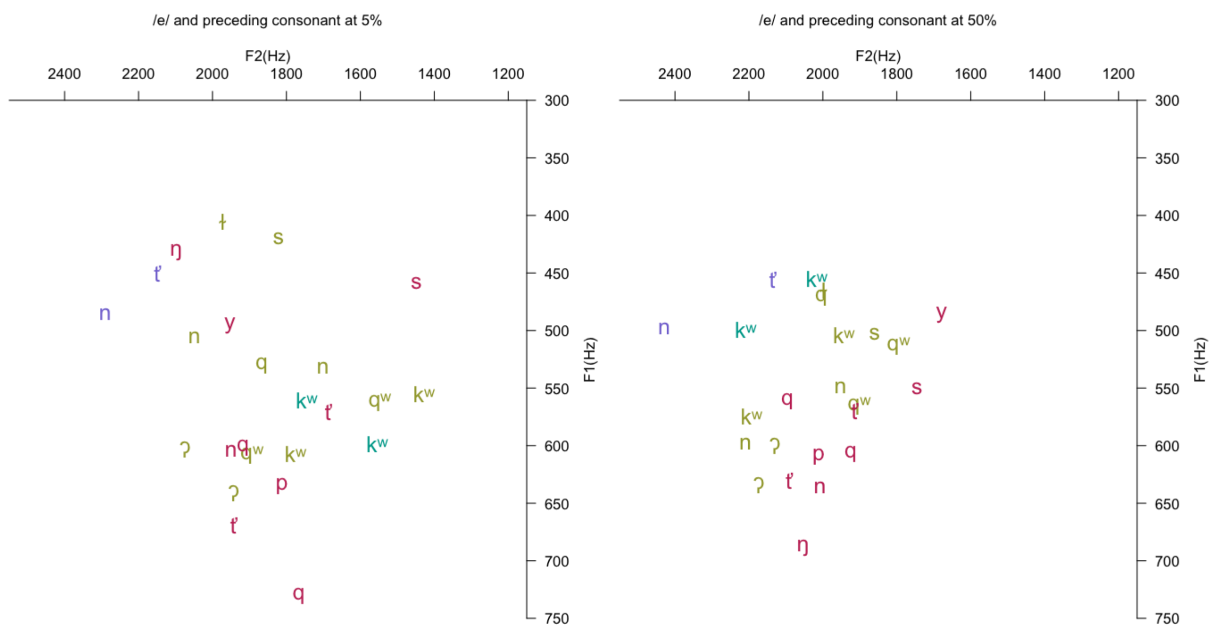

Figure 4.14: /e/ and preceding consonant at 5% and 50%

Figure 4.14 suggests that there is a relation between the labialized stops and the glottal stops (though there are only two of the latter), and the production of [e]. At 5% vowels preceding labialized consonants have retracted F2s, which then increase ~400 Hz, and raised F1s, which decrease ~100 Hz at 50%. Preceding glottal stop appears to have a persistent effect in raising F1 relative the average for /e/. There do not appear to be any other strong persistent or local effects of preceding consonants. Additionally, we see that the split into the two pronunciations [e]/[ɛ] is not immediately present at the 5% mark of the vowels, though the effects of labialisation do seem to have retracted and lowered the onsets of a number of /e/s. By the 50% mark though, this effect has disappeared, with the [e]s and [ɛ]s having bifurcated along an axis inversely related to F1 and F2, and no obvious preservatory coarticulatory effects (save those already mentioned) seem to be taking place. Perception seems to be determined by the middle of the vowel, given its correspondence with the split. Possible coarticulatory effects affecting this split do appear with anticipatory effects of the following consonants.

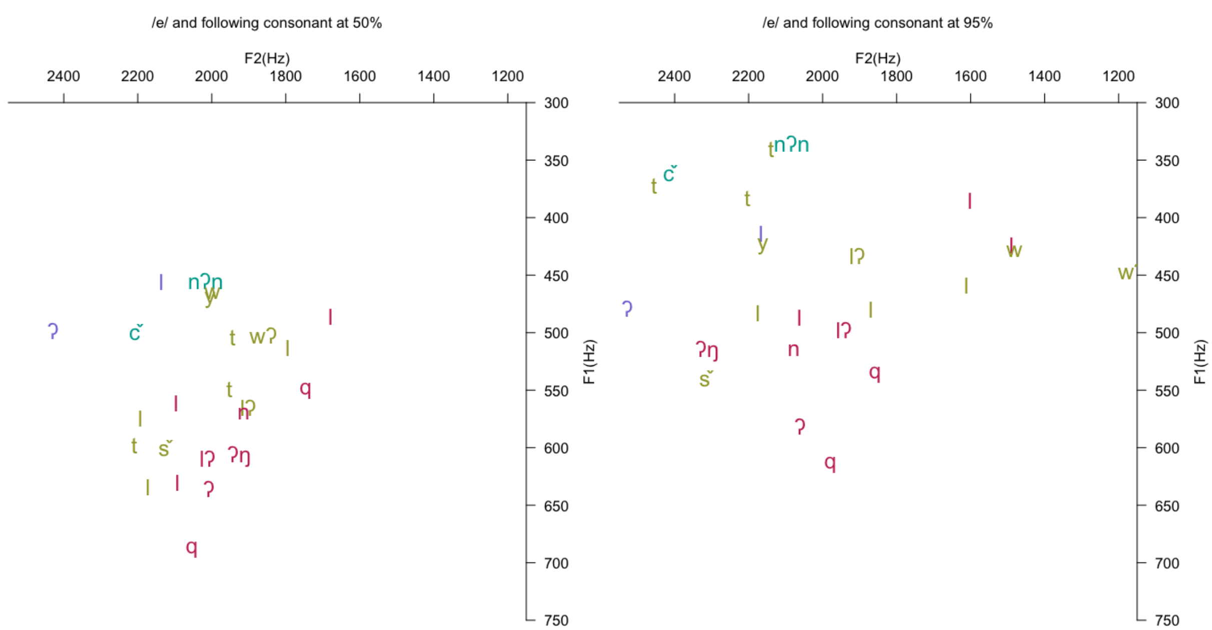

Figure 4.15: /e/ and following consonant at 50% and 95%

Figure 4.15 suggests that some of the difference between /e/ heard as [e] and /e/ heard as [ɛ] can be attributed to following consonants. There seems to be an effect of /q/ and glottal stop influencing preceding /e/ to be pronounced [ɛ], and an effect of coronals /t/, /y/, and /č/ influencing /e/ to [e]. As we can see when comparing the 50% plot and the 95% plot, the /e/ heard as [ɛ] are relatively stable across the course of the vowel, with F2s centred around 2000Hz and F1s centred around 550~600Hz. However, while at 95% they remain clustered together albeit with decreased F1s and a greater diffusion. [e]s on the other hand are more extreme. At 95%, measures for [e] show the strong local effects of coronals and /w/ seen with /i/, with F1 dramatically lowering ~100 Hz, and F2 either increasing ~200 Hz for the coronals or decreasing slightly for /w/. In general tokens heard as [e] have greatly diffused by 95% and no trace of clustering remains. However, as will be taken up in Chapter 5, the fact that the division is clear at the middle of the vowel and that the peripheries do not show a strong effect creating the division, suggests that the retraction of /e/ before uvulars and glottal stops is categorical, and not just an effect of consonant coarticulation (in the same way, e.g., following /w/ is retracting and raising [e] at 95%).

Overall, what is happening with /e/ comes down to two cleanly divided pronunciations, the origins of which become more apparent when investigating anticipatory coarticulatory effects. A similar thing happens for /a/ (N=13), which we can see in Figure 4.16, which has a pronunciation split between those heard as [a] and those heard as [ɑ].

4.2.1.3 Effects on /a/

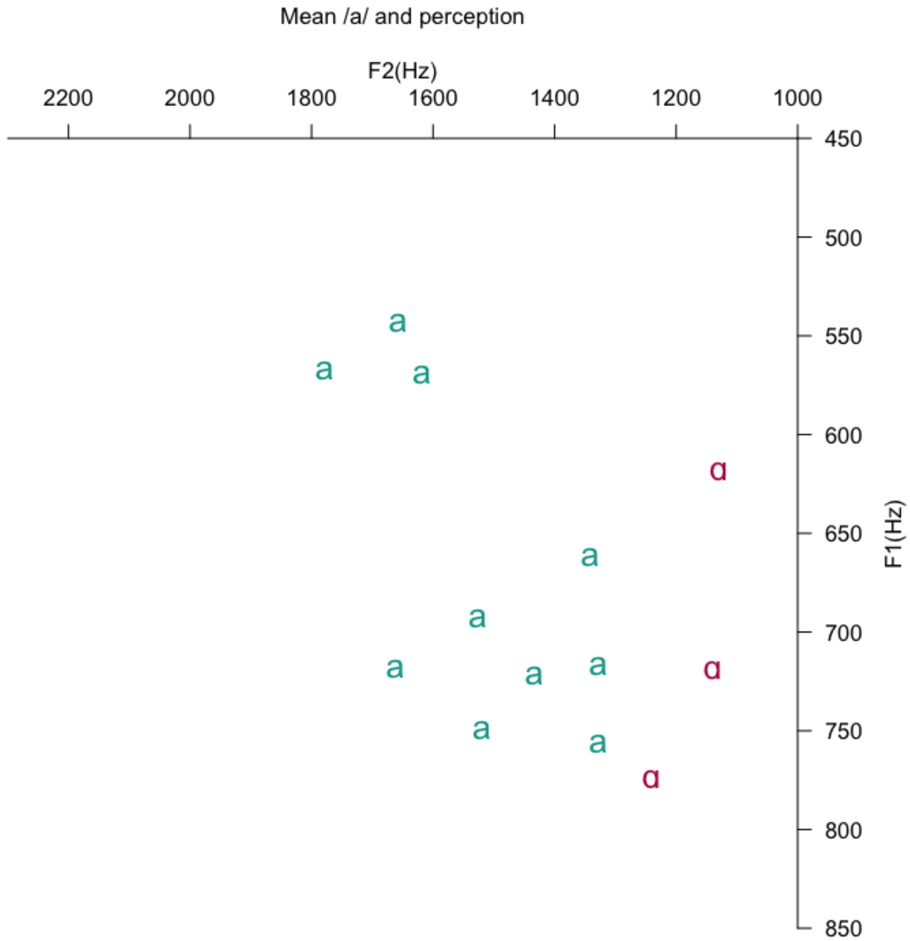

Figure 4.16: Mean measures of /a/

In Figure 4.16 for /a/ we see another two-way split, here between [a] (in blue) and [ɑ] (in red). Opposite of /e/, which had a similar division of pronunciation that was based in anticipatory coarticulatory effects, this division seems to have a basis in only preservatory coarticulatory effects from the preceding consonant, as we see in the section below.

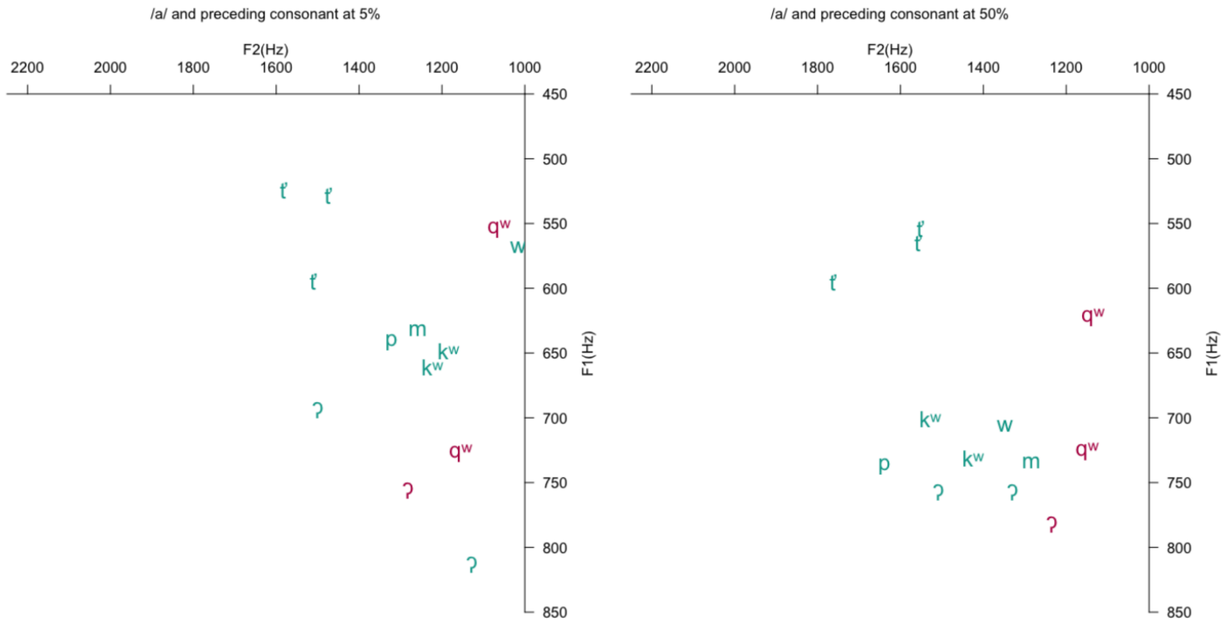

Figure 4.17: /a/ and preceding consonant at 5% and 50%

Figure 4.17 shows a lowering/retracting effect of labialized uvulars, and a slight lowering effect of glottal stops, as well as a raising effect of alveolar ejectives. The effects of the alveolars are persistent, maintaining F1of the following vowel between 550 and 600 Hz and a slightly shifting F2 from 1400 and 1600 Hz to 1600 – 1800 Hz (we will see in Figure 4.18 that this is helped by the following /y/). The effects of glottal stops and labialized uvulars are persistent, with F1 of the following vowel remaining between 700 and 750 Hz from 5% to 50%, and F2 remaining around 1200 Hz. Preceding labialized velars also have a retracing/raising effect on /a/, but this is not persistent: F1 raises from ~650 Hz at 5% to ~750 Hz at 50%, and F2 fronts from 1200 - 1300 Hz to 1300 – 1600 Hz. Both instances of preceding /qʷ/ occur before a retracted /a/, heard as [ɑ]. This retraction is most likely due to the preceding consonant, as we see in the following figure, where anticipatory effects appear to be mostly limited to the offset of the vowel.

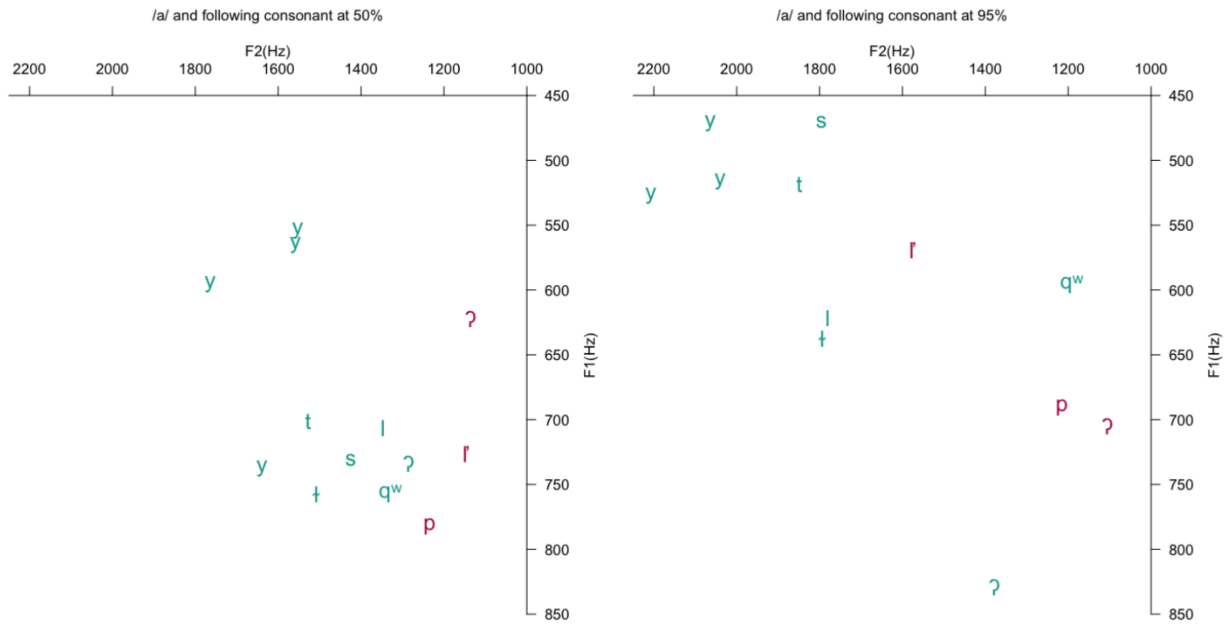

Figure 4.18: /a/ and following consonant at 50% and 95%

Figure 4.18 shows that there does not seem to be any pattern of persistent anticipatory coarticulatory effects of following consonants. Alveolar and palatal consonants draw /a/ forward and up at the 95% mark but only /y/ does at the 50% mark (and this is helped by the preceding alveolar). Conversely, following /p/ and glottal stop keep the offset of /a/ relatively stable with the rest of the vowel. Additionally, though there is only one token, a labialized uvular stop seems to back and raise a preceding /a/, though this could also be due to the timing of the secondary labial articulation (see Section 4.2.3.2 for more discussion on this).

Overall, the full vowels have shown that they are not affected by preceding and following consonants in the same manner. /i/ has both anticipatory and preservatory effects, though almost none are persistently strong. /e/ and has persistently strong effects for the anticipatory context, and these are perceptible. /a/ has persistently strong effects in both preservatory and anticipatory contexts, but only preservatory effects are perceptible.

4.2.1.4 Effects on stressed schwa

Below is Figure 4.19, a plot of the tokens of stressed schwa (N=24), plotted on their mean measurements of F2 and F1. They've been separated into two groups based upon their perception: those heard as a [a], in blue, and those heard as [ʌ], in red.

