A Phonological Analysis of Vowel Allophony in West Greenlandic

Asger Hagerup

Master's thesis in Linguistics

Norwegian University of Science and Technology

Spring 2011

Sammendrag

Et typologisk særpreg ved vestgrønlandsk og andre inuittspråk er at det underliggende lydinventaret består av ganske få enheter. Spesielt gjelder dette vokalene, som det bare finnes tre av. Den allofoniske variasjonen disse tre vokalene har er derimot rik. I denne oppgaven undersøker jeg de ulike vokalkvalitetene som oppstår gjennom allofonisk variasjon i vestgrønlandsk og foreslår fonologiske endringsmønster som jeg analyserer med et optimalitetsteoretisk rammeverk. Analysen viser at den allofoniske variasjonen som vokalene har kan forklares med artikulasjonstedene til konsonantene som omgir vokalene. I oppgaven sammenligner jeg også den fonologiske strukturmodellen elementfonologi med andre strukturmodeller.

Abstract

A typological peculiarity that West Greenlandic and other Inuit languages exhibit is that they have very few underlying segments. This is especially true for the vowels, of which there are only three. However, the allophonic variation of these three vowels is considerable. In this thesis I investigate the different vowel qualities arising through allophonic variation in West Greenlandic, and propose phonological patterns that are subsequently analysed in the framework of Optimality Theory. The analysis will show that the allophonic variation the vowels exhibit can be explained by the place of articulation of the consonants surrounding the vowel. In addition to this I will compare the phonological structures of Element Phonology with other theories of representation.

Takk til

Takk skal dere ha, María Sóley Smáradóttir og Gustav Svihus Borgersen, for motivasjon og gode råd.

Takk skal du ha, Jardar Eggesbø Abrahamsen, ikke bare for god veiledning, men også for meget interessante forelesninger opp gjennom årene.

Takk skal dere ha, Karen Langgård, Per Langgård og Birgitte Jacobsen, for et flott Nordkurs i Nuuk sommeren 2009, med god stemning og høyt faglig nivå.

Takk skal du ha, Judithe Denbæk, for all hjelp.

1 Introduction

1.1 Preliminaries

1.1.1 The languages in Greenland

I will begin this thesis with a very short introduction to the language situation in Greenland. From the perspective of language families there are two different families spoken as mother tongues by the inhabitants of Greenland: Eskimo-Aleut, represented by three main Greenlandic dialects and Indo-European, represented by Danish. By law, Greenlandic is the official language, but Danish is also taught in schools. (K. Langgård 2003, p. 215). Also, though the formal status of Danish is not very well defined, it is commonly used alongside Greenlandic in the fields of media, education, bureaucracy and business, making the language situation in Greenlandic bilingual in practice (P. Langgård 1995, p. 346f.). There are also a number of Danish loan words in Greenlandic, the oldest have been completely adapted to Greenlandic phonology, but many of the newer loanwords enter the language more or less unadapted. The phonology of these loanwords will not be an issue in this thesis either, and loanwords have been avoided in the investigation in chapter 2.

Fortescue (2004, p. 1389) labels the different varieties of Greenlandic, namely West Greenlandic, East Greenlandic and Polar Eskimo, as dialects, but notes that they are "highly divergent". All three dialects are part of a larger dialect continuum of Inuit languages encompassing Greenland and northern parts of Canada and Alaska (Fortescue 1985, p. 188). The differences between the dialects of Greenland will not be an issue discussed in this thesis, however. The dialect I will be studying is West Greenlandic, which is both the dialect with by far the most speakers[1] and the dialect that serves as basis for the official orthography. My main sources to West

[1] 45,000, versus 3,000 speakers of East Greenlandic and 750 of Polar Eskimo, according to Fortescue 2004, p. 1389. As West Greenlandic is spoken over a quite large area, from Uummannarsuaq/Kap Farvel in the south to Upernavik in the north there is dialectal variation within West Greenlandic as well (Olsen 2004, p. 116), but this will not be discussed in this thesis.

Greenlandic are the works mentioned in the next subsection as well as a recording of a native informant, introduced in 2.1, footnote 1. Henceforth I will refer to “West Greenlandic” as simply “Greenlandic”.

1.1.2 Previous works on the phonology of Greenlandic

While the body of linguistics works describing Greenlandic is quite large, with descriptions dating back to as far as 1750 (Fortescue 1985, p. 188), I have the impression that the focus of modern linguistic works on Greenlandic are mostly on syntax and morphology and not “pure” phonology, though phonological considerations, usually under the heading “morphophonemics” (Bergsland 1955, p. 5) or “morphophonology” (Sadock 2003, p. 12, Fortescue 1984, p. 343), do of course enter into morphological analyses, this field of study being the middle ground between syntax and phonology it is. The main work dealing just with Greenlandic phonology the last decades is undoubtably Rishcel’s *Topics in West Greenlandic Phonology* (1974), though I will not be comparing my analysis to corresponding analysis in this work, as I will be employing different theoretical frameworks (see the next section). Other shorter phonological descriptions are found in the works by Bergsland, Sadock and Fortescue, mentioned above. Also, a number of more recent works on Greenlandic phonology have dealt with prosody, such as e.g. Jacobsen (2000) and Nagano-Madsen (1992), but I will not discuss any prosodic issues in this thesis. The work that comes closest to the topic of this thesis is Wood (1971), though his study of allophonic variation of vowels is more phonetically oriented than mine, so my study is not fully comparable with this work either. See 2.6 for a brief comparison of the results from my spectral investigation of vowel quality with that of Wood’s, and also for other descriptions (in terms of IPA symbols) of allophonic variation of vowels in Greenlandic.

1.1.3 Purpose of the thesis

As the title of the thesis suggests, the main objective of this thesis is to investigate the allophonic variation of vowels in Greenlandic and give an analysis of the alternation patterns these exhibit. I will show that almost all the allophonic variation of vowels in Greenlandic can be explained as resulting from their neighbouring consononantal environments. As far as I know, very few analyses of Greenlandic phonological phenonema using Optimality Theory exist, so using Optimality Theory in the analysis is thus a point unto itself. Another objective is to show that the choice of Theory of Representation can be crucial for the analysis to work. I will be employing Element Phonology, which is a theory of representation not as commonly seen as the prevalent SPE-type theories of representation. The use of Element Phonology in an Optimality Theory framework is I believe also quite a novel approach, in that Element Phonology is usually combined with a framework such as Government Phonology.

1.1.4 Structure of the thesis

The remainder of this chapter will introduce the segmental inventory Greenlandic with reference to some of the works in the previous subsection, as well as an introduction to the theoretical framework I will employ in my analysis. Chapter 2 will present an informal phonetic study of vowel quality in Greenlandic, which will form the data basis to most of the analysis that follows. Chapters 3 and 4 constitute the main analysis part of this thesis, where I will use McCarthys's Span Theory (presented in 1.3.2) with Element Phonology structures (1.3.3.3) in an Optimality Theory framework (1.3.1), to analyse the variation patterns of the different vowel qualities presented in chapter 2. Chapter 3 will deal with changes in the vowels that may be labelled as assimilation, and chapter 4 will deal with changes in the vowels that may be labelled as reduction. I will show that using Element Phonology structures these two types of changes can be analysed using the same theoretical apparatus in terms of the Optimality Theory constraint hierarchy developed through the analysis. Finally in chapter 5 I will discuss the analysis presented in chapters 3 and 4 and investigate how assumed structures from two other theories of representation (introduced in 1.3.3) perform in the analysis compared to the structures I have used.

1.2 Introduction to Greenlandic

I will not give a very thorough introduction to various linguistic traits of Greenlandic here, as not very many are needed to proceed with the analysis. It is common, though not always very useful, to begin a phonological analysis of a language by introducing its underlying segmental inventory, so I will do this here. Based on the descriptions in Fortescue (1984, pp. 333-336), Rischel (1974, p. 23) and Bergsland (1955, p. 1) and the data from my informant introduced in 2.1, footnote 1, I will use the inventory of underlying segments shown below. An overview of the segmental inventory presented in this way is of course not so informative as it only has a marginal and very indirect reference to phonological structure, but I will present the relevant structures assumed in the different theories of representation for these segments in 1.3.3 and chapter 2.

Figure 1-1: Greenlandic consonant inventory

	Labials	Coronals	Palatals	Velars	Uvulars
Plosives	p	t		k	q
Nasals	m	n		ŋ	
Fricatives	v	s		ɣ	ʁ
Approximants		l	j		

Excepting /j/, all consonants may appear as either short or long, but phonological length for consonants will not be relevant to my analysis. Not included in this table are some underlying segments that are controversial, marginal or related to allomorphy, these will be mentioned below for the sake of completion.