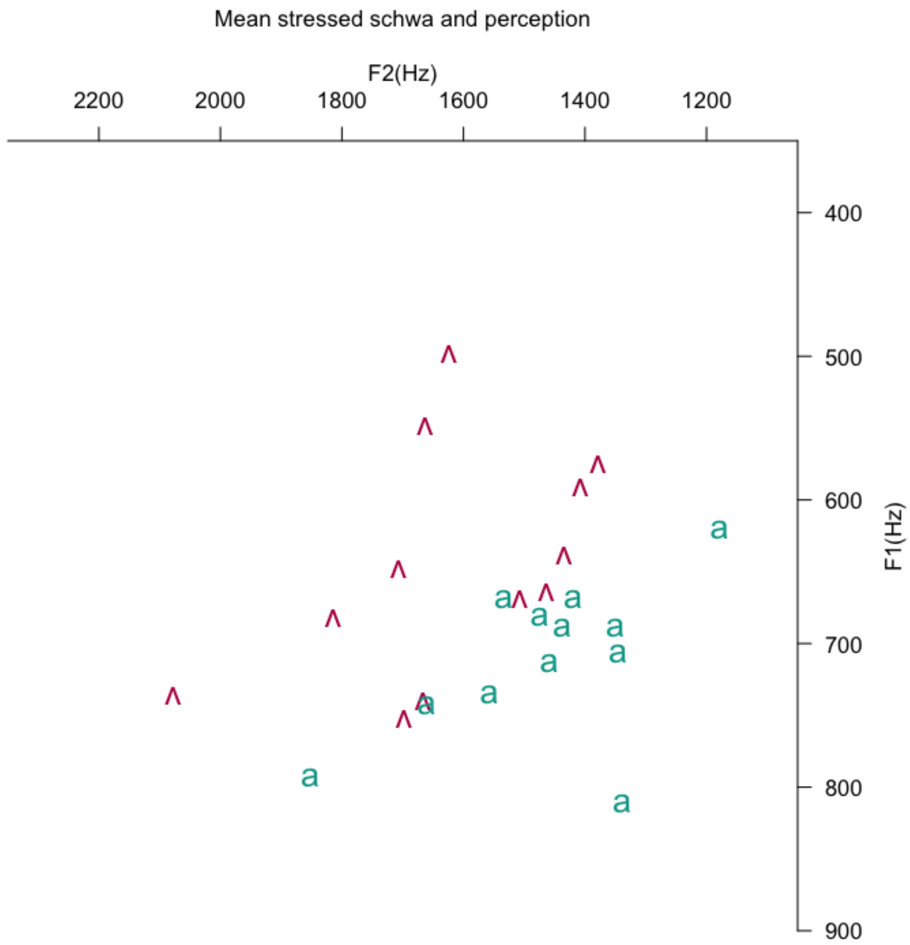

Figure 4.19: Mean measures of stressed schwa

Out of 24 data points, 12 were heard as [ʌ], and 12 as [a]. Additionally, stressed schwa has considerable overlap with /a/ in the vowel space, as seen in Figure 4.10. Like with /e/ and /a/, it is possible that this division in perception could be due to persistent coarticulatory effects. To explore this possibility, the below figure (Figure 4.20) shows measurements of stressed schwa at 5% and 50% into the vowel indicated by their preceding consonants.

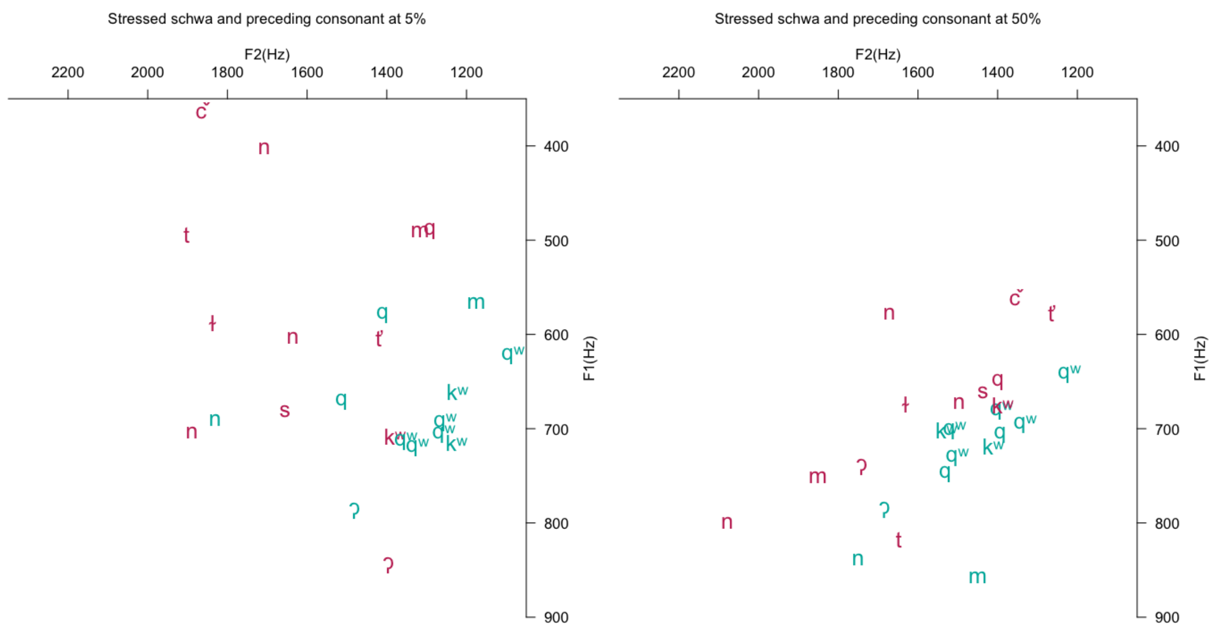

Figure 4.20: Stressed schwa and preceding consonant at 5% and 50%

Figure 4.20 shows that stressed schwa will be more likely to be perceived as [a] when preceded by a uvular, labio-velar, or glottal consonant. The group heard as [a] and preceded by glottal stops and labialized velars and uvulars is consistent from 5% to 50%, with an average F1 of ~700 Hz, and an F2 which shifts forward from ~1300 Hz to 1500 Hz. Vowels following plain uvulars have a lower F1 at 5%, around 500 - 600 Hz, but this increases to ~700 Hz by 50%, while F2 remains unchanged, between 1200 and 1400 Hz. The preservatory effects of preceding uvulars do not necessarily correspond with a change in perception though, as /q/ precedes stressed schwas heard as both [a] and [ʌ].

Coronals (alveolars and palatals) have strong effects at 5%, dramatically fronting and raising stressed schwas to above 1600 Hz for F2 and 500 Hz for F1, but only the raising effects are persistent to 50%. This peripheralness of coarticulatory effects is also seen with anticipatory effects of following consonants, seen in Figure 4.21.

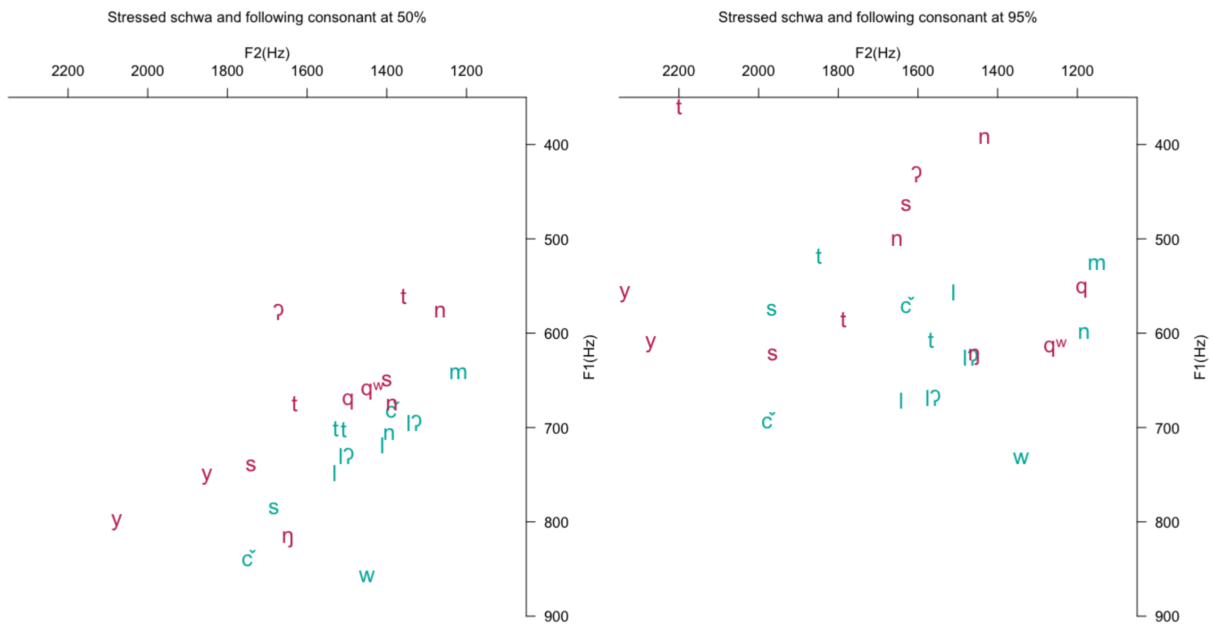

Figure 4.21: Stressed schwa and following consonant at 50% and 95%

The large diffusion (primarily along F2) of the stressed schwas at the 95% mark (on the right), relative to the more compact grouping at the 50% mark (on the left), suggests that the effects of the following consonants seen here is limited to the edge of the vowel. This, however, does not seem to be the case with alveolar and palatal consonants, which pull F2 forward at 50%, and then both F1 and F2 up and forward at 95%, the opposite from their preservatory effects (which remained raised but not fronted). Unfortunately for comparison with preceding consonants, there is only one instance each of stressed schwa preceding a glottal, uvular, or labialized uvular stop. The glottal stop lowers F1 at both 50% and 95% relative to the main group, around 100 Hz at

50% to 200 Hz at 95%. Both the uvular stops retract and raise F1 and F2 slightly from 50% to 95%, around 200 Hz. With only one token each it is not possible to know how generalizable these effects are. Overall, anticipatory effects on stressed schwa are limited to local effects.

Finally, it is important to note that stressed schwas vary in quality from unstressed schwas (explored in the next subsection). Stressed schwas behave more like the full vowels in the persistent effects neighbouring consonants have on them and in the changes of perception they undergo. Unstressed schwas, comparatively, have more persistent changes from more consonants, and perception is more often affected. With this we see that unstressed schwas (whatever their source) behave differently from stressed schwa (whatever their source), and so from other stressed vowels generally.

4.2.1.5 Effects on unstressed schwa

Similar to stressed schwa, unstressed schwa (N=51) can be considerably influenced by coarticulatory effects. However, whereas for stressed schwa these effects were generally more peripheral, for unstressed schwas the effects are more persistent. Figure 4.22 below gives an overview of the variation seen with unstressed schwa, with the perception of unstressed schwa marked. Unstressed schwa is heard as [ɪ], [ɛ], [ɛw], [ʊ], [o], [ʌ], and [a].

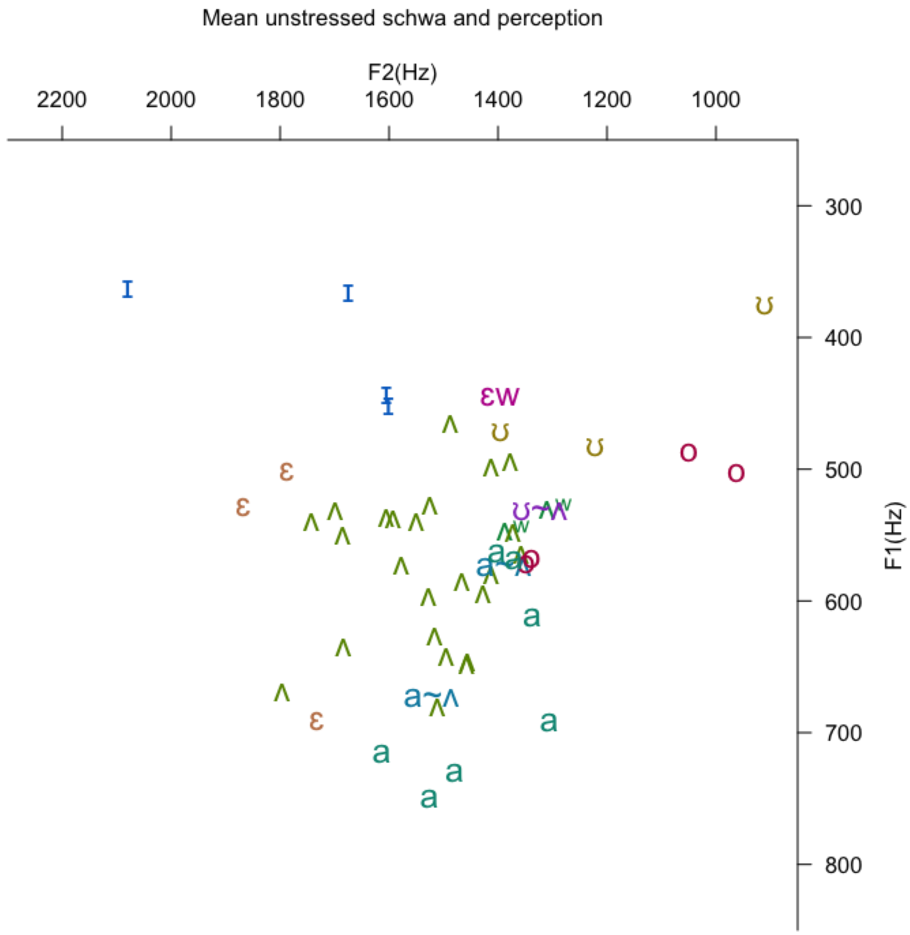

Figure 4.22: Mean measures of unstressed schwa

There are eight main groups of unstressed schwa in Figure 28: the majority heard as [ʌ] (in yellow-green), and seven groups on the peripheries of the vowel space heard as [ɪ] (in dark blue), [ɛ] (in orange), [ʊ] (in yellow), [o] (in red), and [a] (in light blue), as well as one token heard as [ɛw] (in purple-red), two as marginal ([a~ʌ] in blue and [ʊ~ʌ] purple) and two as [ʌ] with secondary labialisation from the following consonant (in green). Influences on each group are explored in the paragraphs below, where, like with the other vowels, data points are marked with the preceding/following consonant and coloured according to their perception.

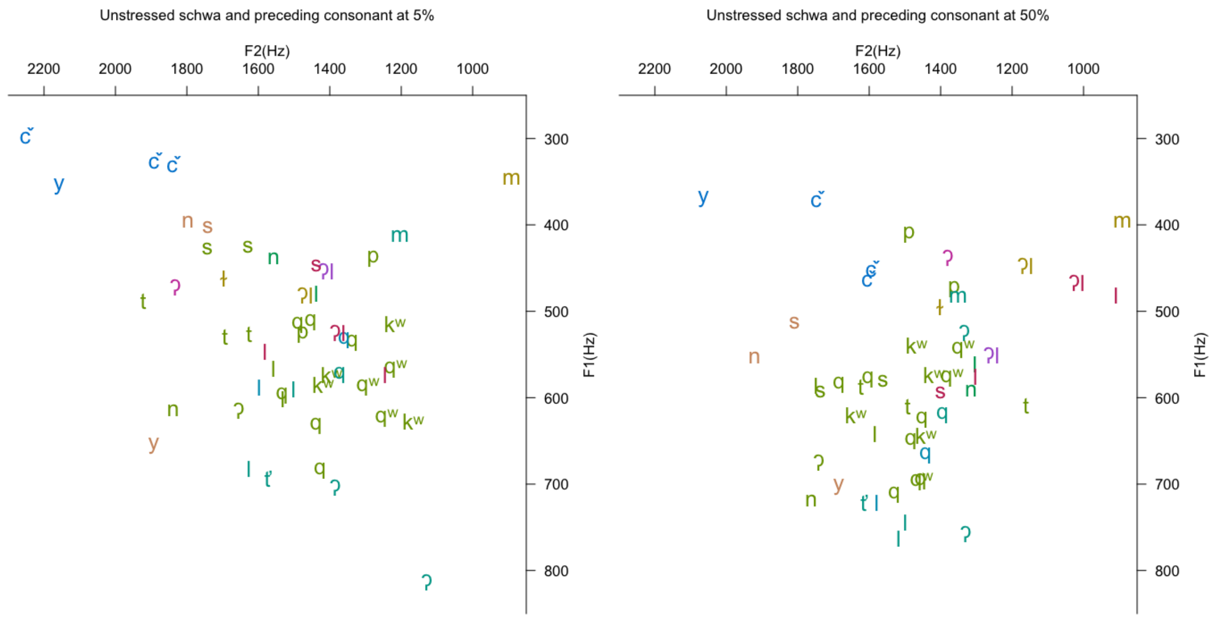

Figure 4.23: Unstressed schwa and preceding consonant at 5% and 50%

In Figure 4.23 the most consistent effect of preceding consonants is that of palatals. At 5% unstressed schwas with preservatory palatal consonant effects have F1 measurements of ~300 Hz and F2 measurements between 1800 and 2200 Hz. They centralise by 50% but retain their peripheral character, centred around 450 Hz and 1800 Hz. In the main clustering of data points (consisting mostly of those heard as [ʌ] (in yellow-green)), at 5% tokens following uvulars have lower F2 measurements and higher F1 measurements, while those following alveolars have higher F2 measurements and lower F1 measurements. Those following labialized consonants, both velar and uvular, are further back and slightly raised as well. /p/ and glottal stop are likewise not too distinguished, with glottal stop being on the higher F2 edge (to the left of the group, around 1800 Hz), and /p/ being slightly retracted and raised, around 500 Hz F1 and 1200 Hz F2. Generally, aside from the effects of palatals, there are not any persistent, strong preservatory effects with a certain consonant or place of articulation. The variations in perception are thus likely to result from anticipatory effects, detailed in the figure below. Figure 4.24 shows unstressed schwa data points indicated by the following consonant and coloured by their perception.