In the first category we have a coronal/palatal affricate which Rischel symbolises as /ȼ/ (1974, p. 59). The controversy here I believe, is whether this segment should be viewed as an affricate rather than consonant cluster consisting of the segments /t/ and /s/. As it is not relevant for my analysis, I will not discuss the status of this segment, but it must be noted that I have classified it as coronal in the investigation in chapter 2. Under the category of "marginal" we have the segments /h/, /ɴ/ and /ṣ/. The first only occurs in some interjections and unadapted loanwords, the second, which Rischel (op. cit.) describes as marginal on p. 22, I could not find any traces of in the recording of my informant, and the third, which is described by Fortescue as an apico-postalveolar voiceless fricative (1984, p. 334) has merged with /s/ for younger speakers (loc. cit., Rischel 1974, p. 21), including my informant as it appears. Lastly, there are some consonantal segments that may be postulated to account for some allomorphic alternations. These are discussed and given a temptative analysis in 5.1.1, but will not be relevant for chapters 2, 3 and 4.

Figure 1-2: Greenlandic vowel inventory

	Front		Back
Close	i		u
Open		a	

When it comes to the vowels, they may also be long and short, but my data indicates that long /a/ is far more common than long /i/ and /u/. One reason for this is that the diphthongs /ai/ and /au/ that may arise from derivation or inflection are not permitted, and surface as [aː], except in the word-final position, where [ai] is permitted (Fortescue 1984, p. 344). A fourth vocalic segment, symbolised /i_2/ by Fortescue (loc. cit.) may be needed to account for some allomorphic alternations between [a] and [i], but as this segment does not have any distinct vowel quality of its own, I do not need to take the possible existance of such an abstract segment into consideration.

1.3 Theoretical background

In this section I will present an introduction to the theoretical frameworks that will be employed in this thesis. To avoid information overload, I will not necessarily include every aspect of these in this introduction, but portion out some of the information throughout the analysis. An important piece of information that will be presented in this section is the underlying structures I will assume for the segments introduced in the previous section. Element Phonology structures assumed for the vowel allophones are given in chapter 2, while the corresponding SPE-type and Parallel Structures Model structures for these are discussed in 5.2.

1.3.1 Optimality Theory

The grammatical framework that will be employed in my analysis is Optimality Theory (OT), a framework originating from the works of Alan Prince, Paul Smolensky and John McCarthy (Kager 1999, p. xi). In OT, phonological processes are analysed as occuring through the interaction of violable constraints. The constraints are thought to be universal, but languages may rank constraints differently, thus producing the variation seen in the languages of the world. Though all phonological material will violate some constraint, the material that obeys the highest-ranked constraints in a given constraint hierarchy is evaluated as "optimal" and thus surfaces as the phonological output. Most of the ideas presented in OT are not uncontroversial, but OT is probably the dominating framework of phonological investigation in use today. As the focus of this thesis is on theories of representation rather than the grammatical framework in which these representations are manipulated, I will not discuss that many aspects of OT in this thesis, but some of the virtues of this framework are mentioned in 5.1.1. I am assuming the basic workings of this framework to be well-known to the reader, so I will not give any further description other than the above here. The relevant OT constraints that will be used in the analysis will of course be properly introduced, partially in the next subsection, partially in 3.1 and otherwise throughout the analysis as they are needed.

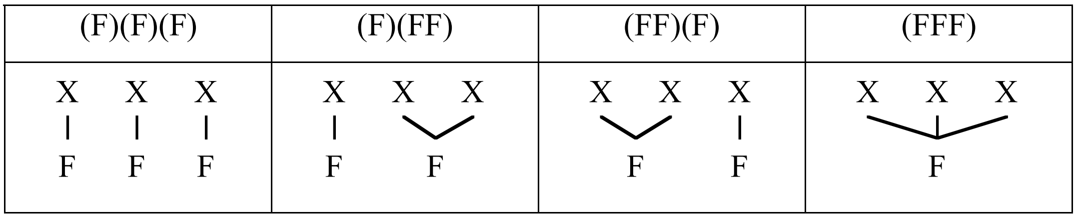
1.3.2 Autosegmental Phonology and Span Theory

Autosegmental Phonology (Goldsmith 1976) can be called an "Umbrella Theory of Representation" in that it is a theory of how the features of any Theory of Representation are organised in larger phonological units than the segment. In fact, Autosegmental Phonology effectively replaces the notion of a segment being a "bunch of features grouped together" with the notion that each feature is itself a segment, an autonomous entity organised temporally by being associated to a positions called skeletal slots in a timing tier. Feature deletion and insertion can thus be viewed as the deletion or insertion of association lines between features and skeletal slots. As Autosegmental Phonology is also well-known and used prevalently today, I will not go into further detail here.

Span Theory (McCarthy 2004) incorporates some further representational assumptions to Autosegmental Phonology and intruduces some new OT constraints for these. It can thus be viewed both as an extension to the grammatical framework of OT and as an extension to Autosegmental Phonology. In Span Theory, a span is a series of one or more identical features that are associated to adjacent[2] skeletal slots. Span Theory includes the representational assumptions that all features are exhaustively parsed into spans (op. cit., p. 2) and that for each span, one skeletal slot (which we may continue to label segment, for the sake of convenience) functions as the unique head of this span (loc. cit.). Thus, for the sequence of features [FFF] we may have the possible parsings [(F)(F)(F)], [(F)($\underline{F}$F)], [(F)(F$\underline{F}$)], [($\underline{F}$F)(F)], [(F$\underline{F}$)(F)], [($\underline{F}$FF)], [(F$\underline{F}$F)] and [(FF$\underline{F}$)], where the parantheses indicate spans and underscores indicate the position of the span head when the span consists of more than one feature. The figure below shows the corresponding autosegmental representations of the different spans (span heads are not indicated here, a skeletal slot is symbolised by "X"):

[2] One common notion in Autosegmental Phonology is that consonants and vowels are coordinated on different timing tiers. In this sense two vowels can be said to be adjacent even though there is an intervening consonant. Since I will be discussing feature spreading, i.e. insertion of association lines, from consonants to vowels, such an interpretations of adjecency will not be needed.

Figure 1-3: Autosegmental representation of spans



McCarthy demonstrates the use of Span Theory by analysing spreading of nasility in the language Jahore Malay, where nasility spreads from nasals to glides and vowels. In this analysis he uses two types of constraint, *A-Span and Head. The former assigns violation marks for occurances of adjacent spans of the same feature. The latter demands that such and such segments head spans of such and such features. The precise definition of these constraints are found in 3.1.1 and 3.1.3, respectively. He presents the following tableau (adapted here from McCarthy 2004, p. 7) for the input /mawasa/, which has the output [mãw̃ãsa] (corresponding span-wise to the candidate [(<u>m</u>awa)(<u>s</u>a)]):

/mawasa/	Head (F, –nas)	*A-Span (nasal)	Head (G, –nas)	Head (V, –nas)
☞ (<u>m</u>awa)(<u>s</u>a)		*	*	***
(<u>m</u>awasa)	*!		*	***
(<u>m</u>a)(<u>w</u>a)(<u>s</u>a)		**!		***
(m)(a)(w)(a)(s)(a)		**!***		

In this tableau, F is an abbreviation for the SPE feature bundle characterising fricatives, G is the corresponding for glides and V is the corresponding for vowels. The two last candidates are here eliminated because they have too many adjacent spans of the feature [nasal] in relation to the winning candidate, while the candidate with the least spans of [nasal] is eliminated because the grammar of Jahore Malay considers it more important that fricatives head oral (i.e. [–nasal]) spans than having as few adjacent spans as possible. There are a few more constraints to Span Theory than the two mentioned above, but these will be introduced as the need for them arises. In the following chapters I will use Span Theory in a manner similar to the analysis above, to spread the Element Phonology equivalent of place features from consonants to vowels.

1.3.3 Theories of Representation

A major part of the discussion in this thesis (see 5.2) will revolve around how some assumed representational structures of different theories of represention will perform in the analysis in chapters 3 and 4. I have chosen Element Phonology, based on its presentation in Harris and Lindsey (1995), as the theory of representation to work with in the analysis. Element Phonology structures will be compared to two other alternatives: 1) textbook SPE-type structures, such as those presented on pp. 54-55 in Katamba (1989), and 2) structures from a more full-blown Feature Geometry model, such as presented in Morén (2003). Each of the three theories of representation will be introduced in a separate section below. Here I will also show the relevant assumed representations for the segments in figures 1-1 and 1-2, and briefly highlight some properties of the different theories of representation.

1.3.3.1 Textbook SPE-type

An SPE-type theory of representation should not need much introduction as theories of representation using SPE features have been around for a while and are widely used. It is worth noting that this theory of representation is usually used with exclusively binary features, and this entails that every feature is present in the representation of every segment[3]. The relevant feature values for the analysis are only the features defining place of articulation that are shared by consonants and vowels, as features unique for consonants would not be able to spread to vowels.

---

[3] Though we can find analyses using SPE features where we can have a three-way opposition between 1) a positive feature value, 2) a negative feature value, and 3) an underspecified feature value or the feature is absent.

Figure 1-4: SPE place features

	labials	coronals	velars	uvulars	a	i	u
high	–	–	+	–	–	+	+
low	–	–	–	+	+	–	–
back	–	–	+	+	+	–	+
tense	–	–	–	–	–	+	+
round	+	–	–	–	–	–	+

1.3.3.2 Morén's Parallel Structures Model

Bulding on work by Clements (1991), Morén has developed a Feature Geometry model entitled "The Parallel Structures Model of Feature Geometry" (2003). With this model he seeks to accomplish three things: 1) unifying the representations of vowels and consonants, 2) economising the amount of structure and features needed and 3) merging spoken language phonology with the phonology of signed languages. Unlike SPE, where features are unbundled, theories with Feature Geometry recognise a relationship between certain features, this is expressed by organising features in a hierarchy and bundling certain features together under a shared mother node. Unlike the previous subsection, all features in this theory of represention are unary, that means that they are either present or not present. In Morén's model there are four nodes: laryngal, place (passive), place (active) and manner. For each of these four nodes there are separate nodes for consonants and vowels, the V nodes being daughters of the C nodes (op. cit., p. 265). This is to block feature spreading from consonants across vowels, which is typologically rare, and allow feature spreading from vowels across consonants (e.g vowel harmony). For my analysis, I will only find use for the manner and passive place nodes, as it is not certain that vowels have an active place node (op. cit., p. 221), and laryngal features do not enter into the analysis of vowel allophony. Under the manner node we find the features [closed], [open] and [lax]. The feature [lax] corresponds to slightly weaker articulator rigidity for both consonants and vowels (op. cit. p. 228), but the features [closed] and [open] correspond to slightly different articulatory aspects whether present under a C-manner node or a V-manner node. What will be relevant for this analysis, is that plosives have [closed] and fricatives [open] under their C-manner noder, while high/close vowels have [closed], low/open vowels have [open] and mid vowels have both [closed] and [open] under their V-manner node (op. cit., pp. 228f.). Under the passive place node we find the features [lab(ial)], [cor(onal)], [vel(ar)] and [phar(yngal)] (op. cit., p. 265). Each of the place features may when present under a C-place node also have the presence or absence of the feature [post(erior)], and consonants with the feature [post] are articulated slightly further back in the oral cavity than consonants without it (op. cit. p. 216). The features we will need in the analysis are summarised in the following table:

Figure 1-5: Manner and place features in Morén's Parallel Structures Model

	labials	coronals	velars	uvulars	a	i	u
lab	√						√
cor		√				√	
vel			√	√			√
phar					√		
post	(v)	(j)		√			
open	Depends on the consonant				√		
close						√	√
lax					?		

Since /v/ is labiodental and /j/ is palatal, they also have the feature [post]. I am uncertain as to whether /a/ should have the feature [lax] or not, if we want a structure for /a/ here corresponding to its structure in the previous subsection, then /a/ should probably have the feature [lax]. As mentioned above, manner features for consonants depends on what consonant we are dealing with.

1.3.3.3 Element Phonology

Of the four Theories of Representation discussed in this thesis, Element Phonology is the one with fewest similarities with the other ToRs. On their own, the atomic units of the other theories are not interpretable as segments until they are bundled together in a certain structure, but even a single element, or prime[4], in Element Theory can be interpreted as a segment. Element Theory is mostly used in the frameworks of Government Phonology, but the types of elements, their interpretation and how they are organised within a segment varies. Elements can be viewed as cognitive unit for a certain trait present in the sound signal of a segment. Harris and Lindsey (1995) use the notion of headedness in segments compounded by several elements, where the head element represents the most salient trait of the segment (p. 58). Another strategy mentioned is using multiple occurances of the same element in the representation of a segment to mark preponderance (op. cit. p. 57), or to make possible a symmetrical dependency relation between elements as well as the asymmetrical dependency relation of head – nonhead (Roca 1994, p. 117). I will only consider the first approach mentioned. The elements described in Harris and Lindsey (1995) are:

[A]: A resonance pattern where the spectral energy minima are found at the top and bottom of the sonorant frequency zone (said to be "roughly speaking between 0 and 3 kHz", op. cit. p. 53). In terms of vowel formants this resonance pattern will have a high F1 converging with F2 and a low F3. Interpreted independently as an open unrounded vowel or a uvular approximant.

[I]: A resonance pattern where the spectral energy minimum is found in the middle of the sonorant frequency zone (low F1, high F2 converging with F3). Interpreted independently as a closed front unrounded vowel or a palatal approximant.

[U]: A resonance pattern where the spectral energy minimum is found above the middle of the sonorant frequency zone (low F1 converging with F2, low F3). Interpreted independently as a closed back rounded vowel or a labial approximant.

[4] I will not use this term, however I may vary between denoting the elements of Element Phonology "elements" and "features". I do not intend any difference in meaning by this.

[ə][5]: A neutral resonance pattern (a roughly equal distribution of spectral energy in the sonorant frequency zone). This element is said to be present in every segment as a "base line on which the elemental patterns associated with [A], [I] and [U] are superimposed." (op. cit., p. 60). A vowel reduction pattern where vowels reduce to schwa is thus viewed as the loss of the more distinct resonance elements [A], [I] and [U], revealing a latent [ə] As the neutral element is always present in every segment, the only way it can have any impact on the sound signal of a segment is when it functions as a head (op. cit., p. 62).

We can for practical purposes consider these four elements the "place features" of Element Phonology, though note that they make no reference to place, which is a big conceptual difference from the other two Theories of Representation introduced above. For plosives and fricatives, some additional elements are needed, as well as a special resonance element for coronals:

[R]: An element marking coronality, which is not properly defined in terms of resonance. The independent interpretation is an alveolar liquid (commonly [l]). I will reject this resonance element and instead define the resonance of coronals in terms of the four elements above in the analysis.

[h]: Noise/stridency, i.e. aperiodic energy in the sound signal. Interpreted independently as a glottal fricative.

[ʔ]: Occlusion, i.e. an amplitude drop and loss of resonance in the sound signal. Interpreted independently as a glottal stop. This element is usually symbolised as [?], but I will use [ʔ] for the sake of clarity. How to represent nasality and voicing is not mentioned in Harris and Lindsey (1995), but I will not need these segmental traits for the analysis.

We can see certain similarities between this theory of representation and that of Morén, for example, the 'resonance elements' [A], [I], [U], [ə] have certain

[5] This element is more commonly symbolised as [@] but I will use [ə] as it is more mnemonic, as the independent interpretation of this element is a central schwa-like vowel or velar approximant: "The supralaryngeal vocal-tract configuration associated with the neutral position approximates that of a uniform tube and produces a schwa-like auditory effect." (Harris and Lindsey 1995, p. 60).

correspondances with the place features [phar], [cor], [lab] and [vel]. Like Morén's theory of representation, the features are exclusively unary, and this theory of representation can also be said to represent an attempt to unify the representations of vowels and consonants.

Figure 1-6: Place features in Element Phonology

	labials	coronals	velars	uvulars	a	i	u
U	Hd						Hd
R		Hd					
I						Hd	
Ə	√	√	Hd	√	√	√	√
A				Hd	Hd(?)		