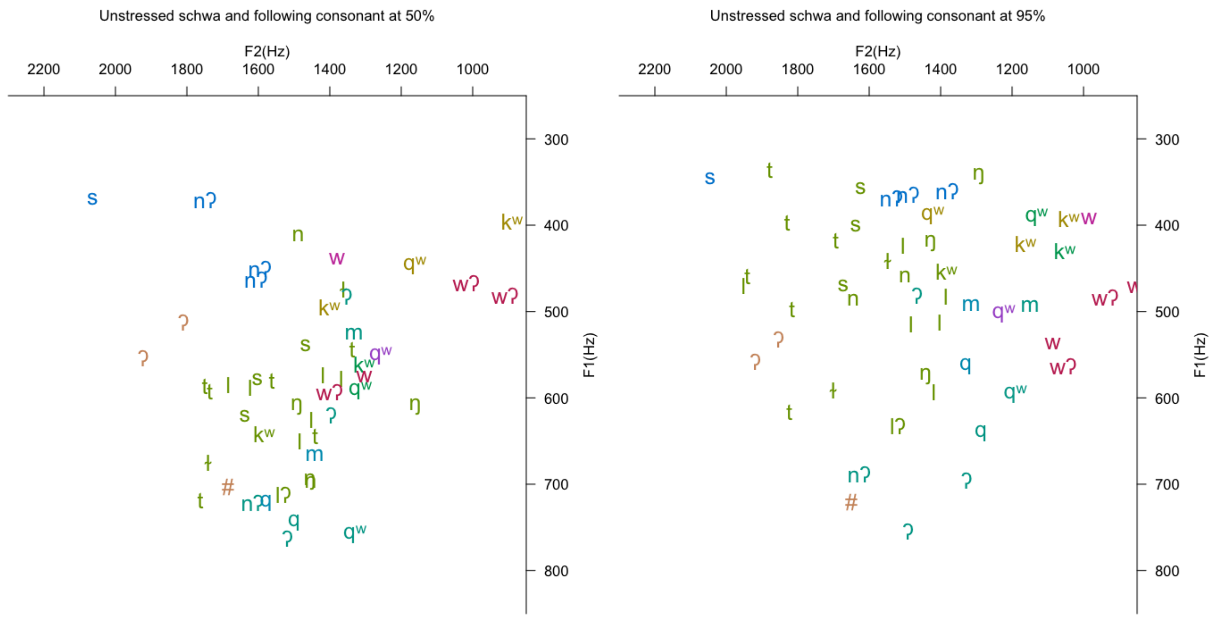

Figure 4.24: Unstressed schwa by following consonant at 50% and 95%

Figure 4.24 shows the effects of following consonants on unstressed schwa quality. For [o], [a], and [ʊ] it is these anticipatory effects which are the most likely to be influencing vowel quality. [ʊ] (indicated in yellow) precedes labialized velar and labialized uvular stops (though not all labialized stops), [o] (in red) precedes /w/, and [a] (in light blue) precedes uvular and glottal stops. At 50% these three allophones have tokens both on the edge of the main grouping of unstressed schwas and on the peripheries, away from the group. By 95% they have all moved away from the main group. Labialized velars and uvulars retract and raise unstressed schwa to 500 Hz F1 and 1200 Hz F2, which then rises further to ~400 Hz at 95%. Uvulars and glottal stops remain stable from 50% to 95% on the bottom of the space of unstressed schwa at ~700

Hz F1 and 1400 Hz F2. The two instances of unstressed schwa preceding glottal stop heard as [ɛ], in orange, between 1800 – 2000 Hz F2 and 550 Hz F1, are actually due to a vowel assimilation effect on schwas across glottal stops, discussed below in Section 4.2.3.1. Unstressed schwa preceding /w/ (heard as [o]) has strong local effects at 95%, retracting from 1400 Hz to 1000 Hz. Other non-persistent localised effects are those of following alveolars, which raise unstressed schwas from 600 Hz / 1600 Hz at 50% to 400 Hz / 1800 Hz at 95%. Additionally, two tokens which precede labialized velar /kʷ/ and labialized uvular /qʷ/ are perceived as [ʌʷ], with the labialisation of the following consonant. Independent of this labialisation, they are already relatively back and raised, being close at 50% to the tokens heard as [ʊ], and by 95% overlap with them.

4.2.1.6 Cross-linguistic comparison and brief summary

Compared to vowels cross-linguistically, the mean F2 of front vowels (/i/ and /e/) from Sophie Misheal's speech is low and the mean F1 of schwa is low. Figure 4.25 below shows the mean F1 and F2 measurements for the phonemic vowels of American English (gold), Modern Hebrew (green), Korean (blue), and Lekwungen (purple). Data points are marked by their vowel. The Lekwungen data comes from this thesis, while the data on the other languages comes from Kent and Read (2002). They aggregate the results of eight studies of adult female American English speakers (Peterson & Barney, 1952; Childers & Wu, 1991; Zahorian & Jagharagh, 1993; Hagiwara, 1995; Hillenbrand, Getty, Clark, & Wheeler, 1995; Yang, 1996; Lee, Potamianos, & Narayanan, 1999; and Assmann & Katz, 2000) and cite Aronson, Rosenhouse, Rosenhouse, & Podoshin (1996) and Yang (1996) on adult female Hebrew and Korean, respectively.

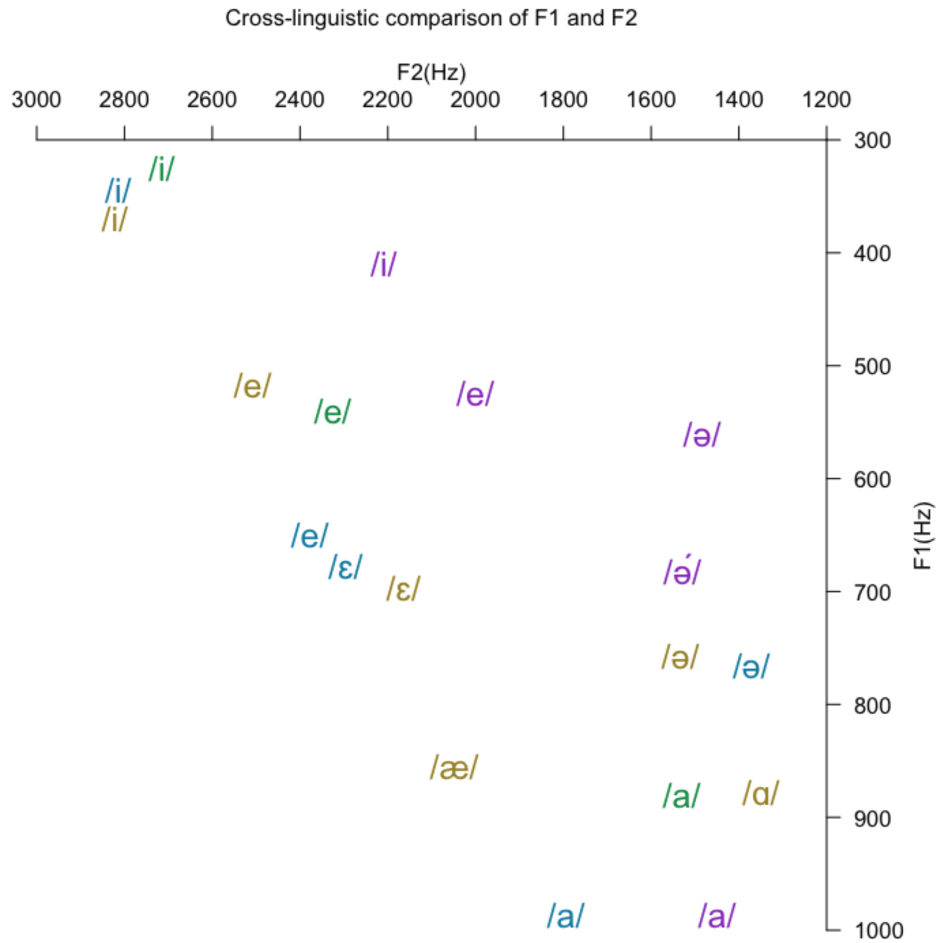

Figure 4.25: Cross-linguistic comparison of F1 and F2 of mean Lekwungen vowels

For American English the mean F1 of /i/ is 369 Hz, and the mean F2 is 2822 Hz. For Hebrew, Aronson et al. found a mean F1 of 325 Hz and a mean F2 of 2715 Hz, while for Korean, Yang found a mean F1 of 344 Hz and an F2 of 2814 Hz. The mean F1 for Lekwungen is 409 Hz, and the F2 is 2208 Hz. Lekwungen mean /i/ is 50 to 80 Hz higher for F1 and 500 to 600 Hz lower for F2 than American English, Hebrew, or Korean. /e/ is not particularly lower or higher for F1: mean F1s were 517 Hz, 540 Hz, and 650 Hz for American English, Hebrew, and Korean, respectively, while the mean for Lekwungen /e/ was 524 Hz. Like /i/ though, F2 is lower on average in Lekwungen than in these other languages, closer in fact to /ɛ/ in American English and Korean. Mean F2s of American English, Hebrew, and Korean /e/ are 2507 Hz, 2325 Hz, and 2377 Hz, while for Lekwungen mean F2 is 2000 Hz. Compare this to mean F2 of /ɛ/ in American English and Korean, which are 2153 Hz and 2285 Hz respectively. Lekwungen mean /e/ is thus further retracted than in these other languages. /a/ has a lower F1 than American English, Hebrew, and Korean. Kent & Read report that for adult female speakers of these languages mean F1s are 866 Hz, 880 Hz, and 986 Hz respectively. Lekwungen mean F1 is 667 Hz. Lekwungen mean F2 isn't greatly different however. Mean F2s are 2048/1349 Hz (/ɑ/ and /æ/), 1530 Hz and 1794 Hz for the three languages, while Lekwungen mean F2 is 1449 Hz. Finally, schwa is slightly higher in Lekwungen, with American English schwa having an average F1 of 757 Hz and Korean schwa of 765 Hz, and American English having a mean F2 of 1533 Hz and Korean of 1371 Hz. Lekwungen mean stressed schwa F1 is 677 Hz and mean F2 is 1543 Hz.

Overall, different vowels have different coarticulatory effects from different consonants, and these can differ in directionality (anticipatory vs. preservatory) and persistence. /i/ does not have strong persistent effects with any consonant, though it is perceptibly affected by following uvular consonants. /e/ has perceptible persistent anticipatory effects from uvular and glottal stops, and /a/ has perceptible persistent preservatory effects from uvular and glottal stops. /a/ also has persistent preservatory and anticipatory effects from alveolars and palatals (which are strong) and labio-velars (which are relatively weak), but these are not perceptible. Stressed schwas are persistently affected by all consonant types in both anticipatory and preservatory contexts (palatals, labio-velars, and glottals in anticipatory contexts; alveolars, palatals, and uvulars in preservatory contexts), but only uvulars and glottals have perceptible effects. Unstressed schwas are affected even more than stressed schwas, and have the greatest number of persistent and perceptible effects of all vowels. They are persistently affected by all consonants in both contexts, though perceptible effects are more numerous in the anticipatory context.

4.2.2 Effects on F3

Overall, there are relatively distinct effects on F1 and F2 by neighbouring consonants, which are fairly consistent across vowels. This is only partly the case, however, for F3. Effects on F3 are characterized by a mix of weak and strong peripheral and persistent effects on F3 from neighbouring consonants, and by a great volatility in these effects, with a range of possible magnitudes for a given consonant-vowel sequence. Because of this volatility, a distinct pattern is difficult to discern for the effects of certain consonants and on vowels. Categorized by preceding consonant, F3 measures have little change from 5% to 50% into the vowel. Conversely, there is considerably more change in F3 measurements from the mean 50% to 95% into the vowel when categorized by following consonant. Mean F3 measurements are also relatively consistent across all five vowels, though a pattern does emerge.

Front vowels /i/ and /e/ have higher mean F3 measurements than central vowels /a/ and /ə/ (both stressed and unstressed). Mean F3 (from the averaged 90% of the vowel) of /i/ is 2693 Hz, of /e/ 2657 Hz, of /a/ 2552 Hz, of stressed schwa 2541 Hz, and of unstressed schwa 2568 Hz. Seen in Figure 4.26, these numbers are low when compared to F3 measurements of the same vowels cross-linguistically, though a pattern of higher F3 measures for front vowels vs. vowels further back is the same. Like with

Figure 4.25, American English is in gold, Modern Hebrew in green, Korean in blue, and Lekwungen in purple.

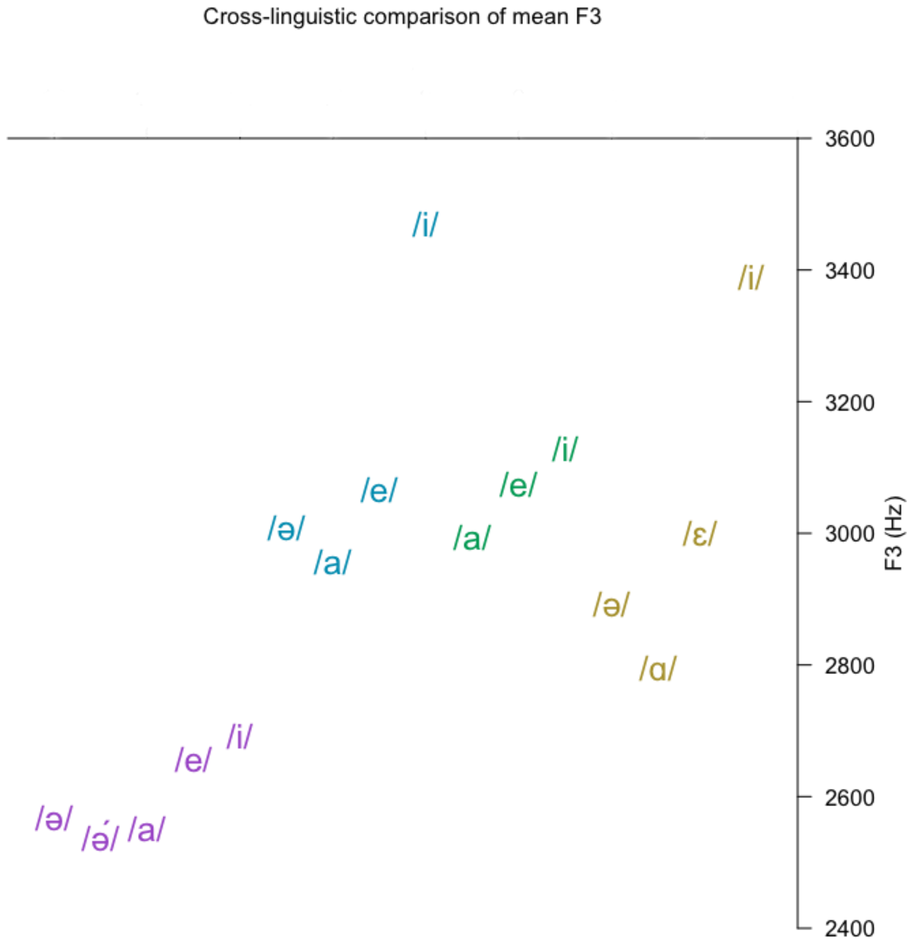

Figure 4.26: Cross-linguistic comparison of mean F3 of Lekwungen vowels

The same pattern in Lekwungen is also found for the other languages, with mean F3 being higher for front vowels (/i/, /e/, /ɛ/) than for back vowels (/a/, /ɑ/, /ə/). Additionally, mean /i/ of American English and Korean is considerably higher (3389 Hz and 3471 Hz, respectively) than mean /i/ of Modern Hebrew (3130 Hz) and Lekwungen (2693 Hz); and overall Lekwungen F3 values are lower for all vowels compared to the other three languages, between 2400 and 2800 Hz, as compared to 2800 to 3200/3400 Hz.

Figure 4.27 shows F3 measures for eight preceding consonants (/t/, /t̓/, /q/, /p/, /ʔ/, /y/, /w/, and /č/, excluding /kʷ/ and /qʷ/, dealt with separately), at the 5% and 50% time points, (on the chart the y-axis is frequency and the x-axis is blank, labels are arranged alphabetically and indicated by the preceding consonant and the vowel).

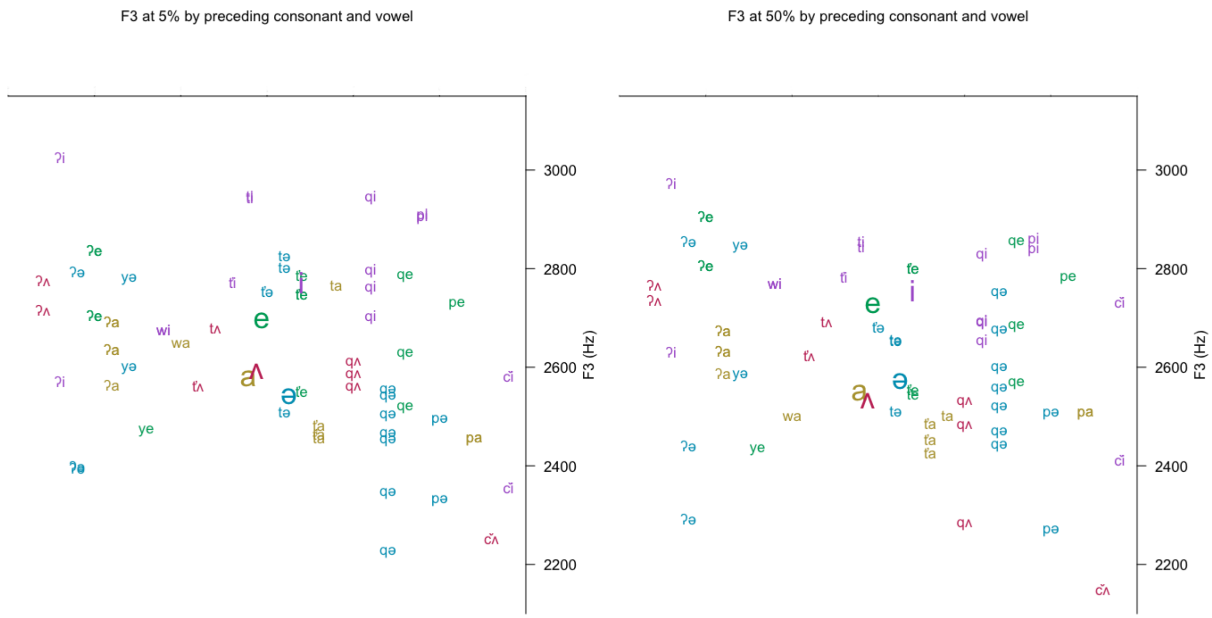

Figure 4.27: Average F3 measures at 5% and 50% by preceding consonant

There are a variety of preservatory effects, and a given consonant does not affect every vowel in the same manner. /č/ persistently lowers F3 of /i/ and stressed schwa (note the /čV/ tokens on the right of the plots, and how they are lower down at both 5% and 50% than either the /pV/ or the vowel means). /q/ persistently lowers F3 of /i/ and /e/ around 200 Hz, persistently raises F3 of unstressed schwa, though only around 100 Hz, and leaves stressed schwa relatively unchanged from mean. /t/ peripherally raises F3 of unstressed schwa 300 Hz, and does not strongly affect /i/, /e/, /a/, or stressed schwa. /w/

peripherally lowers F3 of /i/ and peripherally raises F3 of /a/ 200 Hz each, and /y/ persistently lowers F3 of /e/ and raises F3 of unstressed schwa 250 to 300 Hz each. Glottal stop does not affect /i/ or /e/, but does persistently raise F3 of /a/, stressed schwa, and unstressed schwa by 100 to 400 Hz.