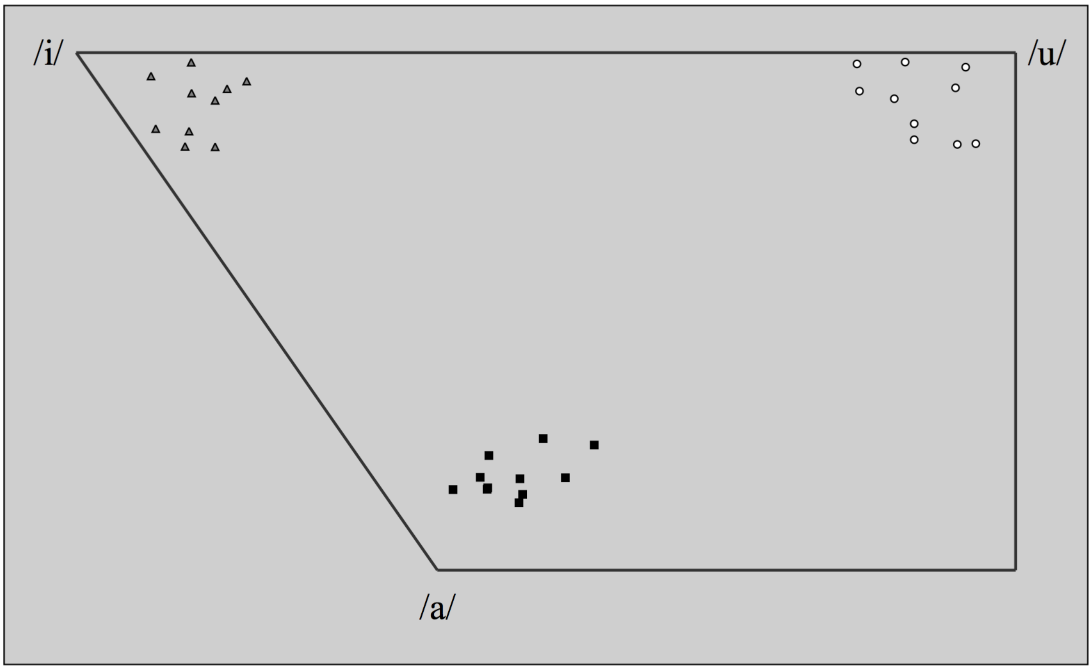
As mentioned, the element [Ə] is always present, but will not have any impact on the segment when it is not in the head position. Therefore, when referencing Element Phonology structures in the text, I will only include [Ə] in structures when it functions as head. I will always write the head element of such structures first, and remain agnostic as to if there are additional dependency relations if more than two elements are present in the structure, i.e. if there is a difference between e.g. [Ə, I, U] and [Ə, U, I], as discussed in 5.1.3. Again, we may wonder what structure we really want for /a/, if it is /A/ or /Ə, A/. I have therefore marked this vowel with a question mark, as to whether [A] is the head or not. Again, if we want a corresponding structure to /a/ as in 1.3.3.1, /Ə, A/ would be preferrable.

2 An informal study of vowel quality

2.1 Introduction

As introduced in 1.2, Greenlandic only has three underlying vowels: /a, i, u/. We would then perhaps expect different realisation of e.g. /a/ to be pretty close to each other in the vowel space, so if we were to somehow plot 10 different realisations of /a/, /i/ and /u/ in the vowel quadrilateral, we would get a plot such as this one, where squares represent realisations of /a/, triangles represent realisations of /i/ and circles represent realisations of /u/:

Figure 2-1: Possible representation of realisations of vowels /a, i, u/



However, this is not the case. Using a recording from a native informant[1], I studied the different realisation of vowels and plotted them in a graph simulating a vowel space akin to the one above.. The reason for doing this is that I wanted my analysis to be based on some form of parametric data rather than just my impressions of what

[1] My informant was a woman in her twenties from the town of Sisimiut, and the recording material was a few pages from a novel in Greenlandic. The data was recorded on the 12th of November 2009 in the Phonetics Lab at the Department of Language and Communication Studies, NTNU.

vowels were pronounced, as the vowel qualities I would perceive would probably be biased by the languages I am used to. One common way of plotting vowels in a space such as the one above is using the frequency of a vowel's first formant (F1) as values for the *y*-axis and a the frequency of the vowel's second formant (F2) as values for the *x*-axis. To simulate a space such as the vowel quadrilateral the values on both axes are plotted in reverse order. This is because values for F1 correlate with the perception of vowel height, where open vowels have a high F1 value and close vowels have a low F1 value, and values of F2 correlate with the perception of vowel frontness, where front vowels have high F2 values and back vowels have low F2 values (Johnson 1997, p. 113). The model I will use in this chapter is a bit more complicated than just plotting values in Hertz for first and second formants. The next section will explain the workings of this model, before the data is presented in 2.3. The chapter ends with an overview of the notation employed in other works to symbolise different vowel allophones.

2.2 Description of the model used

Since some of the values I measured for a vowel's F3 (third formant) went as low as approximately 1,5 kHz and one of the Theories of Representations I will apply has features (the resonance elements described in 1.3.3.3) based the spectral data between 0 and 3 kHz, I wanted to employ a model that takes some higher formants than F2 into consideration too. Also, as this is a paper on phonology I am more interested in how the vowels are perceived, rather than the bare acoustic facts. Therefore, the model I will use is one that uses the notion of an effective second formant (F2′), based on findings that the "perceived second formant" is sometimes different from the actual F2, as two formants are perceived as one if they are sufficiently close together (de Boer 2001, p. 48). Meaning, that the "perceived F2" may sometimes be higher than the actual F2 due to proximity of higher formants. In this model F1 measured in

Barks, a scale that models human perception of pitch[2], gives values for the *y*-axis and values for the *x*-axis are given by the Bark values for F2′. The value for the effective second formant is either F2 itself, a weighted average of F2 and F3 or a weighted average of F3 and F4. The actual algorithm used is:

$$\mathrm{F2}' = \begin{cases} \mathrm{F2}, \text{ if } \mathrm{F3} - \mathrm{F2} > c \\ \dfrac{(2-w_1)\mathrm{F2} + w_1\mathrm{F3}}{2}, \text{ if } \mathrm{F3} - \mathrm{F2} \le c \text{ and } \mathrm{F4} - \mathrm{F2} > c \\ \dfrac{w_2\mathrm{F2} + (2-w_2)\mathrm{F3}}{2}, \text{ if } \mathrm{F4} - \mathrm{F2} \le c \text{ and } \mathrm{F3} - \mathrm{F2} < \mathrm{F4} - \mathrm{F3} \\ \dfrac{(2+w_2)\mathrm{F3} - w_2\mathrm{F4}}{2}, \text{ if } \mathrm{F4} - \mathrm{F2} \le c \text{ and } \mathrm{F3} - \mathrm{F2} \ge \mathrm{F4} - \mathrm{F3} \end{cases}$$

Where the weights used are:

$$w_1 = \frac{c - (\mathrm{F3} - \mathrm{F2})}{c} \text{ and } w_2 = \frac{(\mathrm{F4} - \mathrm{F3}) - (\mathrm{F3} - \mathrm{F2})}{\mathrm{F4} - \mathrm{F2}}$$

and c is the critical distance, i.e. the minimum distance in barks required for two formants not to be perceived as one. The value used in this paper is c = 3.5 Barks which is thought to be optimal for this model (op. cit., p. 49).

The point of interest in my investigation was how the place of articulation of the surrounding consonants affects the vowel quality, so the values for F1 and F2′ were calculated from measurements of the first four formants of a number of short vowels in non-nasal contexts[3]. Also, contexts with central approximants were avoided as these make deciding borders between consonants and vowels difficult. The measurements were done in the computer program Praat (Boersma and Weenink 2010) using the Akustyk script (Plichta 2010) to query the F1 to F4 values at the approximate centre of the vowel, using Akustyk's linear predictive coding (LPC)

---

[2] Values in Barks in this paper are calculated from Hertz (f) with the formula $\frac{26.81 \cdot f}{1960 + f} - 0.53$ (taken from Traunmüller 1990)