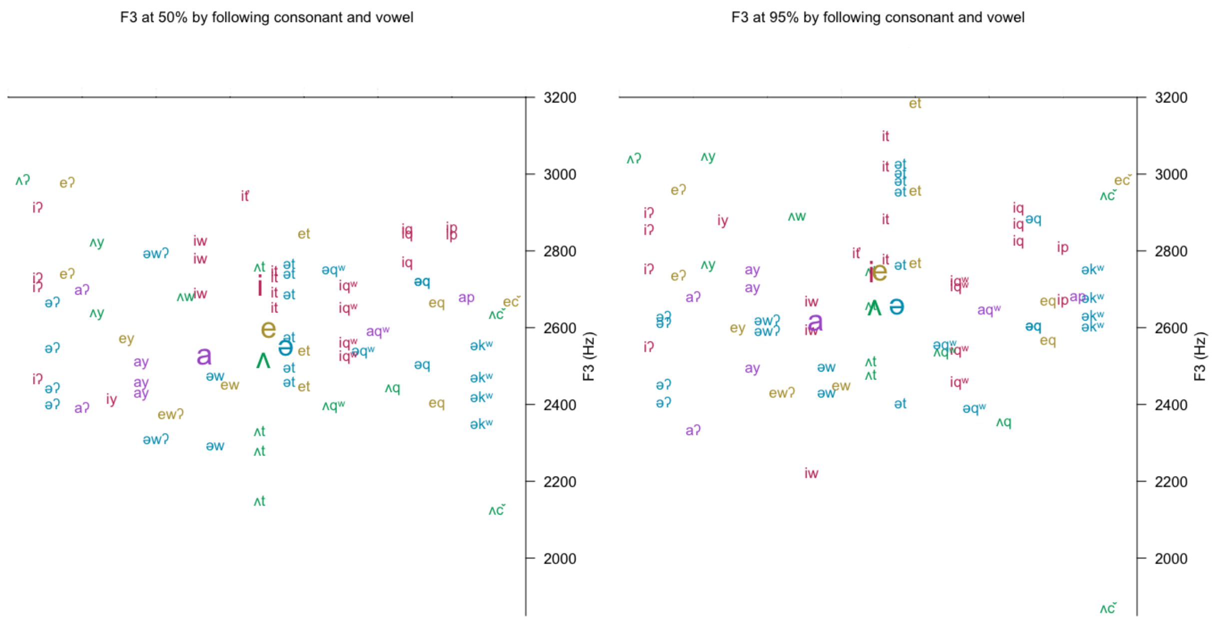

Figure 4.28: Average F3 measures at 50% and 95% by following consonant

The same variety is found in anticipatory effects (Figure 4.28): /č/ peripherally raises F3 of /e/ 200 Hz, but /y/ peripherally lowers F3 around the same amount. However, as there is only one token for each instance, how representative these two are is unknown. /č/ also has two diverging effects on stressed schwa: persistently raising and lowering it. Labio-velars /kʷ/ and /w/ do not greatly affect F3 of unstressed schwa, and /w/ (and /ẇ/) persistently lowers F3 of /e/ and raises F3 of stressed schwa by 200 Hz, and peripherally lowers F3 of /i/, also by 200 Hz. /q/ does not greatly affect /i/ and unstressed schwa, but does peripherally lower F3 of /e/ and stressed schwa by 150 to 200 Hz; while /qʷ/ persistently lowers /i/, /a/, and stressed schwa 100 to 200 Hz, and peripherally lowers unstressed schwa. /t/ peripherally raises /e/, and persistently raises unstressed schwa, both 200 to 400 Hz, but persistently lowers stressed schwa around 200 Hz. /i/ is slightly peripherally raised. Glottal stop slightly lowers /i/, peripherally raises /e/ 150 Hz and lowers /a/ 400 Hz and unstressed schwa 150 Hz, and persistently raises stressed schwa 500 Hz.

Generally, there are a range of F3 effects on different vowels, with F3 being affected differently in different vowels by the same consonant (in contrast to the general pattern of F1 and F2 effects of consonants), and in certain cases conflicting effects on F3 in the same vowel by the same consonant. These differences are present in both anticipatory and preservatory contexts.

Preceding /k^w/ and /q^w/ are presented separate from the other F3 findings in order to highlight possible differences between the two types of labialized consonants. However, Figure 4.29 shows that F3s of vowels following these two consonants show a similar spread of measurements and ascertaining a clear pattern is difficult. On average, labialized uvulars seem to cause more persistent preservatory effects on F3 than labialized velars: average F3 of stressed schwa and /i/ are higher for vowels following /q^w/ at 5% than for vowels following /k^w/, but lower for /e/ and (possibly) /a/. By 50% vowels following /k^w/ have risen more from 5% than those following /q^w/, suggesting that the lowering effects of /q^w/ are more persistent.

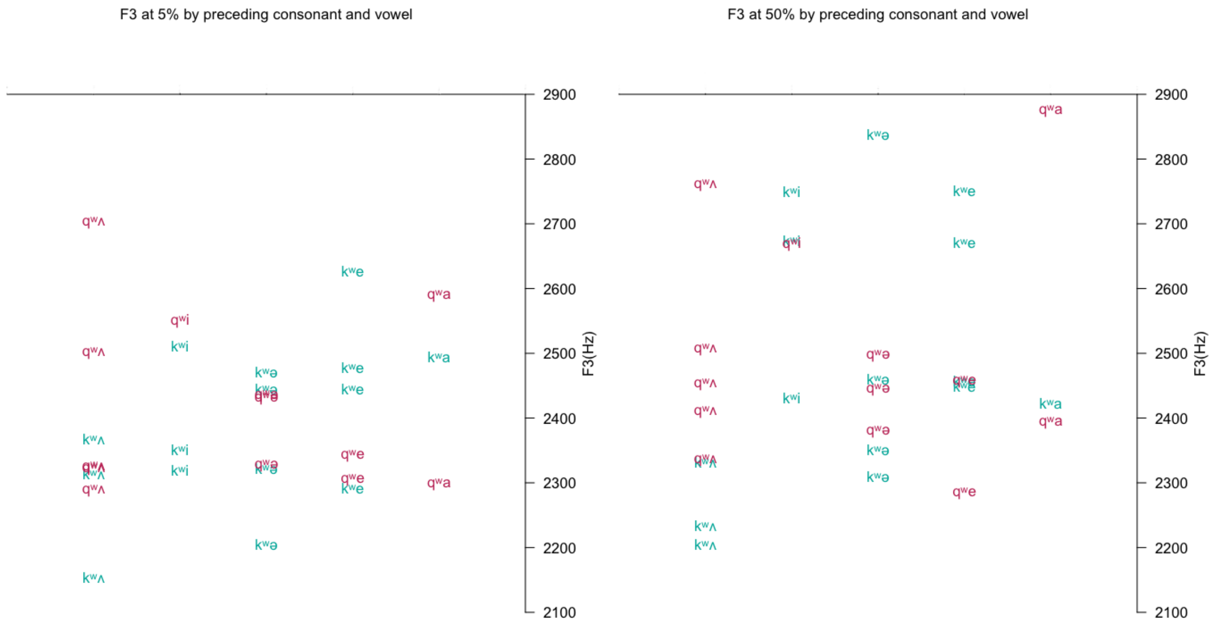

Figure 4.29: F3 measures of vowels at 5% and 50% by preceding labialized consonant

At 5% stressed schwas following /qʷ/ average around 2500 Hz, while those following /kʷ/ average around 2325 Hz. Similarly, for /i/, those following /qʷ/ average around 2550 Hz, those following /kʷ/, around 2400 Hz. Conversely, for /e/, those following /qʷ/ are lower, around 2350 Hz, while those following /kʷ/ are around 2500 Hz. /a/ following /qʷ/ has a wide spread, both at 2600 Hz and at 2300 Hz, while /a/ following /kʷ/ is at 2500 Hz. Unstressed schwas are similar, but with those following /kʷ/ having the spread at 2250 Hz and at 2500 Hz, while those following /qʷ/ are at 2400 Hz.

Changes at 50% are more less for /qʷ/ than for /kʷ/, implying more persistent effects of /qʷ/ than /kʷ/. Stressed schwa following /qʷ/ is still around 2500 Hz (with the same 500 Hz range), /i/ has risen 100 Hz, unstressed schwa around has risen 50 Hz, /e/ on average is unchanged but has a greater spread and remains divided, with one token unchanged and another rising dramatically. Following /kʷ/, stressed schwa has lowered around 100 Hz, /i/ has raised around 200 Hz, unstressed schwa is unchanged (though with one token at 2850 Hz), /e/ has risen around 100 Hz on average, and /a/ has dropped 100 Hz.

As for /qʷ/ vs. /kʷ/ at 5% vs. 50%, /i/ is higher following /qʷ/ at 5%, stressed schwa is higher at both time points, unstressed schwa is even at both time points, /e/ is lowering at both time points, and /a/ is higher at 50%.

Overall, there are a range of consonantal coarticulatory effects on F3, either preservatory or anticipatory, in the data analysed. A consonant can have different effects (i.e., lowering or raising F3) on different vowels, or even different tokens of the same vowel. The patterns that different consonants produce across vowels are discussed in Chapter 5, where we see that, despite the greater variability in a consonant's effects on F3 compared to its effects on F1 or F2, general patterns do emerge.

4.2.3 Other effects of consonants

This section briefly reports on two effects described in the literature reviewed in Chapter 2 and found in data collection and analysis: vowel quality assimilation of unstressed schwa across glottal stops, and timing of secondary labialisation.

4.2.3.1 Vowel quality assimilation of unstressed schwa

Firstly, seven instances of unstressed schwas (nearly) assimilating to the quality of a full vowel have been found[25]. In six of the cases, unstressed schwa was pronounced with similar quality to an /e/ which preceded (in three cases) or followed it (in three cases), separated by a glottal stop: /nəʔétəŋ/ [nɛʔétəŋ], 'to name someone', /səʔétəŋ/ [sɛʔétəŋ], 'to tell someone', /sƛ̓əʔéšən/ [sƛ̓ɛʔéšən], 'a feast', /sx̣éʔəs/ [sx̣éʔɛs], 'bad', /šč̓əc̓éʔəŋ̓/ [šč̓əc̓éʔɛŋ̓], 'corner', /qʷəléʔəl kʷə/ [qʷəléʔɛl kʷə] 'to send a message'.

[25] This effect was first noted late in the data collection process, so the numbers given here may not represent actual frequency in the corpus.

Another case was found which involved schwa assimilating to /a/ which preceded it: /ƛ̓áʔəs/ [ƛ̓áʔas], ‘meet’. A similar effect was described by Bird, Czaykowska-Higgins, & Leonard (2012) in SENĆOŦEN and by Montler (1998) in Klallam. Figure 4.30 below gives an illustrative spectrogram of one of these occurrences. The first vowel is an unstressed schwa (the segment highlighted in yellow), following the glottal stop is /e/, and the unstressed schwa has formants of 520 Hz F1 and 1950 Hz F2, right in the main range of /e/.

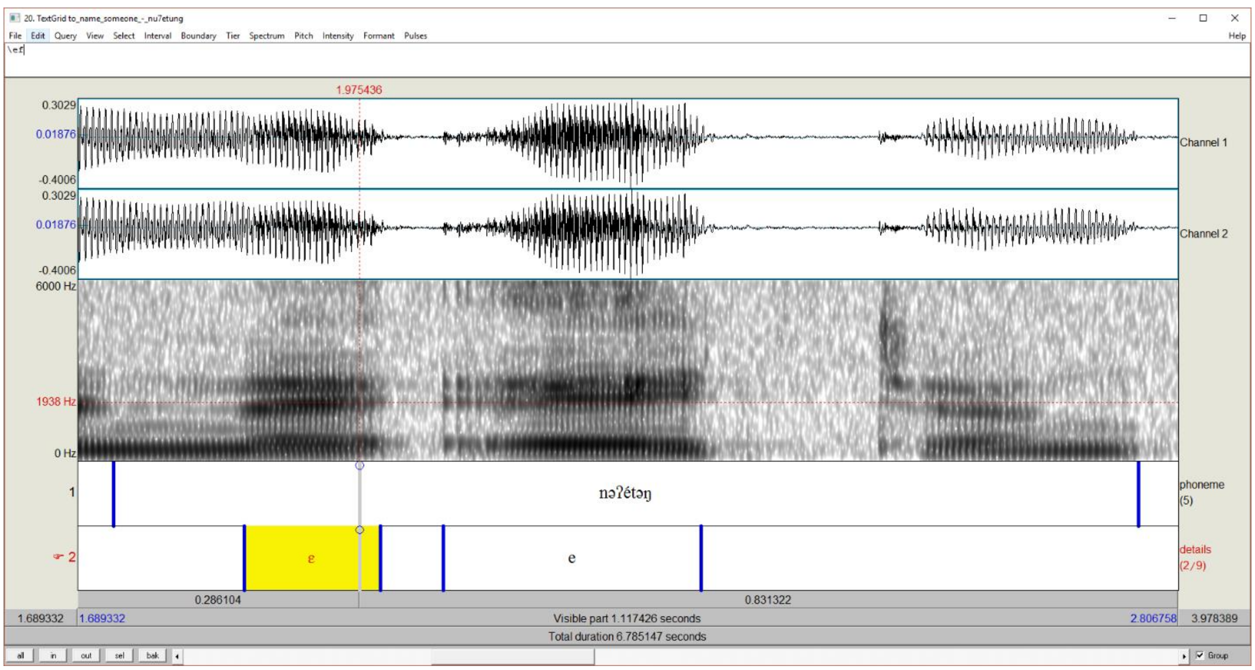

Figure 4.30: Quality assimilation of unstressed schwa across a glottal stop in *nəʔétəŋ*

In the cases with /e/, the unstressed schwa was perceived as [ɛ] and is acoustically in the range of [ɛ] (so this is not full assimilation), but elicited and recorded by Marjorie Mitchell as schwa. The same for the case with /a/, where the schwa was perceived as [a]. This has been found five times so far, with /e/ or /a/ as the full vowel. Unstressed schwas followed by syllable-final glottal stops otherwise (that is, when the glottal stop is word-final, part of a glottalized resonant, or followed by a consonant) are perceived as [a].

4.2.3.2 Variability of secondary labialisation timing

Finally, the last part of consonantal coarticulatory effects under investigation is the timing of secondary labialisation from /k^w/ and /q^w/ relative to preceding and following vowels. As discussed in Chapter 2, the labialisation on these sounds may be realized phonetically either after/at stop release or before the stop closure. When preceded and/or followed by a vowel, the nature of this variable timing may be observed. Variation in the timing of labialisation occurs among the speech of speakers of closely-related SENĆOŦEN (Bird, 2016), and so, might be expected in Lekwungen as well.

In Sophie Misheal's careful speech in isolated words analysed for this thesis, there are 14 instances of labialized stops following vowels. In all of these, secondary labialisation is realized after/at the stop release. Figure 4.31 illustrates how this often appears, with the relative stability/flatness of F2 across the schwa before the stop closure, followed by a stop release with burst energy concentrated at the lower frequencies (here under 1440 Hz):

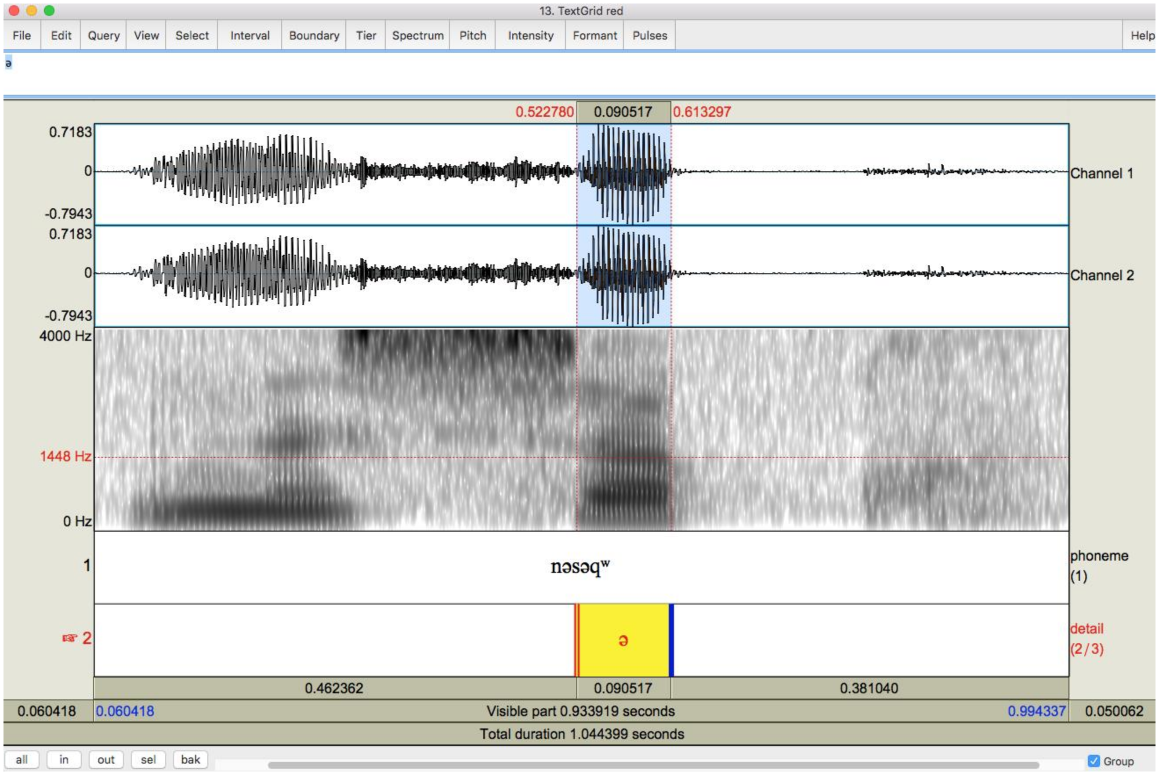

Figure 4.31: Post-stop realisation of secondary labialisation in *nəsə́qʷ*

Of the 14 tokens analyzed so far however, six have lowering of F2 at the end of the vowel preceding the labialized consonant, as well as lowering of F2 on the following vowel, or (if no vowel follows) just burst/release energy concentrated at a lower frequency than plain stops, all characteristic of labialisation. Figure 4.32 shows an unstressed schwa featuring a drop in F2 over the latter part of the vowel, which is characteristic of the realisation of labialisation before the stop closure.