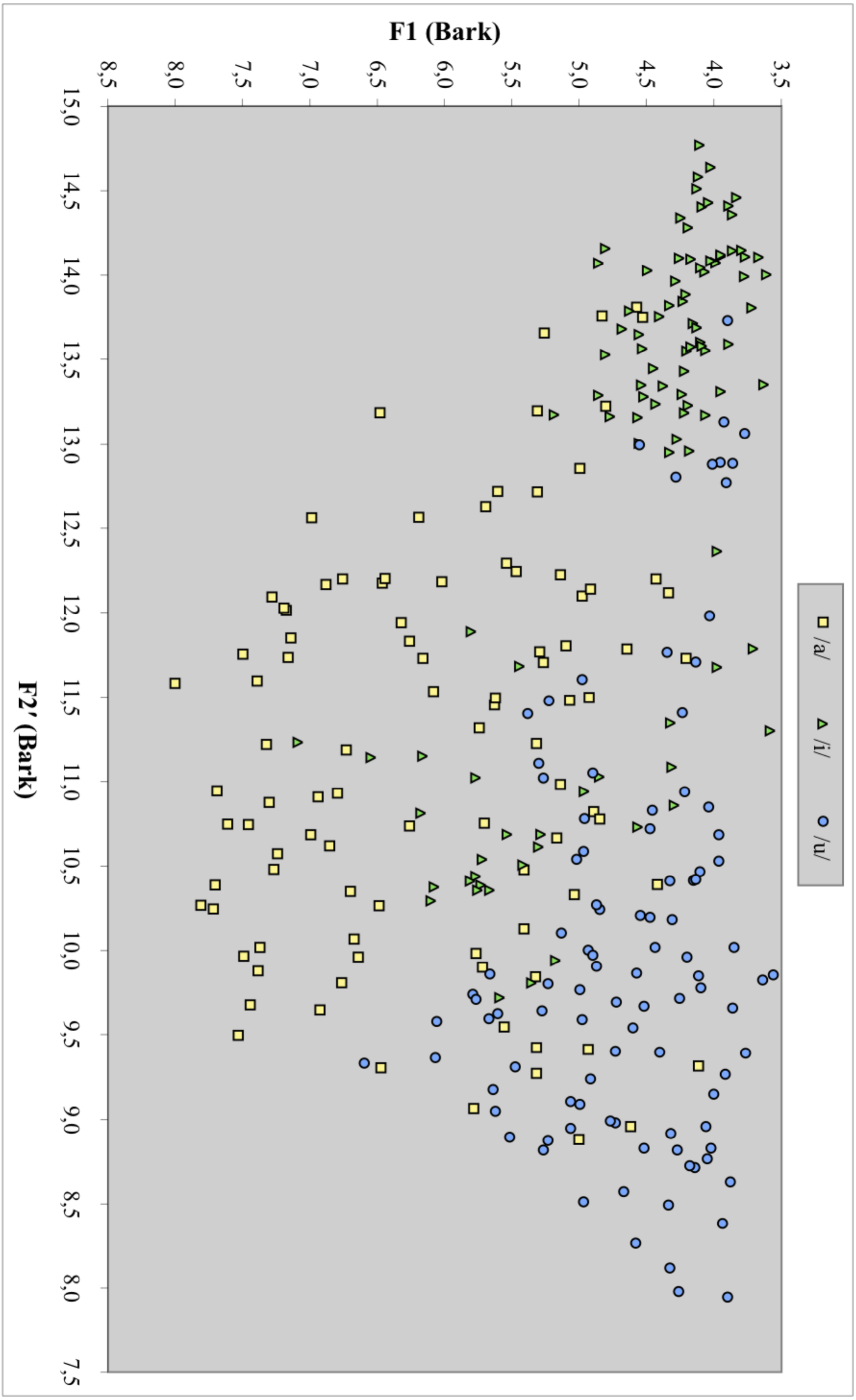
[3] Nasal contexts were excluded as nasalised vowels show different spectral features due to resonances in the nasal cavity.

algorithm, and taking note of the place of articulation of the surrounding consonants. With all this said I now find it appropriate to issue a very strong *caveat* about this investigation: as the title of this chapter suggests, it is an "informal study". There are many considerations to be taken when measuring formants, many of which I have ignored. As mentioned above, the investigation in this chapter is an alternative to basing my analysis on impressionistic data of the vowel qualities, so whether or not this parametric data is completely reliable or not, it is at least somewhat more transparent than the alternative.

2.3 The data

In the text the results will be presented graphically, but I also include a list of all values measured and calculated in Appendix B. To get started, we can have a look at all the tokens measured simply sorted by the underlying vowel in figure 2-2. This graph is somewhat like the vowel quadrilateral, the *x*-axis represents varying degrees of close to open and the *y*-axis varying degrees of front to back. This graph is not so useful in deducing a phonological system, but it shows very clearly that there is a great deal of overlap between the three different underlying vowels. Rather than just occupying a confined space at the corners of the vowel quadrilateral, the different realisations of vowels fill a much larger space. However, when we sort the different tokens into categories depending on their contexts (i.e. the place of articulation of the surrounding consonants), we can see a pattern. It is this pattern I will analyse in chapters 3 and 4 using Span Theory as presented in 1.3.2 and Element Phonology representations, as presented in 1.3.3.3. But first, I will present graphs of the same format as figure 2-2 for each of the three vowels to be used as data to decide what the different allophones of the vowels may be.

Figure 2-2: All vowel realisations in an F1-F2' space sorted by underlying vowel



For each vowel I will present two graphs, first one where tokens have been sorted to show the place of articulation for both the preceding and the following consonant, then one where I have conflated the contexts which I believe yield same allophones. In all the graphs, the allophones I propose are indicated by outlined areas.[4] The graphs are preceded by a description of the allophones, where the structural descriptions of the allophones in terms of Element Phonology are introduced. Note that the structural descriptions here are more important than the choice of IPA symbol I use to denote the allophone, though I have tried to select IPA symbols that I mean adequately describe the vowel quality of the allophones. The structural descriptions will not be fully justified until the analyses in chapters 3 and 4.

The graphs that follow (figures 2-3 to 2-8) all have legends to show what tokens represent what, but there is a pattern to this that I will briefly explain here in order to ease the understanding of the graphs. In the graphs that show the full context of the vowel's environment, the form of the marker showing a token shows the following context and its colour shows the preceding context. In the conflated graphs, one form for each vowel is used, and its colour shows the process I believe have affected that token. This can be summed up in a table:

Marker form	**Meaning in graph**	
	Full	*Conflated*
Dash	_#	not used
Circle	_labial	/u/
Triangle	_coronal	/i/
Diamond	_velar	not used
Square	_uvular	/a/

Marker colour	**Meaning in graph**	
	Full	*Conflated*
Black	#_	Faithful
Blue	labial_	Rounded
Green	coronal_	Fronted
Red	velar_	Centralised/reduced
Yellow	uvular_	Retracted/lowered

[4] The areas where decided by drawing a line arount the majority of the tokens in question and then shrinking this area to about half the size so as to not have so much overlap between the different realisations. It must be stressed that it is not a product of a statistical treatment of the data, but meant to serve illustrative purposes.

It must also be mentioned that there are some contexts where no tokens were measured. These are marked with an asterix (*) in the legend. For reference, a graph showing the allophones of all vowels together (i.e. a conflation of figures 2-4, 2-6 and 2-8) is shown in Appendix C.

2.3.1 Realisations of /u/

Based on figure 2-3, I propose the following four allophones for /u/:

Allophone (IPA)	Description of realisation	Found in the context(s)	Structural description assumed
[u]	Faithful	#_non-uvular _labial	[U]
[ʉ]	Fronted	coronal_coronal	[U, I]
[ʊ]	Centralised/reduced	_# _coronal _velar	[Ə, U] (Harris and Lindsey 1995, p. 64)
[o]	Lowered	_uvular	[U, A] (op cit., p. 57)

I have not been able to find a source describing [ʉ] as [U, I]. Roca, using symmetrical dependencies as well as asymmetrical, as described in 1.3.3.3, uses the asymmetrical [U, I] as the structure for [ɯ], whereas the structure of [ɨ] (the unrounded counterpart of [ʉ]) is said to be a mutual dependency between [U] and [I] (1994, p. 119). Since I will not be using symmetrical structures, [U, I] seems a better choice than [I, U], as this structure will be used to represent [y] (see 2.3.3, below). See 3.2 for a further discussion of the structure of this allophone. In the analysis in 3.3, points to the structure of [o] being [A, U], see that section for a discussion. Figure 2-4 shows the realisations of /u/ sorted by the allophone I propose they belong to.