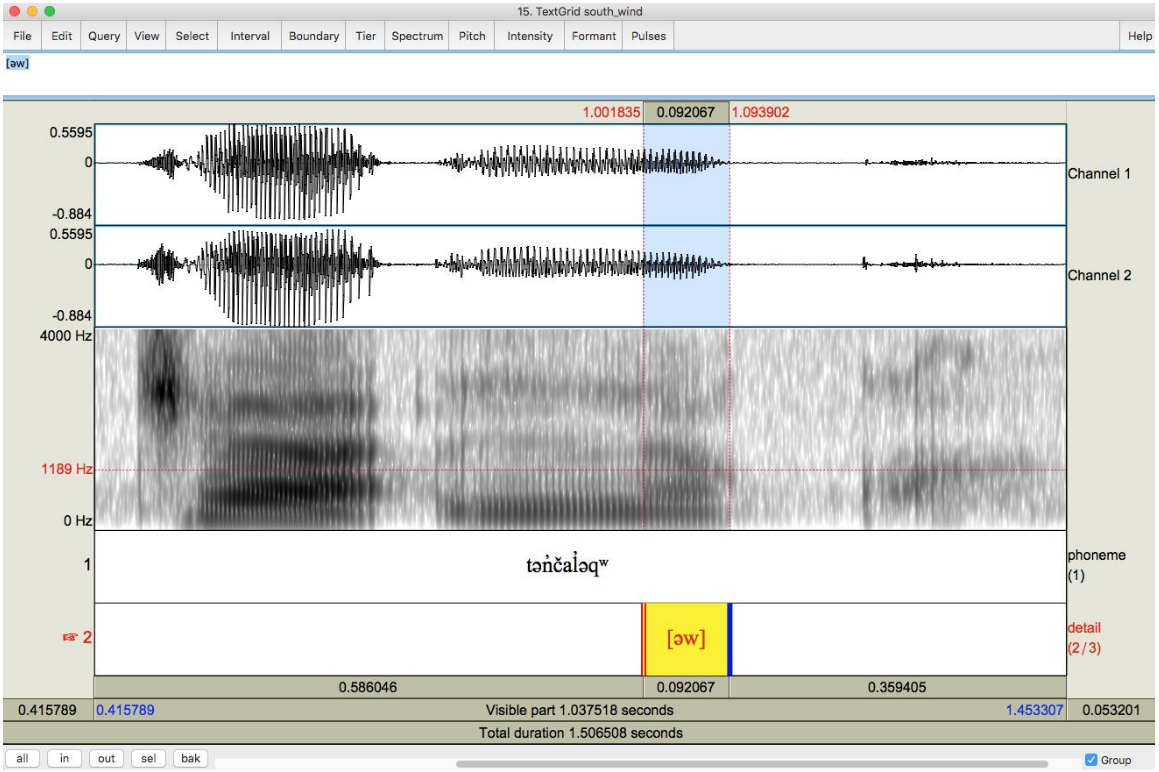

Figure 4.32: Pre-stop realisation of secondary labialisation in *tən̓čál̓əqʷ*

So far this has been found in schwas (as seen here) and in close vowel /i/. The total count is:

Pre-stop (and post-stop)	Post-stop only
6	8

Table 4.1: Labialisation timing (including unstressed schwas)

Overall, secondary labialisation seems to always be realized at or after the stop release in Sophie Misheal's speech, at least in her careful speech when producing isolated words, but sometimes it is also realized before the closure, on the latter part of the preceding vowel.

4.3 Summary

Chapter 4 has presented the results of data collection and analysis. Word-level seems to correlate in Lekwungen with longer duration, higher pitch, and greater intensity of stressed vowels. Stressed schwas in Lekwungen also behave differently than the other vowel categories in this regard, being closer to unstressed schwas in duration, but similar to full vowels in pitch and intensity. Additionally, stressed schwas are distinct from the other vowel categories in that consonants following them are lengthened. For most vowels in isolated words in Lekwungen, consonant coarticulatory effects are peripheral, limited to the temporal edges of vowels. Effects which are persistent include:

- palatalised consonants have a raising and fronting effect when preceding and following stressed and unstressed schwa and /a/
- labio-velar consonants have a backing and raising effect following unstressed schwa, a backing effect preceding /i/ and a raising effect preceding /e/
- uvular consonants have a lowering effect preceding and following stressed and unstressed schwa, and a backing effect following /e/
- glottal consonants have a backing effect following /e/ and a lowering effect preceding stressed schwa and preceding and following unstressed schwa
- unstressed schwas separated from a full vowel by a glottal stop (nearly) assimilate in quality to the full vowel
- labialisation is realized as a [w] (a lowering of F1 and F2) on the following vowel, and sometimes labialisation on a word-final consonant is realized as a [w] on the preceding vowel

Importantly, not all cases of a change in perception were accompanied by a persistent effect on vowel quality (chiefly /i/ with uvulars and /a/ with glottals). Chapter

5 will address the findings further, discussing them in relation to overall effects of consonants on all vowels, the literature discussed in Chapter 2, and the goals of the thesis.

Chapter 5

Discussion

This chapter discusses the results presented in Chapter 4, and how they pertain to the hypotheses laid out in Chapter 2, and to the overall goals of the thesis. Following the structure laid out in previous chapters, I first discuss correlates of stress and then discuss the different consonantal coarticulatory effects, moving from consonant to consonant. At the end of each section I also provide a summary of the overall effects discussed and what they mean for writing/learning Lekwungen, if a phonemic orthography is chosen. The table below lays out the predictions made in Section 2.6 and whether or not they were supported by the results. As you can see, the results presented in Chapter 4 confirmed almost all of the predictions made:

Environment	Prediction of vowel quality effects?	Prediction supported by results?
Stress	Duration, pitch, and amplitude will be correlated with stress in Lekwungen	Yes
Palatals and Labio-velars	Lekwungen /ə/ will exhibit persistent effects of palatal and labio-velar consonants	Yes
Uvular consonants	Lekwungen vowels will exhibit persistent backing/lowering effects of uvular consonants	Partly: yes for /e/ and /ə/
Glottal consonants	Lekwungen vowels will exhibit persistent lowering effects of glottal consonants	Partly: yes for /e/ and /ə/
Ejective consonants	Lekwungen vowels will **not** exhibit persistent place-independent effects of ejective consonants	Partly: yes for full vowels, possibly no for unstressed /ə/

Table 5.1: Confirmation of predictions

5.1 Correlates of Stress

The results related to stress effects are fairly straightforward given what the literature had to say, and in implications for what we know about Lekwungen. Like in the results section, this section will go over duration, pitch, and amplitude.

The hypothesis predicted that duration would be longer in stressed vowels than in unstressed vowels. This is proven correct by the results: stressed vowels are indeed longer in duration than unstressed vowels in Lekwungen; however, they exhibit an interesting pattern, described here. Lekwungen has a three-way distinction of length between full vowels, stressed schwas, and unstressed vowels (as schwas), a finding which is similar to a pattern Tamburri-Watt et al. (2000) found for Sḵwx̱wú7mesh and Barthmaier (1998) found for Lushootseed (two languages without unstressed vowel reduction to schwa), and the same as Leonard (2007) found for SENĆOŦEN, but different from what Montler (1998) found for Klallam (two languages with unstressed vowel reduction to schwa). For Lekwungen, stressed full vowels are on average 190 ms, stressed schwas 124 ms, and unstressed schwas 98 ms. This patterning of duration matches the type of distinction made in Salish linguistics more generally, between full vowels and schwas. In this thesis, as in the literature, full vowels have considerably longer duration when stressed than schwas do, reflecting their different phonological and phonetic behaviour (Czaykowska-Higgins & Kinkade, 1998).

A novel factor in duration that wasn't predicted in the hypothesis is consonant lengthening following stressed schwas. This appears to affect all main categories of consonants (stops, fricatives, affricates, and resonants). Data for affricates is minimal, only three tokens have been found, but the pattern seems to be reflected there as well; for fricatives lengthening is minimal, and while tokens exist for all vowel categories, the number of tokens are low. This low token count is not due to an overall lack of tokens in the recordings available, but rather to the fact that this phenomenon was discovered after data collection had already begun. The project was not set up around collecting an equal number of consonant types to study their lengthening effects, so the numbers of tokens given here reflect the number that were incidentally collected through the data collection process. As such, token counts are variable. Stops and resonants, however, do have numerous tokens each, and the pattern is robust. This consonant lengthening is not a feature attested to in SENĆOŦEN, but is similar to a pattern in ʔayʔaǰuθəm (Blake, 2000), where consonants geminate after stressed schwas. First observed in the Lekwungen language workshops, it was thought that this would only be seen for consonants following stressed schwas and preceding an unstressed schwa (e.g., *ʔə́**s**ə*, ‘I’). In fact, it appears that consonants following stressed schwas lengthen whether they are intervocalic or word-final (e.g., *čɬə́**t***).

Overall the pattern for consonants in this environment appears to be fairly clear: following stressed schwas, consonants lengthen.   It is possible that this due to the style of speech. The fact that data is taken from isolated words and the fact that the words are spoken in isolated speech, as hyperforms (Lindblom, 1990), suggests that they could be showing an important fact about the nature of consonants in this environment. Perhaps they show a compensatory lengthening related to the syllable weight, but that in normal speech this would not occur (as they are privileging information over economy, whereas in normal speech economizing constraints might be more constraining). A study of consonant duration in similar environments in more naturalistic (e.g. from storytelling) speech would be needed to confirm if this is a feature that a Lekwungen speaker would use normally. In any case, this feature has not been observed for SENĆOŦEN, and most phonetic studies of SENĆOŦEN are of elicited forms as well. If lengthening were an underlying effect common to both languages that was just appearing here due to elicitation type, we would expect it in SENĆOŦEN too. That it hasn't been attested to lends support to the notion that this could be a unique Lekwungen phenomenon.

Finally, the hypothesis for the remaining two acoustic correlates of stress is also supported: pitch and amplitude are higher and greater in stressed vowels than in unstressed vowels. The pattern however is different than that for duration: here stressed full vowels and stressed schwas pattern together, versus the unstressed schwas, a two-way pattern different from the three-way pattern for duration. Average pitch for stressed full vowels and stressed schwas was 199 Hz and 201 Hz respectively, near equal. Average pitch for unstressed schwas was 152 Hz. The pattern was the same for amplitude: stressed full vowels and schwas had average amplitudes of 82 dB and 80 dB, and unstressed schwa 74 dB.

Overall, correlates of stress were as predicted, though patterns differed for vowel categories depending on the acoustic correlate. Stressed vowels are longer, they have a higher pitch, and they are relatively louder than unstressed vowels. Additionally, stressed schwas are longer than unstressed schwas, but shorter than stressed full vowels. It is important to note that these findings are for word-level stress (and presumably phrasal stress), not sentence-level stress patterns. Further study will be needed to investigate the correlates of stress beyond the word level.

Implications for writing/learning stress and vowels

For writing/learning Lekwungen, stress correlates should prove relatively unproblematic for English speakers. The correlates of stress in English are the same: stressed vowels are longer in duration, higher in pitch, and greater in intensity (Sluijter & van Heuven, 1996). It may suffice to simply note that stress in Lekwungen can be realized the same as in English. Stress correlates can also serve as a useful tool for determining the underlying character of a vowel when encountering an ambiguous-sounding stressed vowel in Lekwungen. As stressed schwas may often sound like [a] to English speakers, because of lowering effects of /ʔ/ and uvulars (see below for more on this), the length of the vowel could prove the deciding factor in determining whether or not to teach/learn/write it as schwa or /a/. The actual length of the vowel in question will vary with speech style, but a clue can lie with comparing the vowel in question to the surrounding vowels: if it is as long as or near equal to the surrounding full vowels, it is likely /a/; if it is shorter than full vowels but longer than unstressed schwas, it's likely a stressed schwa. This is doubly important because the other correlates of stress investigated in this thesis did not show this pattern in regards to stressed full vowels vs. schwa: for amplitude and pitch, stressed full vowels and stressed schwas were nigh indistinguishable. In addition, another clue to the underlying vowel is that consonants are likely to be long after stressed schwas. If this turns out to be a feature of naturalistic speech, learners and teachers will need to be made aware of it, and possible consequences for writing will need to be discussed.

Before moving on to coarticulatory effects, I briefly discuss some phonological aspects of Salishan schwas, in order to situate the results of stress just presented and consonant coarticulatory effects coming up next, as they pertain to full vowels vs.

stressed schwas vs. unstressed schwas. Kinkade (1993, 1998) details four sources of schwas in Salishan languages: epenthesis, excrescence, vowel reduction, or segment derivation. Epenthetic schwas can bear stress and are phonologically inserted. In this thesis these could be the schwas considered as 'stressed' (along with underlying schwas, though distinguishing between the two depends upon analysis). Excrescent schwas are considered not to interact with the phonology and are the result of transitional effects. Schwas from vowel reduction are what remains when a full vowel which would otherwise have taken stress is unstressed in a word (e.g., the first vowel in *c̓éʔkʷət*, 'to wash' vs. *c̓əʔkʷétəŋ* or *c̓əkʷəlkʷə́təŋ*, 'to be washed'). In SENĆOŦEN (Leonard, 2007) and Lekwungen these vowels can also simply delete (e.g., *c̓íq̓ʷət*, 'to stab' vs. *c̓q̓ʷítəŋ*, 'to be stabbed'). Schwas from excrescence and vowel reduction, along with unstressed epenthetic and underlying schwas, would be the 'unstressed schwas' in this thesis. The final category of segment derivational schwas are found only in Interior Salish languages, and so are not relevant to Lekwungen.

The results of this thesis could be of relevance for phonological accounts of schwa in North Straits Salish and Central Salish languages then, as they contribute acoustic evidence to the possible phonological distinctions between the different types of schwas discussed above, both in general and in a language not previously analysed. This thesis found that the stressed schwas behaved differently in terms of acoustic correlates of stress and consonant coarticulatory effects on vowel quality from stressed full vowels and unstressed schwas. Section 5.2 presents these consonant coarticulatory results.

5.2 Consonant coarticulatory effects

Along with acoustic correlates of stress, this thesis also sought to determine what acoustic effects consonants had on vowels. Whereas the results for stress were straightforward in terms of predicted results and patterns in the data, the results for consonant coarticulatory effects are more complex.

At the end of Chapter 2, I made predictions on the effects likely to be found, summarized in Table 5.2 (see also Table 5.1):

Environment	Prediction of vowel quality effects?
Palatals and Labio-velars	Lekwungen /ə/ will exhibit persistent effects of palatal and labio-velar consonants
Uvular consonants	Lekwungen vowels will exhibit persistent backing/lowering effects of uvular consonants
Glottal consonants	Lekwungen vowels will exhibit persistent lowering effects of glottal consonants
Ejective consonants	Lekwungen vowels will **not** exhibit persistent place-independent effects of ejective consonants

Table 5.2: Predictions of coarticulatory effects

These hypotheses were partly supported by the results, though they generally underestimated the extent of persistent effects, and not all persistent effects were as predicted. Palatals /č/, and /y/ have more persistent than peripheral effects when both preceding and following vowels, most saliently schwa and /a/. Labio-velars /w/ and /k^w/ are similar to palatals, having strong persistent effects on several vowels, including schwa, /i/, and /e/. Uvulars, both plain and labialized, have persistent effects on preceding /e/ and unstressed schwa, and persistent effects on following /e/, stressed schwa, and unstressed schwa. Glottal stops have persistent effects on preceding /e/, stressed schwa, and unstressed schwa, and on following /e/, /a/, and unstressed schwa, and a number of these were backing effects, not lowering effects.

The following discussion will progress ‘backwards’ along the oral tract, starting with /p/, which, having no lingual articulation, serves as a baseline; then to alveolar /t/ and palatal /y/ and /č/; then to labio-velar /w/ and /kʷ/; uvular /q/ and /qʷ/, and finally to glottal stop /ʔ/, and ejective /t̓/. Each subsection on the consonants will provide at least two things: first it will summarize the findings presented in Chapter 4 for the effects on F1, F2, and F3 of the consonant on the various vowels, and second it will provide a description of what the findings for each consonant mean for writing and pronouncing Lekwungen vowels.

In the following sections I present numerical results from Chapter 4 in the forms of tables. Whereas Chapter 4 provided results vowel-by-vowel, the results are recast in this chapter consonant-by-consonant, as numerical tables of the effects of a certain consonant when it is both preceding and following all vowels. The aim is to gain an idea of the effects a certain consonant is having on all the vowels. This is especially important in determining the effects on F3. In Section 4.2.2 measurements showed that there was considerable variation in the range of magnitudes of effects consonants might have on F3. By recasting the results for discussion on a consonant-by-consonant basis, this section will attempt to discover patterns of F3 effects that may be difficult to determine from the results as presented previously. The discussion draws on both these tables and the figures in Chapter 4. Care should be taken to note that the tables that follow are showing means for each vowel at each time point (unlike Chapter 4, which showed individual data points for all vowels at all time points). They will show a general trend for a certain consonant and vowel, but the discussion will note when the average is masking an important distinction (such as is the case with /e/).

5.2.1 Baseline /p/

Measurements with /p/ are not available for all vowels. Stressed schwa has no tokens with /p/, and only /i/ and /a/ have tokens with both following and preceding /p/. /e/ and unstressed schwa have tokens with a preceding /p/, but not a following /p/. Nonetheless, I will use measurements associated with /p/, where available, as a baseline to judge vowels' variation associated with other consonants, because /p/ involves no lingual articulation which might affect the vowel. Where measurements for /p/ are unavailable I calculated a vowel's mean across all measures at a given time point.

Table 5.3 summarizes the findings for vowels following and preceding /p/, and shows baseline measurements and calculated averages (shaded) for each vowel. The top half shows mean F1, F2, and F3 measurements at the first two time points (5% and 50%) for vowels following /p/. The bottom half shows F1, F2 and F3 measures for the last two time points (50% and 95%) for vowels preceding /p/. Baseline averages for all stressed schwa time points are calculated, as are 95% time point averages for /e/ and unstressed schwa.

/p/_ & calculated averages	F1 (Hz)		F2 (Hz)		F3 (Hz)	
	5%	50%	5%	50%	5%	50%
/i/	~400	~400	~400	~2360	~2900	~2750
/e/	~650	~610	~610	~2000	~2730	~2780
/a/	~640	~740	~740	~1240	~2450	~2500
Unstressed schwa	~470	~450	~450	~1410	~2410	~2390
Stressed schwa	~630	~700	~700	~1530	~2750	~2480
_/p/ & calculated averages	F1 (Hz)		F2 (Hz)		F3 (Hz)	
	50%	95%	50%	95%	50%	95%
/i/	~400	~400	~2360	~2390	~2750	~2850
/e/	~610	~540	~2000	~2010	~2780	~2700
/a/	~740	~700	~1240	~1220	~2500	~2640
Unstressed schwa	~450	~490	~1410	~1470	~2390	~2620
Stressed schwa	~700	~570	~1530	~1650	~2480	~2720

Table 5.3: Baseline /p/ and averages for all vowels

Having established baseline measurements for all five vowels at the three time points for the three formants, let’s now move on to the consonants which, having lingual articulation, were found to have effects on preceding and following vowels.