Figure 2-3: Realisations of /ʊ/ in an F1-F2' space sorted by full context

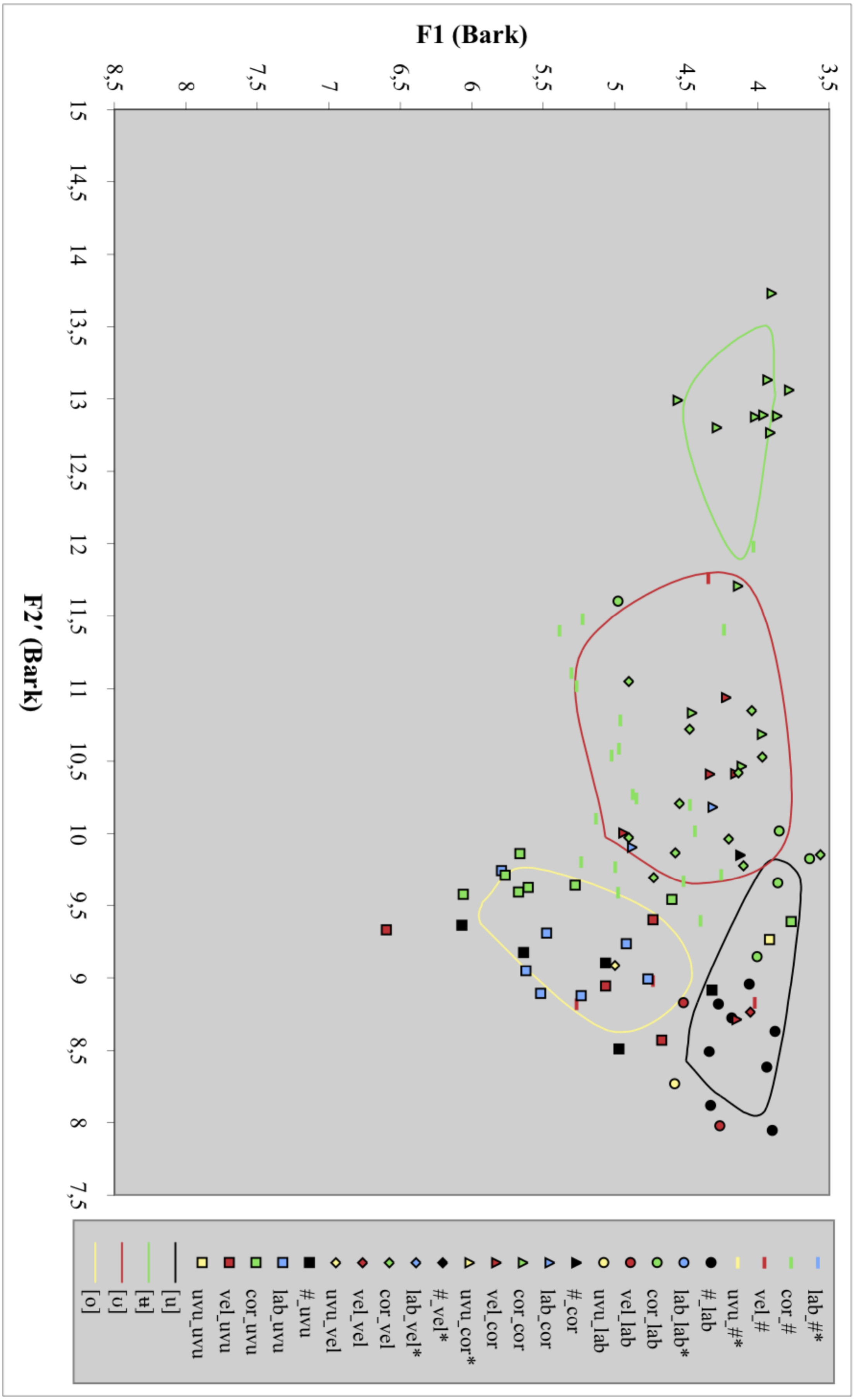
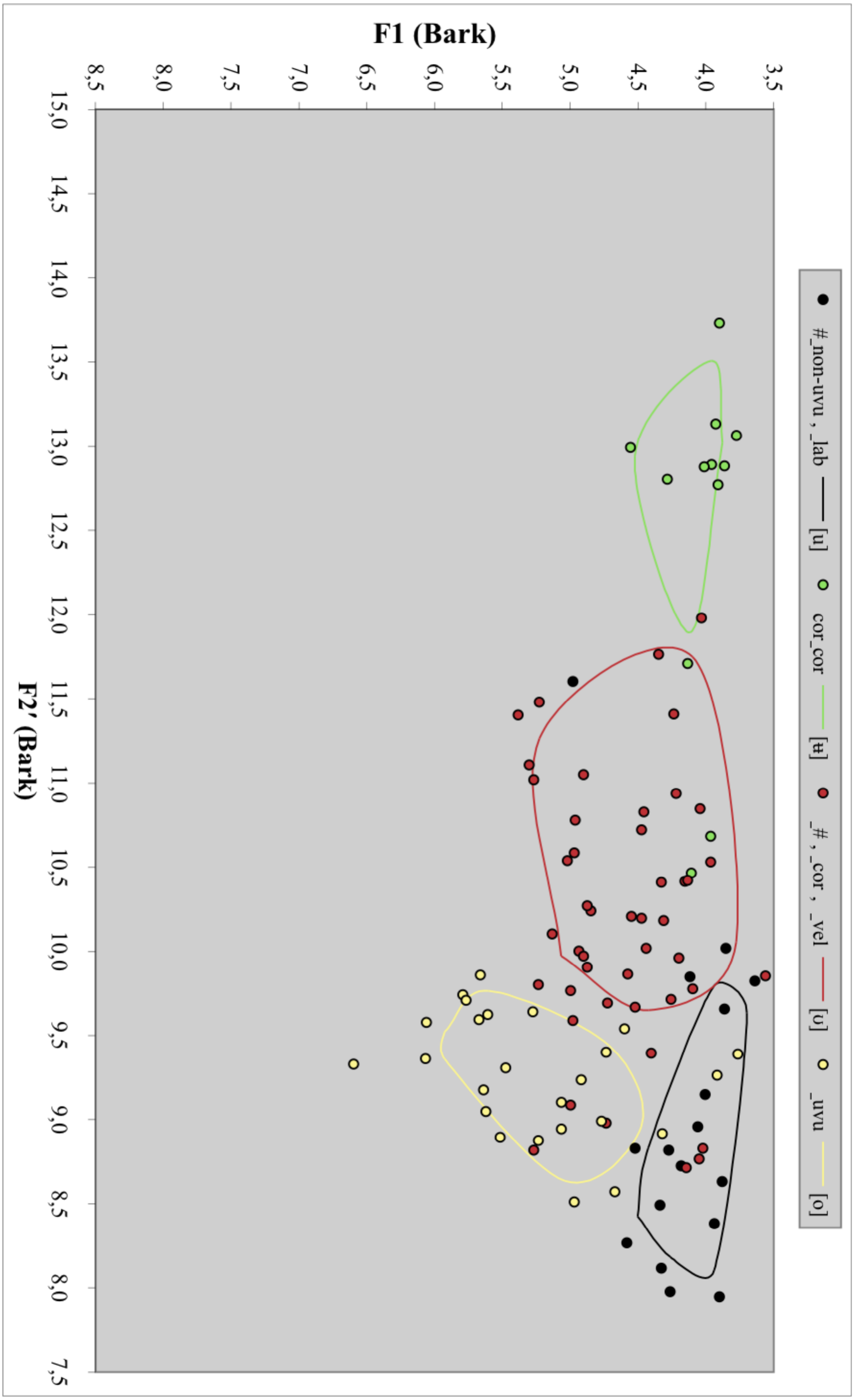


Figure 2-4: Realisations of /ɯ/ in an F1-F2' space sorted by conflated context



2.3.2 Realisations of /a/

Based on figure 2-5 I propose the following three allophones for /a/:

Allophone (IPA)	Description of realisation	Found in the context(s)	Structural description assumed
[a]	Faithful	#_non-uvular _#	[Ə, A]
[ə]	Centralised/reduced	_non-uvular	[Ə] (Harris and Lindsey 1995, pp. 61, 64)
[ɑ]	Retracted/tensed	_uvular	[A]

Again I have not been able to find a source of the structural description for one of the allophones, this time it is the structure of [a] as [Ə, A]. I have chosen this structure for two reasons. The first, as seen in figure 2-5, is that this allophone seems to be rather open, hence the need of the presence of the element [A] which represents such a quality (Roca 1994, p. 115). The second reason is that one possible distinction between [a] and [ɑ] is that the former is lax while the latter is tense (cf. the feature matrix in Katamba 1989, p. 54). If [a] is lax vowel it should thus be headed by [Ə] in its structure (cf. [ʊ] in the previous subsection). It can also be noted that the other allophones headed by [Ə] seem to cover a larger area than allophones who do not have [Ə] as their head, which fits well with figure 2-5 where realisations of [a] covers a larger area than realisations of [ɑ]. The last allophone seems to have no clear identity, as the realisations are spread out over a large area in figure 2-5. This fits well however with the interpretation of the [Ə] element, as Harris and Lindsey notes: "In element theory, the independent realization of [@] may be understood as covering the area of the traditional vowel diagram which is non-palatal, non-open and non-labial."[5] (1995, p. 61). Figure 2-6 shows the realisations of /a/ sorted by the allophone I propose they belong to.

[5] Note that I am using the more mnemonic symbol "Ə" instead of "@".