5.2.2 Alveolar /t/ and palatal /č/ and /y/

Table 5.4 below recasts the results presented in Chapter 4 as mean measurements for vowels following /t/ (on top) and preceding /t/ (on the bottom). They are organized into larger columns of F1, F2, and F3, subdivided into 5%, 50%, or 95% columns. Note that in the tables displaying consonant effects (Table 5.4 and beyond), the shading now indicates what are considered ‘strong’ effects, defined as effects involving formant measurements that differ from baseline (Table 5.3) by 100 Hz or more (e.g., /a/ following /t/ has at 5% and 50% F2s 250 to 300 Hz above baseline, indicating a strong and persistent raising effect on F2). I chose a difference of 100 Hz or more from baseline, given that ~100 Hz difference is the point where a difference in formant measurements can be considered meaningful (and not the error of automatic prediction) (Vallabha & Tuller, 2002). Using shading to reflect effects of more than 100 Hz, we can quickly visualise which effects, at what time points on which vowels, had a greater influence on formant measurements than others. The arrows indicate if the formant measurement was greater than baseline (an up arrow) or lower than baseline (a down arrow). Note that in the paragraphs below, 'strong' effects are not to be confused with 'persistent' effects: 'strong' refers to size in frequency, whereas 'persistent' refers to duration (specifically, presence of effect at 50%); strong effects can be either transitory (present at 5% or 95% of the vowel) or persistent (present at 5% and 50% or 50% and 95% of the vowel). Finally, blank cells indicate a gap in the data.

/t/_	F1 (Hz)		F2 (Hz)		F3 (Hz)	
	5%	50%	5%	50%	5%	50%
/i/	↑26	↑34	↓155	↑2	↑47	↑100
/e/						
/a/	↓40	↑4	↑296	↑248	↑316	↑2
Unstressed schwa	↑44	↑152	↑377	↑15	↑303	↑218
Stressed schwa	↓136	↑118	↑427	↑118	↓70	↑212
_/t/	F1 (Hz)		F2 (Hz)		F3 (Hz)	
	50%	95%	50%	95%	50%	95%
/i/	↑4	↓74	↓34	↑64	↓43	↑96
/e/	↓60	↓175	↑35	↑256	↓168	↑271
/a/						
Unstressed schwa	↑161	↓36	↑188	↑360	↑232	↑237
Stressed schwa	↓41	↓53	↓24	↑200	↓99	↓119

Table 5.4: Mean effects of /t/ on vowels

Overall, 24 out of 48 cells are shaded, meaning that 50% of time point measurements exhibited strong effects. Of these, 6 out of 24 cells are shaded at 50% (in a manner consistent with persistence, i.e., same direction of formant change as the peripheral cell), meaning that 25% of persistent effects are strong, and 18 out of 24 cells are shaded at 5% or 95%, meaning 75% of transitory effects are strong. The 24 shaded cells include six instances (in 12 cells) where effects are shaded at both 5/95% and 50%, meaning effects are persistent, and 12 instances (in 12 cells) where effects were shaded at only 5% or 95%, meaning they were peripheral. 10 out of 12 cells are shaded at 5% and 8 out of 12 are shaded at 95%, meaning strength of **transitory** effects is asymmetrical in favour of preservatory effects 83% vs. 67%. **Persistent** effects do not demonstrate the same asymmetry: 3 out of 12 cells (25%) are shaded at 50% for both preservatory and anticipatory effects. F1 has fewer effects than F2 or F3, and they are only transitory (4 out of 16 cells shaded, 25%). Both F2 and F3 have 10 out of 16 cells shaded (63%), and three of the effects are persistent. Finally, unstressed schwa is the most affected, with 75% (9 of 12) cells shaded, followed by stressed schwa (58%, 7/12), /a/ and /e/ (each 50%, 3/6), and /i/ (17%, 2/12).

In sum then, most strong effects of /t/ were peripheral (only transitory). These peripheral effects were more numerous in the preservatory context than the anticipatory (persistent effects did not show this asymmetry). F1 was less affected than F2 and F3, and unstressed schwa was the most affected vowel, followed by stressed schwa, /a/, /e/ and /i/. There were no effects on perception, meaning that all of the vowels were perceived as expected given their transcription.

The /t/ effects are similar in terms of formant effects but differ in terms of persistency to those of palatals /č/ and /y/, presented next in Table 5.5.

/č/_ and /y/_	F1 (Hz)		F2 (Hz)		F3 (Hz)	
	5%	50%	5%	50%	5%	50%
/i/	↓35	↓28	↓263	↑10	↓431	↓178
/e/	↓155	↓124	↑143	↓321	↓259	↓347
/a/						
Unstressed schwa	↓78	↑21	↑637	↑330	↑280	↑324
Stressed schwa	↓268	↓139	↑391	↓173	↓498	↓330
_/č/ and _/y/	F1 (Hz)		F2 (Hz)		F3 (Hz)	
	50%	95%	50%	95%	50%	95%
/i/	↓49	↓77	↓1	↑93	↓337	↑29
/e/	↓125	↓147	↑106	↑279	↓161	↑91
/a/	↓127	↓200	↑389	↑932	↓32	↓22
Unstressed schwa						
Stressed schwa	↑68	↑38	↑237	↑404	↑43	↑162

Table 5.5: Mean effects of /č/ and /y/ on vowels

Overall, 31 out of 48 cells are shaded, meaning that 65% of time point measurements exhibit strong effects. Of these 12 out of 24 cells are shaded at 50% meaning that 50% of the persistent effects are strong, and 19 out of 24 cells are shaded at 5% or 95%, meaning 79% of transitory effects are strong. The 31 shaded cells include 11 instances (in 22 cells) where effects are shaded at both 5/95% and 50%, meaning effects are persistent, and seven instances (in seven cells) where effects were shaded at only 5% or 95%, meaning they were peripheral. 11 out of 12 cells are shaded at 5% and 8 out of 12 are shaded at 95%, meaning strength of transitory effects is asymmetrical in favour of preservatory effects, 92% vs. 67%. Persistent effects demonstrate the same asymmetry: 7 out of 12 cells (58%) are shaded at 50% for preservatory effects, and 5 out of 12 (42%) are shaded at 50% for anticipatory effects. F1 exhibits fewer strong effects than F2 or F3, with 9 out of 16 cells shaded, (56%), only four of which are persistent. Both F2 and F3 have 11 out of 16 cells shaded (69%), with four persistent for each, though F2 has more persistent anticipatory effects and F3 has more persistent preservatory effects. Finally, unstressed schwa and /e/ are the most affected vowels, with 83% (10 of 12 for /e/, 5 out of 6 for unstressed schwa) cells shaded, followed by stressed schwa and /a/ with 67%, and /i/ with 33%.

In sum then, most of the effects of palatals are persistent. There are more strong effects and more persistent effects in the preservatory context than the anticipatory context, meaning that **preceding** alveolar/palatal consonants have stronger effects on vowel quality than **following** ones. F1 is affected less than F2 and F3, and unstressed schwa and /e/ are the most affected vowels, followed by stressed schwa and /a/, and /i/. Additionally, there is a change in perception of unstressed schwa to [ɪ] following palatals.

It is important to note that /e/ is realized as [e] and not as [ɛ] preceding palatals, and possibly as [ɛ] and not [e] following palatals. Given that [e] is fairly diphthong-like in quality in Lekwungen (with unstable F1 and F2), it is likely that the effects given for /e/ in the _/č, y/ context are reflecting that, and the effects of palatals are exacerbating the unstable formants.

Thus, overall, the effects of alveolars and palatals partly confirmed the predictions. These results correspond with the descriptions of Blake (2000) and Suttles (2004) for other Central Salish languages, and with Raffo's (1972) and Montler's (1986) descriptions of Lekwungen and SENĆOŦEN.

Implications for writing vowels with alveolars and palatals

What this means for writing Lekwungen is that perception is unlikely to be unchanged with alveolars (/t/, /s/, /ł/, /l/, /n/), despite the persistent effects, given the lack perceptual effects. Perception should only be affected for unstressed schwas by palatals

(/č/, /š/, /y/). When listening to Lekwungen, the alveolar sounds and the palatal sounds are unlikely to saliently (relevantly) affect what one hears (though this is only a prediction, no perception study has been undertaken to determine if the changes to pronunciation associated with alveolars affect perception meaningfully), so writing should be unambiguous in these cases, except for when a palatal sound precedes an unstressed schwa, which will likely be heard as [ɪ]. In this case vowel length (see Section 5.1) could help play a role in making this unambiguous, as the [ɪ] of /ə/ should be short, and the [ɪ] of /i/ (see Section 5.2.4 on the effects of uvulars) should be long.

5.2.3 Labio-velar /w/ and /kʷ/

As predicted in Section 2.6, the effects of the labio-velars /w/ and /kʷ/ are for the most part, like /t/, limited to the temporal edges of vowels, but can have persistent effects on unstressed schwa. These effects are enough to alter perception of unstressed schwa, to [o] before /w/ and to [ʊ] before /kʷ/. These effects correspond, like those for the alveolars and palatals, to those found by Blake (2000), Suttles (2004), Raffo (1972), and Montler (1986). The two consonants are grouped together here for discussion because they both involve a point of articulation at the lips and at the velum. The velum is the primary point of articulation for the labialized velar /kʷ/, with the lips the secondary point of articulation, and /w/ is doubly articulated at the velum and the lips (see /w/'s placement in the 'labio-velar' column of the consonant inventory chart in Section 2.1).

$/k^w/\_$	F1 (Hz)		F2 (Hz)		F3 (Hz)	
	5%	50%	5%	50%	5%	50%
/i/	0	↓13	↓366	↓153	↓506	↓131
/e/	↓70	↓102	↓185	↑90	↓269	↓198
/a/	↑7	↓4	↓142	↑134	↑45	↓77
Unstressed schwa	↑105	↑144	↓71	↑81	↓49	↑100
Stressed schwa	↑65	↓2	↓199	↓88	↓471	↓332
$\_/k^w/$	F1 (Hz)		F2 (Hz)		F3 (Hz)	
	50%	95%	50%	95%	50%	95%
/i/						
/e/						
/a/						
Unstressed schwa	↑73	↓66	↓115	↓310	↑60	↑48
Stressed schwa						
_/w/	F1 (Hz)		F2 (Hz)		F3 (Hz)	
	50%	95%	50%	95%	50%	95%
/i/	↑36	↑15	↑4	↓424	↑18	↓353
/e/	↓126	↓103	↓71	↓687	↓366	↓260
/a/						
Unstressed schwa	↑61	↓1	↓208	↓489	↑145	↓74
Stressed schwa	↑157	↑162	↓80	↓309	↑200	↑169

Table 5.6**: Mean effects of $/k^w/$ and /w/ on vowels**

Overall, 36 out of 60 cells are shaded, meaning that 60% of time point measurements exhibit strong effects. Of these, 13 out of 30 cells are shaded at 50% meaning that 43% of persistent effects are strong, and 24 out of 30 cells are shaded at 5% or 95%, meaning 80% of transitory effects are strong. The 36 shaded cells include 12 instances (in 24 cells) where effects are shaded at both 5/95% and 50%, meaning effects are persistent, and 11 instances (in 11 cells) where effects were shaded at only 5% or 95%, meaning they were peripheral. 11 out of 15 cells are shaded at 5% and 12 out of 15 are shaded at 95%, meaning strength of transitory effects is symmetrical (leaning slightly in favour of anticipatory effects): 73% vs. 80%. Persistent effects demonstrate the same symmetry: 7 out of 15 cells (47%) are shaded at 50% for preservatory effects, and 6 out of 15 (40%) are shaded at 50% for anticipatory effects. F1 has fewer effects than F2 or F3, with 8 out of 20 cells shaded (40%), three of which are persistent. Both F2 and F3 have 14 out of 20 cells shaded (70%), and four are persistent for F2 while five are for F3. Finally, unstressed schwa is the most affected, with 92% (11 of 12) cells shaded, followed by /e/ with 75%, stressed schwa with 67%, /i/ with 50%, and /a/ with 25%.

In sum then, the effects of labio-velars are split almost evenly between persistent and peripheral. The effects, in terms of persistence, are fairly symmetrical, though anticipatory effects cause a greater deviation from baseline for F2 and F3 than the preservatory effects, different from alveolars and palatals. F1 was affected less than F2 and F3, and unstressed schwa was the most affected vowel, followed by /e/, stressed schwa, /i/, and /a/. Additionally, there was a change in perception of unstressed schwa to [ʊ] preceding /kʷ/ and to [o] preceding /w/.

Implications for writing vowels with labio-velars

Overall, what we know about the labio-velars (/kʷ/, /k̓ʷ/, /xʷ/, /w/) in general, is that they should be expected to affect the perception (and thus the writing) of unstressed schwas, but that they should not affect the perception of the other vowels in a manner noticeable to English speakers. When unstressed schwa is followed by /w/, it will usually sound like [o] (in fact, the /w/ is not usually even pronounced on its own)[26]. When followed by a labialized velar, it will usually sound like [ʊ]. Thus, for writing, when an

[26] Interestingly, this is how Mitchell (1968) originally transcribed these sequences.

[o] is heard, it is likely to be a /əw/ (how it is currently written), and when an [ʊ] is heard it is likely to be a /ə/ with a following labio-velar (or uvular, as discussed below).

5.2.4 Uvular /q/ and /qʷ/

Differing from palatals and labio-velars, uvulars /q/ and /qʷ/ have mostly strong peripheral effects on the vowels looked at here. When effects are persistent, in line with what Bird & Leonard (2009) found for SENĆOŦEN and other Salish languages, they and the perceptible effects of uvulars are asymmetrical. In general, the effects of following uvulars were stronger than the effects of preceding uvulars. In addition, following uvulars affected perception, while preceding uvulars did not. In Section 2.6 it was hypothesised that uvulars would lower and retract vowels, and the results in Chapter 4 support this. This section looks at both labialized uvulars and plain uvulars, because of the similar effects they had on preceding and following vowels. The tables below, Table 5.7 and 5.8, show the mean measurements for vowels following and preceding plain uvular /q/ and labialized uvular /qʷ/.

/q/_	F1 (Hz)		F2 (Hz)		F3 (Hz)	
	5%	50%	5%	50%	5%	50%
/i/	↑42	↑36	↓138	↑34	↓98	↓34
/e/	↓30	↓64	↑40	↑9	↓87	↓78
/a/						
Unstressed schwa	↑103	↑191	↑56	↑96	↑18	↑170
Stressed schwa	↓50	↑1	↓69	↓89	↑39	↓49
_/q/	F1 (Hz)		F2 (Hz)		F3 (Hz)	
	50%	95%	50%	95%	50%	95%
/i/	↑26	↑43	↓30	↓241	↑73	↑18
/e/	↑9	↑35	↓101	↓92	↓250	↓86
/a/						
Unstressed schwa	↑145	↑169	↓79	↓115	↑219	↑120
Stressed schwa	↓28	↓17	↓34	↓461	↓41	↑9

Table 5.7: Mean effects of /q/ on vowels

/q^w/_	F1 (Hz)		F2 (Hz)		F3 (Hz)	
	5%	50%	5%	50%	5%	50%
/i/	↑117	↑33	↓601	↓55	↓349	↓80
/e/	↓65	↓71	↓90	↓152	↓406	↓409
/a/	↑1	↓66	↓212	↓98	↓155	↓112
Unstressed schwa	↑122	↑156	↓120	↓24	↓12	↑50
Stressed schwa	↑61	↓10	↓221	↓140	↓536	↓88
_/q^w/	F1 (Hz)		F2 (Hz)		F3 (Hz)	
	50%	95%	50%	95%	50%	95%
/i/	↑54	↑87	↓85	↓631	↓139	↓245
/e/						
/a/	↑5	↓55	↑238	↑96	↓19	↓43
Unstressed schwa	↑121	↓44	↓124	↓293	↑252	↓151
Stressed schwa	↓39	↑45	↓94	↓395	↓87	↓186

Table 5.8: Mean effects of /q^w/ on vowels

Overall, 43 out of 102 cells are shaded, meaning that 42% of time point measurements exhibit strong effects. The majority of these are with /q^w/: /q/ has 16 shaded cells out of 48 (33%), and /q^w/ has 30 out of 54, (55%). Of these, 14 out of 51 cells are shaded at 50% meaning that 27% of the persistent effects are strong, and 31 out of 51 cells are shaded at 5% or 95%, meaning 61% of transitory effects are strong. The 43 shaded cells include 13 instances (in 26 cells) where effects are shaded at both 5/95% and 50%, meaning effects are persistent, and 15 instances (in 15 cells) where effects were shaded at only 5% or 95%, meaning they were peripheral. Effects differ between /q/ and /q^w/ in symmetricality. For /q/, 3 out of 12 cells are shaded at 5% and 8 out of 12 are shaded at 95%, meaning strength of transitory effects is asymmetrical in favour of anticipatory effects: 25% vs. 67%. For /q^w/ 11 out of 15 cells are shaded at 5% and 10 out of 12 are shaded at 95%, meaning strength of transitory effects is asymmetrical in favour of anticipatory effects: 73% vs. 83%. Persistent effects demonstrate a different pattern: for /q/ 1 out of 12 cells (8%) is shaded at 50% for preservatory effects, and 4 out of 12 (33%) are shaded at 50% for anticipatory effects. For /q^w/ 5 out of 15 cells (33%) are shaded at 50% for preservatory effects, and 4 out of 12 cells (33%) are shaded at 50% for anticipatory effects. /q/ favours anticipatory persistent effects while /q^w/ is symmetrical. F1 exhibits fewer effects than F2, but more than F3, with 15 out of 34 cells shaded (44%), five of which are persistent. For F2 and 17 out of 34 cells are shaded (50%), and three are persistent. F3 has 14 out of 34 cells shaded (41%), and four are persistent. This is the first time F1 has exhibited more strong effects than another formant. Finally, unstressed schwa is the most affected, with 67% (16 of 24) cells shaded, followed by stressed schwa, /a/, /e/, and /i/, all with 33%.

In sum then, the effects of uvulars were almost split evenly between peripheral and persistent. This is a pattern different from that of palatals and similar to that of labio-velars (though labio-velars leaned slightly in favour of persistent effects and uvulars lean slightly in favour of peripheral effects). The effects in terms of persistence are fairly symmetrical for /qʷ/, though favour anticipatory effects, and asymmetrical favouring anticipatory effects for /q/. F1 was affected less than F2 but more than F3, and unstressed schwa was the most affected vowel, followed by /i/, stressed schwa, /e/, and /a/. Additionally, there was a change in perception of /i/ to [ɪ] preceding uvulars, of /e/ to [ɛ] preceding uvulars, of stressed and unstressed schwa to [a] preceding /q/, and of unstressed schwa to [ʊ] preceding /qʷ/.

There seems to be a mismatch between what we know about the persistent effects of uvular stops and their effects on the perception of /i/. /i/ lowers slightly and retracts slightly, but not persistently before uvulars. However, it can still be perceived as [ɪ] (when /i/ is realized as [iᵊ] this lack of persistence is not problematic). These two realisations of /i/ preceding uvulars - [ɪ] and - [iᵊ] are two resolution strategies to the inherent articulatory conflict between /i/ and /q/ (c.f. Gick & Wilson, 2006). Additionally, /i/ preceding /qʷ/ can also exhibit the secondary labialisation of the following /qʷ/, and this might be an additional compensatory strategy for labialized uvulars alone (as evidenced by the one token of [iʷ], which did not lower or retract or epenthesize a schwa).

Comparatively to /i/, /e/ will retract to [ɛ] before uvulars, and this is reflected in persistent lowering of F2. This contrasts with SENĆOŦEN, where /e/ lowers to [æ] before uvulars (though Montler, 1986, does document SENĆOŦEN /e/ behaving like Lekwungen /e/ in this case). After uvulars, /e/ is realized as [e]. After uvulars, /a/ retracts to [ɑ]. Before uvulars, /a/ peripherally retracts as well, though the one case here did not change perception, remaining as [a]. Stressed and unstressed schwas retract and lower before and after uvulars, and were perceived as both [ʌ] and [a] in these cases. Unstressed schwas additionally retract and raise after labialized uvulars, like they do after labialized velars, to [ʊ]. However, like /i/, stressed schwas only exhibited peripheral effects. In general, regardless of persistency, F1 was raised and F2 lowered for close vowels, as was found by Bessell (1997) and Namdaran (2006). Similar to what Rose (1997) found cross-linguistically, vowels were generally retracted or lowered preceding and following uvulars.

Implications for writing vowels with uvulars

What this means for writing is that uvulars (/q/, /qʷ/, /q̓/, /q̓ʷ/, /x̣/, /x̣ʷ/) will, in most cases, not affect writing, because the variants are still characteristic of the letter they are represented by (e.g., an English speaker will still likely associate an /e/ heard as [e] and an /e/ heard as [ɛ] with the letter 'e'). Uvulars do, however, have the greatest implications for pronouncing Lekwungen, because they have the most perceptible effects on vowels. All the retraction/lowering effects mentioned in the preceding paragraph will need to be kept in mind for learning/speaking, but writing need only be remembered in the cases of schwa, where it is heard as [a] (before plain uvulars) and [ʊ] (before labialized uvulars). The distinction between schwa heard as [a] and /a/ heard as [a] can be determined by the difference in length (see Section 5.1 and 4.2.1): unstressed and stressed schwa will be shorter than /a/.

5.2.5 Glottal /ʔ/ and ejective /t̓/

The final set of consonants investigated are glottal consonants. This section will look at the effects preceding and following glottal stop and ejective /t̓/ had on vowel formant measures. In Section 2.6 I predicted that glottal stop would lower schwas, but that other vowels would be unaffected, and that ejectives would not affect vowel quality. These predictions were partly confirmed in the results. Table 5.9 below summarises results for glottal stop and /t̓/.

/ʔ/_	F1 (Hz)		F2 (Hz)		F3 (Hz)	
	5%	50%	5%	50%	5%	50%
/i/	↓13	↓5	↓9	↑16	↓101	↑53
/e/	↓28	↑7	↑198	↑150	↑42	↑77
/a/	↑115	↑26	↓18	↑117	↑181	↑131
Unstressed schwa	↑127	↑96	↑252	↑74	↑120	↑139
Stressed schwa	↑185	↑63	↓37	↑182	↓4	↑272
_/ʔ/	F1 (Hz)		F2 (Hz)		F3 (Hz)	
	50%	95%	50%	95%	50%	95%
/i/	↑10	↓29	↓88	↓32	↓45	↓84
/e/	↓43	↓10	↑218	↑283	↑82	↑150
/a/	↓62	↑67	↓30	↑21	↑47	↓131
Unstressed schwa	↑136	↑114	↑189	↑140	↑110	↓65
Stressed schwa	↓123	↓139	↑141	↓47	↑508	↑324
/t̓/_	F1 (Hz)		F2 (Hz)		F3 (Hz)	
	5%	50%	5%	50%	5%	50%
/i/	↑5	0	↓8	↑16	↓128	↑33
/e/	↓87	↓58	↑117	↑48	↓34	↓145
/a/	↓91	↓169	↑204	↑385	↑18	↓45
Unstressed schwa	↑223	↑272	↑204	↑206	↑344	↑292
Stressed schwa	↓27	↓123	↓55	↓264	↓188	↑144

Table 5.9: Mean effects of /ʔ/ and /t̓/ on vowels

Overall, 45 out of 90 cells are shaded, meaning that 50% of time point measurements exhibited strong effects. For glottal stop, 29 out of 60 cells are shaded (48%), and for /t̓/ 17 out of 30 are shaded (57%). For glottal stop, 9 out of 30 cells are shaded at 50% meaning that 30% of the persistent effects were strong, and 18 out of 30 cells are shaded at 5% or 95%, meaning 60% of transitory effects were strong. For glottal stop the 29 shaded cells include nine instances (in 18 cells) where effects are shaded at both 5/95% and 50%, meaning effects are persistent, and 10 instances (in 10 cells) where effects were shaded at only 5% or 95%, meaning they were peripheral. For /t̓/ the 18 shaded cells include six instances (in 12 cells) where effects are shaded at both 5% and 50%, and two instances (in two cells) where effects were shaded at only 5%.

Effects are generally symmetrical for glottal stop: 10 out of 15 cells are shaded at 5%, and 8 out of 15 are shaded at 95%, a slight favouring of preservatory transitory effects: 67% vs. 53%. Persistent effects are also generally symmetrical: 4 out of 15 cells (27%) are shaded at 50% for preservatory effects, and 5 out of 15 cells (33%) are shaded at 50% for anticipatory effects. F1 has fewer effects than F2 and F3, with 8 out of 20 cells shaded (40%), three of which are persistent. For F2, 10 out of 20 cells are shaded (50%), and three are persistent. F3 has 11 out of 20 cells shaded (55%), and three are persistent. Finally, unstressed schwa is the most affected, with 83% (10 of 12) cells shaded, followed by stressed schwa with 67%, /a/ and /e/ with 42%, and /i/ with 8%. Symmetry cannot be compared for /t̓/ because no pre-/t̓/ tokens were included in the dataset, but 8 out of 15 cells are shaded at 5%, and 9 out of 15 cells are shaded at 50%. F1 is affected less than F2 and F3, with 5 of 10 cells shaded for F1, vs. 6 out of 10 for F2 and F3. Unstressed schwa is also the most affected, with all six cells shaded, followed by stressed schwa and /a/ with five each, /e/ with two and /i/ with one.

In sum then, the effects of glottal stops were split almost evenly between peripheral and persistent effects, and the effects of /t̓/ were majority persistent.

For glottal stops the effects of persistence are fairly (though not exactly) symmetrical, but the effects on perception are not. When both preceding and following glottal stop, F1 was affected less than F2 and F3, and unstressed schwa was the most affected vowel, followed by stressed schwa, /a/, /e/, and /i/. However, there was a change in perception of /e/ to [ɛ] preceding glottal stop and of stressed and unstressed schwa to [a] preceding glottal stop, but not following. There were no perceptual effects of /t̓/.

If glottal stops (similar to /p/) do not involve lingual articulation, then there should be no changes to formant values beyond those associated with the vowel itself. Ejectives should be similar; the glottal articulation of the ejective should not affect vowel formants for full vowels (though the lingual articulation should). However, this is not what has been found for glottal stops, at least in Salishan and nearby languages. In Nłeʔkepmxcín (Carlson, Esling, & Harris, 2004) and Nuučaan̓uł (Esling, Fraser, & Harris, 2005) glottal stops and glottalization involve sphinctering of the lower pharynx. In these cases the pharynx is constricted as the aryepiglottic folds collapse over the epiglottis, though Esling (2005) notes that they are unsure how much tongue retraction is involved in this. Nonetheless, it is certainly possible that glottal stops and glottalized consonants would have coarticulatory effects on vowel quality if glottalization also involves pharyngealization. In this regard it is odd, though not inconsistent with other languages, that Lekwungen close vowels are not affected by glottal stop. Bessell (1997) discusses that St’át’imcets glottal stops do not affect the vowel quality of full vowels, but Blake (2000) found that in ʔayʔaǰuθəm schwa lowered to [a] before glottal stops. The results in this thesis show that glottal stop does not affect close vowels, but does retract /e/ as well as /a/ (an open/retracted vowel) and schwas. Additionally, /t̓/ has similar effects. It has the same effects as /t/ on full vowels, but it dramatically lowers unstressed schwa. However, there is only one token of this occurrence, so the possibility that this is common is disputable.

A Perturbation Theory analysis of the effects seen with glottals in Lekwungen could account for the formant effects in a manner suggesting pharyngeal sphinctering (Chiba & Kajiyama, 1941; see Johnson 2003 for more on Perturbation Theory). It would suggest that the pharyngeal sphinctering is more considerable for /e/, /a/, and stressed and unstressed schwa, and less so for /i/.

Implications for writing vowels with glottal stops and ejectives

Overall, the implications of glottal stop (/ʔ/) and ejectives (/t̓/, /c̓/, /č̓/, /ƛ̓/, /k̓ʷ/, /q̓/, /q̓ʷ/) (and possibly of glottalized resonants [/y̓/, /w̓/, /l̓/, /m̓/, /n̓/, /ŋ̓/] which involve glottal stop as a component) for writing and pronouncing Lekwungen are not surprising. For glottal stops, /e/ should not be affected, and no special care will be needed when listening and writing, as [ɛ] is easily associated with /e/. /a/ will likely retract before a glottal stop, but this shouldn't affect perception much ([a] and [ɑ] are not contrastive in English). The difference between [a] and [ɑ] should, however, affect pronunciation and efforts to have a 'Lekwungen-sounding' accent. Schwas will lower to [a] before and after a glottal stop, so extra care will be needed when listening and writing, and it is likely that other knowledge of word structure (or prior knowledge of spelling), or reference to duration (/a/ is longer than stressed for unstressed schwa) will be needed to know when to write 'a' or 'ə'. For ejectives, expected effects on vowels should be the same as those from non-ejective consonants with the same place of articulation (see Appendix), except it is possible that unstressed schwas will lower after (and perhaps before) /t̓/ to [a]. There is, additionally, one other effect glottal stops might have: allowing the harmony of unstressed schwas with full vowels. Section 5.2.6 discusses this and the variable realisation of secondary labialisation.

5.2.6 Other consonantal coarticulatory effects

Finally, I shall discuss the two other effects consonants had on vowels found in the data: harmony of unstressed schwa and full vowels over glottal stops, and timing of secondary labialisation. This section will briefly discuss each in turn and give information on the implications they have for writing/pronouncing Lekwungen.

There are two instances found of an unstressed schwa being realized as [ɛ] when followed by a glottal stop which was itself followed by an /e/, two instances of an unstressed schwa being realized as [ɛ] when the /e/ preceded the glottal stop and the schwa, and one of /a/ preceding a glottal stop and schwa. In the first case, unstressed schwa, instead of lowering before the glottal stop, assimilates in production to the vowel quality of the /e/. It is the same in the cases where schwa follows the glottal stop, for both /e/ and /a/. This would likely be expected with /i/ as well. This has not been seen with other consonants, nor has it been seen with a schwa and glottal stop followed by another consonant. As mentioned in Chapter 2, Bird, Czaykowska-Higgins, & Leonard (2012) studied a similar pattern in SENĆOŦEN, as did Montler (1998) in Klallam and Jacobs (2012) in Sḵwx̱wú7mesh (Jacobs further cites Shaw, Blake, Campbell, & Shepherd, 1999, as describing a similar pattern in hən̓q̓əmin̓əm̓). When a /Vʔə/ sequence was spoken in rapid speech, the glottal stop appeared as creaky voice and the schwa assimilated in quality to the preceding vowel. This is different from the pattern in SENĆOŦEN and Sḵwx̱wú7mesh, but like the pattern in Klallam (both Montler's examples involve a /əʔV/). In SENĆOŦEN and Sḵwx̱wú7mesh the effect is only seen when the full vowel precedes the schwa, and not in reverse (in SENĆOŦEN the environment is the same as Lekwungen, in Sḵwx̱wú7mesh it is a copy vowel on unaffixed roots). Lekwungen is showing this effect with both a following and preceding full vowel. Additionally, in the examples found here, the assimilation is happening in slow, careful speech, with the glottal stop realized as a full stop. Future work could look at the realisation of this in more naturalistic speech, such as storytelling, like Bird, Czaykowska-Higgins, & Leonard did.

Implications of other consonantal effects for writing vowels

The implications for writing and pronouncing these other effects go hand-in-hand. It will have to be decided if the schwa in these cases should be written as 'ə' or as the vowel it is heard as. If it is written as a schwa, then care will need to be taken to inform learners that, if Sophie Misheal's pronunciation is to be preserved, this schwa will need to be pronounced like the preceding or following vowel. If it is written as the other vowel, then possible underlying information about the word might become obscured, which could give rise to an explicit situation that might have to also be explained to learners. Ultimately, the decision is not mine to make.

The other feature found during data collection, was the variable timing of secondary labialisation. As discussed in Section 2.4.5, languages can vary in the timing of a secondary articulation relative to the primary articulation. With the labialized stops in Lekwungen, the labialisation can occur before or after the stop closure and release. Variable timing of secondary labialisation is found in SENĆOŦEN (Bird, 2016), and the data presented above shows that it is found in Lekwungen as well. As for the implications of the timing variability on writing/pronouncing the language, one issue that should be considered is whether or not to write the variability of secondary labialisation: should ‘^{w}k’ be an option along with ‘k^{w}’? Otherwise, I believe that it should be adequate to make the variability known, at least so that learners when writing can know they can associate a diphthong-like offglide [w] before a labialized stop with the stop, and not have to decide if they must write a ‘w’ as well. In terms of pronouncing the language, variable timing is not necessarily a voluntary activity, but rather a feature of a speaker’s own variable timing of articulators. Individual speakers can vary the realisation of secondary labialisation, even without realising that this variability is possible. This section and the results served to document that this is indeed a feature of at least Sophie Misheal’s Lekwungen, so future listeners/speakers should know that they should expect to hear it too.

5.2.7 General Discussion

The tables below (Table 5.10 and Table 5.11), summarize the strong persistent and perceptual effects of the various consonants on the vowels, discussed throughout this Section. Table 5.10 shows the effects of preceding consonants, and Table 5.11 shows the effects of following consonants. Arranged left to right on each table are the five vowels, and top to bottom are the consonants. Check marks under the columns ‘F1’, ‘F2’, and ‘F3’ indicate if an effect of a given consonant was persistent on the vowel, and under the column ‘P?’ indicates if the consonant had an effect on perception. Blank cells mean there was no persistent effect, and the shaded cells indicate where there is a gap in the data.

Preceding Consonant	/i/				/e/				/a/				Stressed schwa				Unstressed schwa			
	F1	F2	F3	P?	F1	F2	F3	P?	F1	F2	F3	P?	F1	F2	F3	P?	F1	F2	F3	P?
/t/										✓				✓					✓	
/č/ & /y/			✓		✓		✓						✓		✓			✓	✓	✓
/kʷ/		✓	✓				✓			✓					✓		✓			
/w/																				
/q/								✓								✓	✓			✓
/qʷ/							✓				✓	✓		✓		✓	✓			
/ʔ/						✓					✓	✓				✓	✓		✓	
/t̓/									✓	✓					✓		✓	✓	✓	✓

Table 5.10: Persistent coarticulatory effects and effects on perception of preceding consonants

Following Consonant	/i/				/e/				/a/				Stressed schwa				Unstressed schwa			
	F1	F2	F3	P?	F1	F2	F3	P?	F1	F2	F3	P?	F1	F2	F3	P?	F1	F2	F3	P?
/t/															✓			✓	✓	
/č/ & /y/					✓	✓			✓	✓				✓						
/kʷ/																		✓		✓
/w/					✓		✓						✓		✓			✓		✓
/q/				✓		✓		✓								✓	✓		✓	✓
/qʷ/			✓	✓												✓	✓	✓		✓
/ʔ/						✓		✓					✓		✓	✓	✓	✓		✓
/t̓/																				

Table 5.11: Persistent coarticulatory effects and effects on perception of following consonants

F3 exhibits the most persistent effects, followed by F2, then F1 (21 out of 60 possible chances to be persistently affected are found for F3, compared to 19 for F2 and 16 for F1). F1 and F2 are generally symmetrical. F1 has eight check marks both in preservatory and anticipatory effects, while F2 has nine in preservatory and 10 in anticipatory. F3, conversely, is asymmetrical in favour of preservatory effects: 14 checkmarks in the preservatory context and only seven in the anticipatory. Schwa is the most affected of the vowels: 53% of possible persistent coarticulatory effects are found with unstressed schwa, 31% with stressed schwa, 31% with /e/, 27% with /a/, and 12% with /i/. Additionally, eight of the nine consonants have effects on the perception of unstressed schwa, while only three do for stressed schwa and /e/, and two for /a/ and /i/. As for symmetricality, glottal stops and uvular stops (both plain and labialized) have slightly more persistent anticipatory effects than preservatory (11 checkmarks vs. nine checkmarks). The opposite is true for palatals, which have more persistent preservatory effects than anticipatory ones (seven vs. five) as well as for labio-velars, which have an equal number of anticipatory and preservatory effects (six both preceding and following).

As for perception effects, unstressed schwa is more affected by a following consonant than by a preceding consonant (five changes to perception vs. three), as are /i/ and /e/ (two and two vs. zero and one), but /a/ is more affected by preceding consonant (two as opposed to none) (though /a/ also suffers from serious gaps in the data), and stressed schwa is equally affected by both.