Figure 2-5: Realisations of /a/ in an F1-F2' space sorted by full context

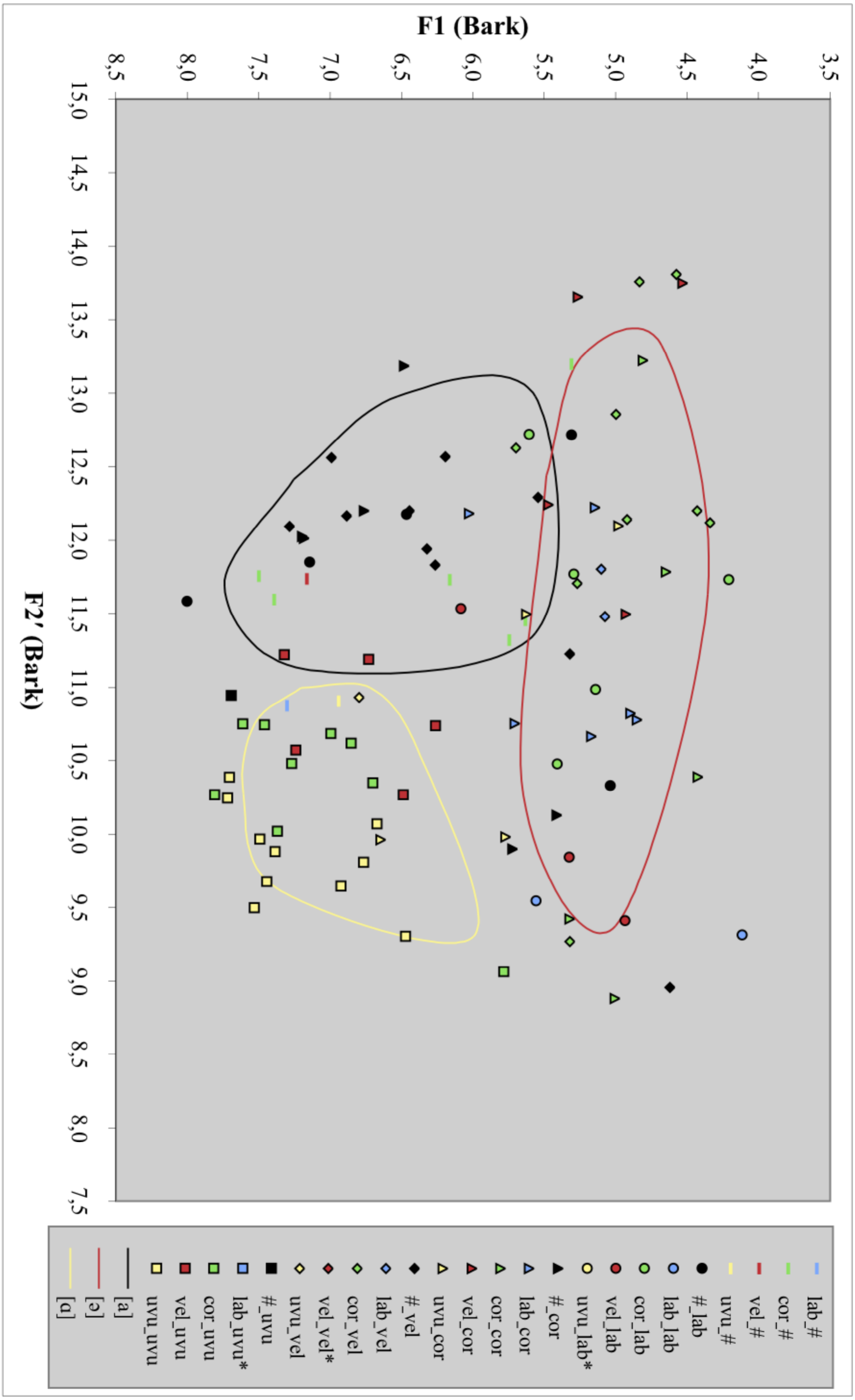
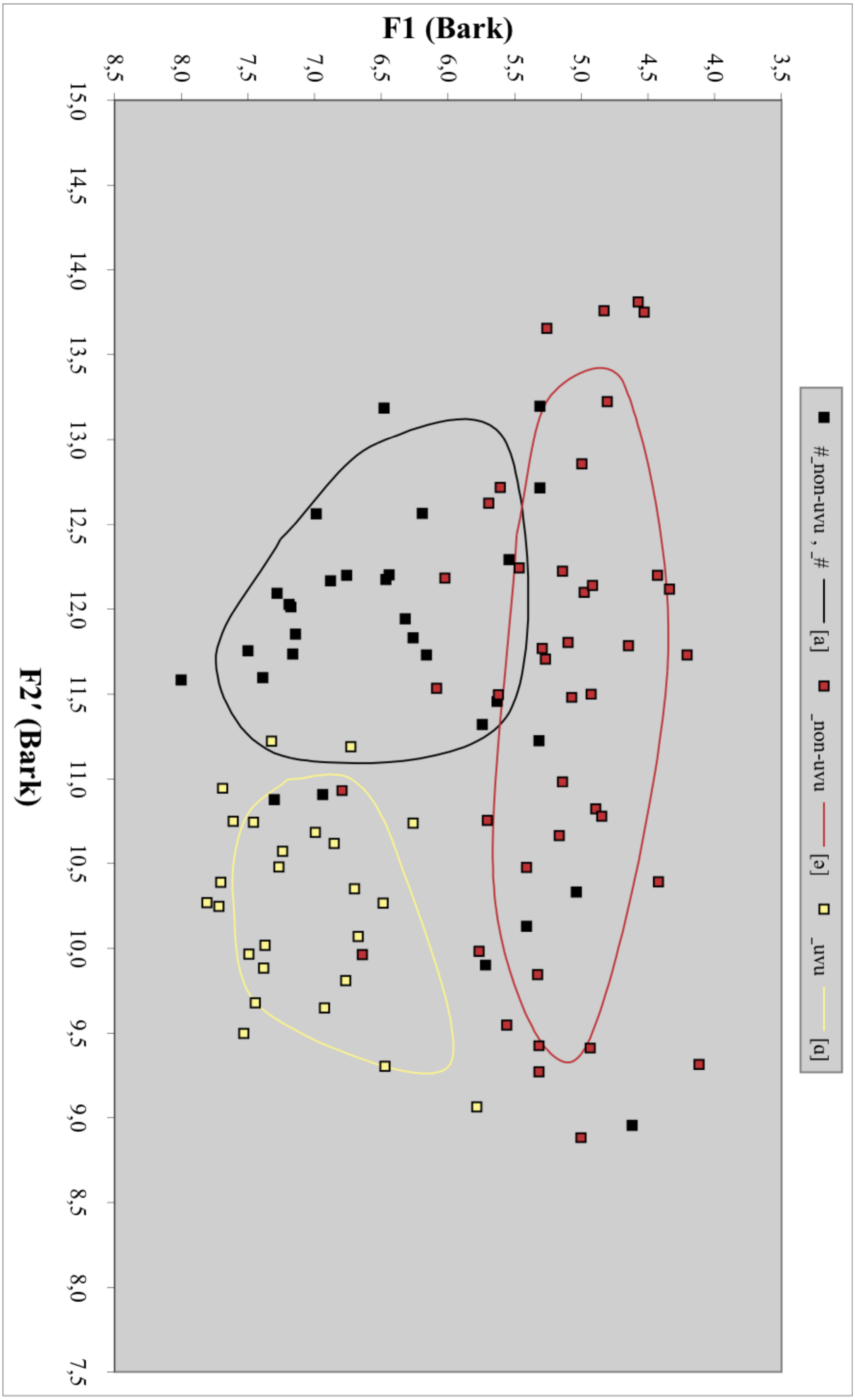


Figure 2-6: Realisations of /a/ in an F1-F2' space sorted by conflated context



2.3.3 Realisation of /i/

Based on figure 2-7, I propose the following four allophones for /i/:

Allophone (IPA)	Description of realisation	Found in the context(s)	Structural description assumed
[i]	Faithful	#_non-uvular	[I]
[y]	Rounded	_labial	[I, U] (Roca 1994, p. 119)
[ɪ]	Centralised/reduced	_non-uvular _#	[Ə, I] (Harris and Lindsey 1995, p. 64)
[ɐ]	Retracted/lowered	_uvular	[A, I]

It is not as easy as in the case of the other two vowels to separate the different tokens for /i/ into non-overlapping groups. The excepetion is of course the tokens of realisation of /i/ before uvulars, which are clearly much more open and retracted than the other allophones. Based on the area these realisations are found in relation to other vowel qualities, I will use [ɐ] to denote this allophone and the structure [A, I] for this vowel will be justified in 3.3. It is possible that the allophonic variation of /i/ should be analysed as simply [i] before non-uvulars and [ɐ] before uvulars, this is discussed in 4.4. Figure 2-6 shows the realisations of /i/ sorted by the allophone I propose they belong to.