There is not always a one-to-one relation between the persistence of formant effects and an effect on perception (Bird & Leonard, 2009, also found a mismatch between auditory and acoustic effects on /i/ adjacent to uvulars in SENĆOŦEN). /i/ preceding /q/ and /qʷ/ exhibited a change in perception, but only /qʷ/ had persistent effects on a preceding /i/ (on F3). Similarly, /e/ preceding and following /q/ exhibited a change in perception, despite only persistent anticipatory effects on formants. Stressed schwa was heard as [a] following and preceding /q/, /qʷ/, and /ʔ/, but did not exhibit persistent effects when following /q/ or /ʔ/, or when preceding /q/ or /qʷ/. What is likely to be happening here is a combination of two things: Lekwungen /i/ is more retracted than English /i/ (see Section 4.2.1.6) and there are salient effects on formants (likely F1 or F2) that are not persistent to the 50% mark of the vowel, but that are strong enough, through enough of the vowel, to cross a perceptual threshold and so affect my perception of them). /i/ preceding /q/ was heard as [ɪ], without strong formant effects, and stressed schwa, even without co-articulatory effects, often sat along a perception threshold, being heard sometimes as [ʌ] and sometimes as [a]. Such could also be the case for /e/ preceding /q/ and glottal stop and following /y/ (all cases where /e/ is heard as [ɛ]), given mean F2 of /e/ in Lekwungen is closer to American English /ɛ/.

Furthermore, in the case of stressed schwa, given the fact that stressed schwa has a sometimes-ambiguous perception ([ʌ] or [a]), and the fact that labio-velars and uvulars are retracting stressed schwa less than unstressed schwa, it is likely that stressed schwas in Lekwungen (or at least Sophie Misheal's speech) are produced further retracted and lower than unstressed schwa. However, as with most of the findings related to changes in perception, further study is needed (see Chapter 6).

The ambiguity around the perception of stressed schwas leads into an additional point of discussion: the interaction of stress correlates and perception/formant effects. There are several cases where consonantal coarticulatory effects can have an effect on perception that could lead to confusion between different underlying vowels for learners: when /i/ retracts to [ɪ] and /ə/ raises to [ɪ], when /e/ retracts to [ɛ] and /ə/ fronts to [ɛ], and when /ə/, both stressed and unstressed, lowers to [a], while /a/ remains as [a]. In these cases, the correlates of stress are useful for avoiding ambiguity. The fact that full vowels are considerably longer than stressed or unstressed schwa means that the retracted /i/, /e/, and baseline /a/ should be distinguished from fronted or lowered schwa by length. A short [ɪ], [ɛ], or [a] (around 100 to 140 ms) is likely to be a schwa, and not a full vowel. Additionally, in these cases, consonantal environment could be a clue as well. The fronted schwas and the retracted /i/ and /e/ do not occur in the same consonantal environments. An [ɪ] or [ɛ] with a uvular is going to be a retracted full vowel.

Alveolars, palatals, and labio-velars have proportionally fewer persistent effects on full vowels than on schwas, and their effects on perception are exclusively with unstressed schwas. Uvulars and glottals also have proportionally fewer persistent effects on full vowels than on schwas, but their effects on perception are on all vowels. For both uvulars and glottals their effects on full vowels are mostly retracting effects, while with schwas they are lowering and/or retracting effects.

5.3 Summary

This chapter recast the results found in Chapter 4 from the perspective of the target consonants, and discussed the patterns that were found in the background literature discussed in Chapter 2 and discussed the implications the results have for writing/pronouncing Lekwungen. Duration of vowels, mean pitch in vowels, and mean intensity in vowels were all found to be reliable acoustic correlates of stress in Lekwungen. The coarticulatory effects of consonants on vowels were **not** as predicted, with palatal and labio-velar consonants having more persistent effects on all vowels (not just unstressed schwa) than peripheral effects, and uvular consonants (both plain and labialized) having fewer persistent than peripheral effects on all vowels. Additionally, not all persistent effects altered perception of the vowels, an important point for learners to be aware of. Glottal stops did not affect front vowels /i/ and /e/, but did lower schwas, changing their perception as well. Ejectives did not have effects on vowels separate from their place of articulation. These observed coarticulatory effects are summarised in Table 5.12, done in the same style as those presented in Chapter 2, compared with those found by Raffo (1972):

	Lekwungen (This thesis)	Lekwungen (Raffo 1972)
/i/	[ɪ] or [iᵊ] before uvulars [i] elsewhere	[i~e] before velars, uvulars, /s/, /š/ [ɪ] between glottals [i] elsewhere
/e/	[ɛ] before glottals and uvulars, after palatals [e] elsewhere	[ɛ] before /y/ and when long [æ~ɛ] otherwise
/a/	[ɑ] after uvulars [a] elsewhere	 [a]
/ə/	*When stressed*: [a] before glottal stops and before and after uvulars [ʌ] elsewhere *When unstressed*: [ʊ] before labialized velars and uvulars [o] before /w/ [a] before glottal stops and uvulars [ɪ] after palatals [ʌ] elsewhere	 [ʊ] between a resonant and /xʷ/ or /x̣ʷ/ [ɔ] before /k̓ʷ/ and /h/, after /q̓ʷ/ [ʌ] elsewhere

Table 5.12: Summary of coarticulatory effects of consonants on vowel perception

The findings on the nature of perceptible effects on vowels due to consonantal coarticulation differ from those found by Raffo (1972). Raffo did not find retraction of /i/ before uvulars, just as here I didn't find retraction of /i/ neighbouring glottals. Raffo also did not find a retraction of /e/ before glottals and uvulars, nor a lowering of schwa in the same environment. I did also not encounter /e/ heard as [æ]. We both found a raising and rounding of unstressed schwa with labialized velars, but this thesis did not find the rounding and lowering of unstressed schwa with uvulars that Raffo did. Due to their different analysis of the underlying vowels and how they did not assume glottalized resonants, Raffo did not find [o] as a variant of unstressed schwa preceding /w/, but rather analysed it as an unstressed variant of /u/, which this thesis did not study. Given that we worked with information from the same speaker and were both trained in phonetic transcription, several of these inconsistencies may be due to the fact that I worked with isolated words and Raffo may have had the chance to hear tokens in more natural speech, but they may also be due to the fact that our perceptions differed. Raffo's English would have been a different variety (both spatially and temporally) than my own. This supports the usefulness of further perception studies to determine what exactly most learners will be hearing, and points to the importance of acoustic analysis in documenting vowel variation, to provide physical measurements independent of linguists' perceptions.

Given the nature of the speech analysed in this thesis (careful speech, isolated words), the regularity and consistency of the coarticulatory effects reported here are likely to be less prominent than they would be in natural speech. Following Hypo- & Hyperspeech Theory (discussed in Section 2.5), the slow rate of speech in the isolated word list elicitations would mean the words analysed here are likely not to demonstrate the true extent of coarticulatory effects which would be found in natural or natural-like speech. Sophie Misheal's isolated words included many cases where perception was not affected for some cases of persistent coarticulatory effects when it was for others. Future studies of the vowels of Lekwungen on more natural speech might reveal some coarticulatory effects not found here, or find a greater number or ratio of persistent effects than found in the data investigated here.

Chapter 6

Conclusion

This last chapter finishes the thesis with three components. First, the research question, validity of the hypotheses, and conclusions are summarized. Second, the contributions of this thesis to Lekwungen language revitalisation and knowledge of Salishan linguistics are noted. Third, the limitations of the thesis and directions for future research are discussed.

This thesis sought to answer the research question ‘in Lekwungen, how do stress and consonants affect the quality of vowels?’ To answer this question, measurements of vowel duration, pitch, amplitude, F1, F2, F3 were taken from CVC sequences contained in isolated words. All six hypotheses were found to be valid, in some respect. Duration, pitch, and amplitude were all found to be acoustic correlates of stress on vowels. Palatal and labio-velar consonants did persistently affect schwa, but they also had more persistent effects than peripheral. However, their only perceptible effects were on unstressed schwas. Uvular stops had more peripheral effects than persistent effects, but they had a perceptible effect on every vowel. Glottal stops were split between persistent and peripheral effects and had a perceptible effect on most vowels. Finally, ejective consonants did not appear to have place-of-articulation-independent effects on vowel quality. In terms of expectations as to which formants and which vowels would be the most affected, results were as expected. Overall, F3 was the most persistently affected formant by consonant coarticulatory effects, with F2 the second-most and F1 the least affected. This follows from the Perturbation Theory model, given that the wavelengths of F3 are shorter than F2 and F1, so there are more points of maximal and minimal velocity, and thus more chances for dramatic effects on formant values. Unstressed schwas were the most affected vowel, followed by stressed schwas, /e/, /a/, and /i/, in that order.

One of the goals of this thesis was to provide useful and useable information to Lekwungen language learners. In endeavoring to provide that, the Discussion chapter (Chapter 5) provided short summaries of the implications of findings for teaching and learning to write and pronounce Lekwungen. These have been extracted from the thesis and made into a kind of ‘cheat sheet’ for quick reference, included in the Appendix. Additionally, I hope to create further materials for informing learners and teachers based on the findings in this thesis, such as audio or audio-visual materials demonstrating the what the sound changes found in this thesis actually sound like. The other goal of this thesis was to provide an acoustic phonetic study of vowel variation and coarticulatory effects in a Central Salish language. Given the validity of the hypotheses and the general robustness of the findings, this goal, despite the gaps in the data present, can be considered obtained.

Finally, on that note, a word on the limitations of the findings and implications for future research. There are a number of gaps in the data. No instances of /w/ preceding /e/ or stressed and unstressed schwa were found, nor was /w/ following /a/. /k^w/ was not found following /i/, /e/, /a/, or stressed schwa. /q/ was not found preceding or following /a/, nor /q^w/ following /e/. Palatals were not found preceding /a/ or following unstressed schwa, and /t̓/ was not found following /e/, /a/, or stressed or unstressed schwa. These gaps could be filled in a future study looking at other recordings of Lekwungen, or the stories also present on the tapes used in this study. Another advantage of studying coarticulation effects from stories would the presence of more natural-like speech, and thus a picture of consonantal coarticulatory effects that more closely resembles natural speech. Additionally, results were reported in a physical scale (Hertz), as opposed to an auditory scale (e.g., Barks), which might be more favoured given the aspirations of this thesis. This choice was made to increase overall comparability of the results to those of other acoustic studies on Salishan languages and because this was a groundwork-laying acoustic study of Lekwungen, but does limit some learner-accessibility of the results. I have tried to mitigate any effects of this as much as possible by providing clear and comprehensive interpretation and discussion of the results in areas which pertain to pronunciation and perception. Future learner-focused work could choose to report results in an auditory scale if deemed more useful for learners. The one other area for further study implied through this research, also in line with a focus on learners, is a study of perception among Lekwungen language learners. Currently this thesis uses only my own perception of vowels and their variation to draw conclusions and make recommendations for teaching/learning. A useful area of future study would be to ascertain how learners (or potential learners) of Lekwungen perceive vowel variation, and what possible effects training might have on their perception.

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Appendix A
Tips for writing Lekwungen vowels

This appendix provides a draft of a potential ‘cheat sheet’ and guide compiled from the information in the various ‘Tips for Writing ….’ written throughout the discussion section into one document for easy access. It includes page references for where the tips originally come from, so that those interested may look for further information.

There can be two ways to write the vowel sounds of Lekwungen. One way is to write vowel sounds as they sound to English speakers. Another is to write what we know to be the 'meaningful' vowels, where a difference in the vowel creates a change in the word meaning. For example, the only difference between Lekwungen *ʔíŋət* 'to step', and *ʔáŋət* 'to give', or between English *pen* and *pin*, is the vowel. Change the vowel, and the meaning of the word changes. The decision on which way to write the vowels will have to be made, but this provides a guide for how to write vowels if this 'meaningful' way is chosen.

Sometimes, how a vowel sounds can change, without actually changing the meaning of the word. One of the ways this can happen is when the vowel is influenced by the consonant next to it. My thesis studied this, and found that there are several places where this can happen in Lekwungen. For example, the vowel written with the letter *i* in *ʔíŋət* and in *sɬíqʷ* sound different: the first is like the vowel sound in *beet*, the other like the vowel sound in *bit*. In a system where vowels were written as they sound to English speakers, these two vowels would be written differently. But in a system where only the meaningful vowels were written, they would be written the same. This is because we know it is the *qʷ* in *sɬiqʷ* that is changing how the *i* is said and sounds, so we know it is still the same *i* as in *ʔíŋət*. Lekwungen has another vowel – schwa – that usually sounds like the vowel in *but* that also changes how it sounds when next to certain consonants, and it changes a lot. It can sound like the vowel sound in *book*, like in *boat*, even like in *bit*, but this change only happens with specific consonants, so we know that the difference is not meaningful, and so all the variations can be written with the letter *ə*.

Quick-Reference to writing vowels in Lekwungen

If it sounds like…	And is…	Then write…	Page reference
the *i* in *bit*	before q, qʷ, q̓, q̓ʷ, x̣, or x̣ʷ	i	Pg. 131
	after č, č̓, or y	ə	Pg. 124
the *ee* in *beet* or the *ea* in *beat*	anywhere	i	
the *e* in *pet*	anywhere (usually before ʔ, q, qʷ, q̓, q̓ʷ, x̣, or x̣ʷ; after č, č̓, or y)	e	Pg. 124, 131, 136
the *a* in *fate*	anywhere	e	
the *oo* in *book* or the *u* in *put*	anywhere (usually before kʷ, k̓ʷ, qʷ, q̓ʷ, xʷ, or x̣ʷ)	ə	Pg. 127
the *o* in *poke* or the *oa* in *boat*	anywhere	əw	Pg. 127
the *u* in *but*	anywhere	ə	
the *a* in *father*	before ʔ and before and after q, q̓, qʷ, q̓ʷ, x̣ʷ, or x̣	ə	Pg. 131, 136
	anywhere else	a	
Short like the first or third *a* in *banana* (vs. the *second a* in *banana*)	anywhere	ə	Pg. 112

Appendix B
Word List

This word list includes all the words from which tokens were extracted for data analysis. English translations come from Mitchell (1968) and the recordings, Lekwungen spellings come from Mitchell (1968) or the workshop's transcriptions. Cases where two Lekwungen spellings have been provided are cases of schwas assimilating quality from a full vowel across a glottal stop. Both possible spellings discussed in Section 5.2.6 are given. Syllables analysed or discussed in the thesis are bolded.

Lekwungen	English
c̓á**kʷəs**	seven
č̓ál̓**əqʷ**	mountain
c̓íq̓ʷət	stab
c̓q̓ʷí**təŋ**	to be stabbed
c̓éʔkʷət	to wash
c̓əkʷétəŋ	to be washed/cleaned
c̓ə**kʷəlkʷə́t**əŋ	to be washed/laundered
č̓ə́**l̓əw**t	turn it
čəm̓č̓ə**m̓íqʷ**	great-grandparents
čəqʷ	to be burned
číyəʔ	blue jay
č**łət**	thick
čł**qə́n̓**xʷ	to starve
čqʷə́**təŋ**	to burn
há**qʷət**	to smell
həlí**sət**	to come back to life
kʷásən	star
k̓ʷé**t̓ən**	mouse
kʷə́ləŋ	to fly

kʷə**nét**əŋ	to grab someone
kʷə́nət	to take something
kʷən**síʔ**stəl̓	to hold hands
kʷəx̣**sín̓**əŋ	screaming
kʷín̓təl	fight
kʷítšən	chinook, spring salmon
líʔəl̓	far
łew̓	to be healed
łə**qʷén̓**əq	heal
ł**qel**č	month
ł**qéŋ̓**ət	west wind
ł**qit**	clothing
ƛ̓**áʔə**s or ƛ̓**áʔa**s	to meet
máʔəqʷ	duck
mə́wəč	deer
nə́čəŋ	laugh
nə**néy**əŋ	to always laugh
nə**qʷáy**	green
nə**sə́qʷ**	red
nə**ʔé**təŋ or n**eʔé**təŋ	to be named
ŋéqəʔ	snow
páyə	beer
pípa	paper
p**qʷə́č**ən	sand
qəláʔs	to be dull, unsharpened
qə́ləx̣	fish eggs
qəlí:məʔ	dirty
qəl̓qə́l̓əl	to be damaged, spoiled

q̓ʷá**qʷət**	to tan deer hide
qʷaʔ	water
qʷáʔ**pəł**p	devils club
qʷəl̓	soft
qʷəl**éʔe**l kʷə or qʷəl**éʔə**l kʷə	to send a message
qʷə**qʷél̓**	a speech
sə**séw̓**tətəŋ̓	to lay someone down
sə́w̓qtəl̓	whisper
s**əʔé**təŋ or s**eʔé**təŋ	to tell someone
siʔál̓ə**m̓iw**s	right side
síʔsəł	holy
s**kʷéč**əl	day
s**kʷéləqʷəs**	someone killed
skʷé**qəŋ**	flower
s**kʷin**áŋət	spirit power
s**łiq**ʷ	meat
sƛ̓é**ləqəm**	beast, monster
sƛ̓**eʔé**šən or (sƛ̓**əʔé**šən)?	a feast
s**méyəs**	deer
s**net**	night
š**néʔə**m	‘Indian doctor’
sŋé**nət**	rock, stone
spxʷə́**ləʔ**	wind
s**qəl**élŋəx̣ʷ	tree
s**qítəw̓**	a great fisherman
sq̓**qʷəm**	axe
sq**séq**	Galiano Island?

s**qʷel̓**	talk (n)
s**qʷə́l̓**əs	boil
sqʷə**qʷə́l̓**	sun
s**qʷín**qʷən	beads
stá**l̓əw̓**	river
š**təŋ**	walk
stə**qéy**əʔ	wolf
sti**qíw**	horse
stiqi**wál**əł	colt
stiw̓iʔəłə́wtxʷ	church (lit. spirit house)
stƛ̓**pél̓**qən	feathers
sx̣**éʔə**s or sx̣**éʔe**s	bad
s**ʔáłqəʔ**	snake
s**ʔél**əxʷ	someone old
s**ʔəł**tə́nəŋ	berry
s**ʔím**ələs	famine
ščəc̓**éʔə**ŋ̓ or ščəc̓**éʔe**ŋ̓	corner
táyəl	to go upstream
t̓áyəməŋ	to make someone put something on
t̓áyəmt	to put something on
t̓áyəmtəs	he/she put it on him/her
t̓é**ləw̓**	wing/arm
t̓ént̓ən	to arrive
tən̓čá**l̓əqʷ**	south wind
təŋəxʷ	earth
t̓íləm	to sing
wíqəs	to yawn

x̣**čit**	to know
x̣ʷəŋé**ləq**ən	currents, swift water
xʷsə́**lət**əŋ	to get blistered
yəsástəŋ	to be told
ʔápən	ten
ʔəmát(t)əŋ	to make someone sit down
ʔə́sə	I
ʔíɬən	to eat