Figure 2-7: Realisations of /i/ in an F1-F2' space sorted by full context

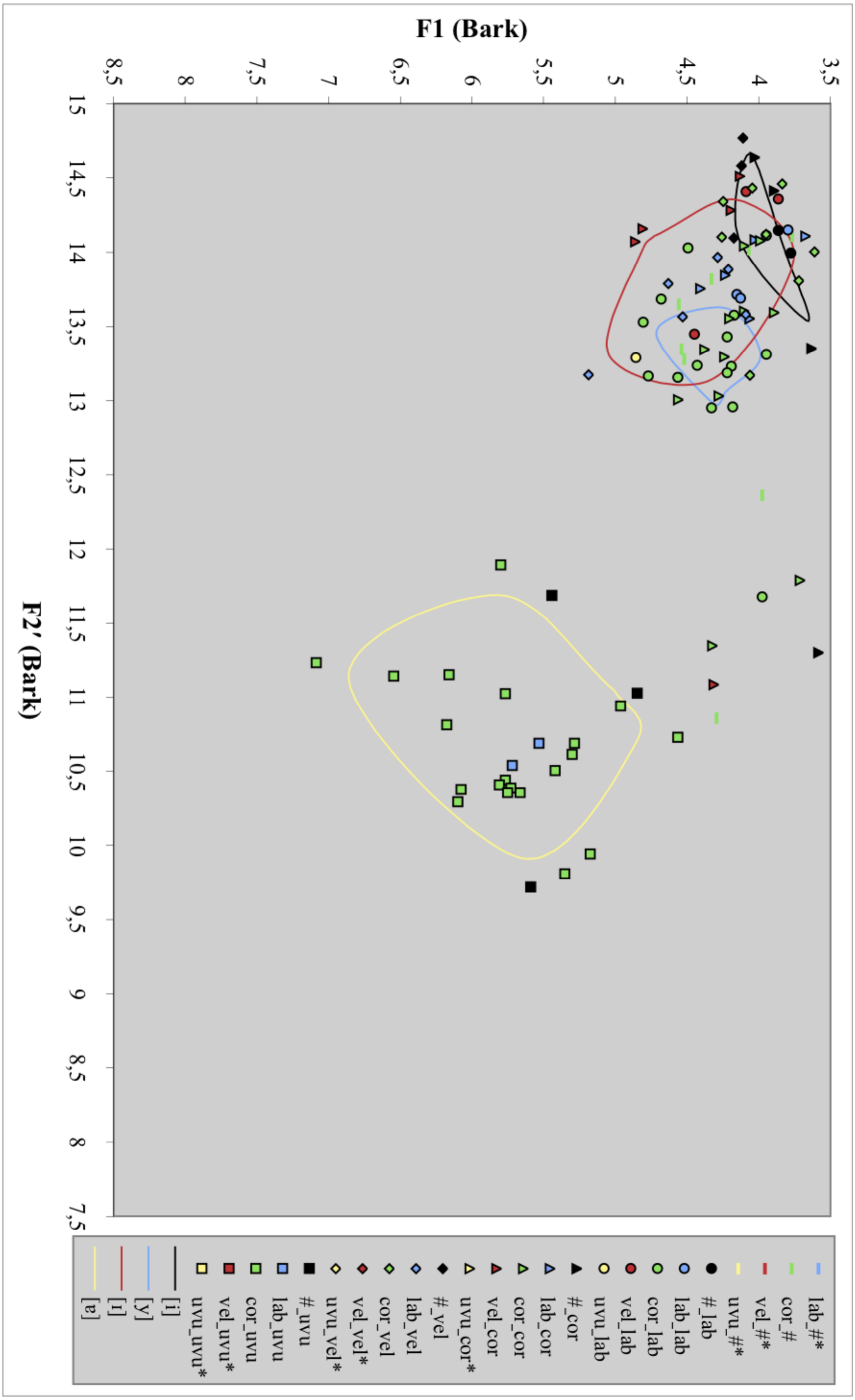
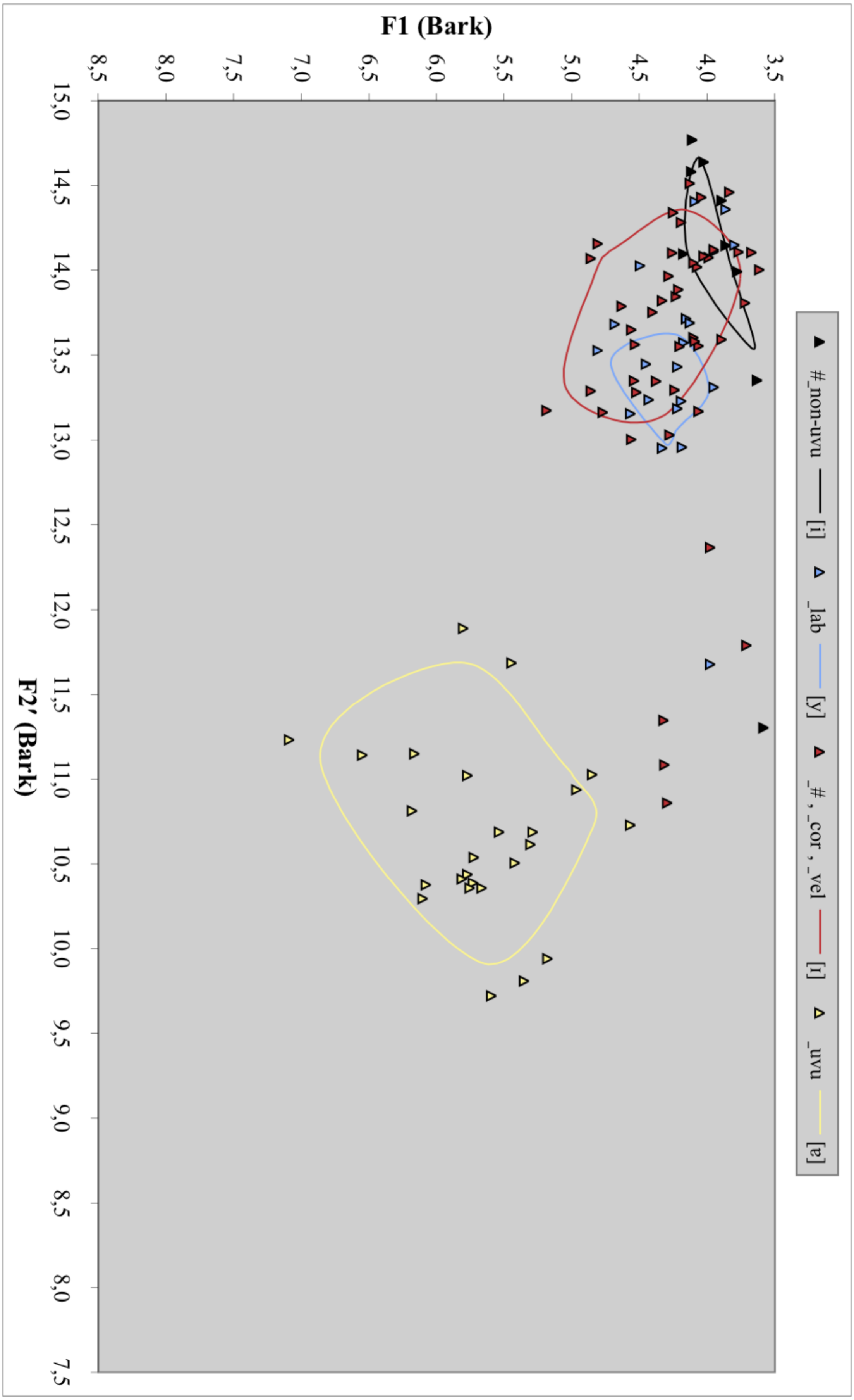


Figure 2-8: Realisations of /ɪ/ in an F1-F2' space sorted by conflated context



2.3.4 Long vowels

As the long vowels, especially /iː/ and /uː/ are much less frequent than the short vowels, I will not include any parametric data for these. The alternation pattern for the long vowels does not seem to be as complicated as that of the corresponding short ones, the data I have studied indicates that long vowels are realised faithfully except before uvulars, where they conform to the same changes as their corresponding short vowels. The required modifications to the analyses in order to incorporate long vowels is made in 3.5 and 4.6.

2.4 Descriptions of vowel quality in other sources

In this section I will briefly compare the data in this section with other descriptions of Greenlandic vowal quality. Rischel (1974, p. 135f.) notes that the vowel quality ranges from [ɛ] to [ɑ] for /a/, from [i] to [ë] for /i/ and from [ʉ] to [ɔ] for /u/, depending mostly on the quality of the following consonant, with most open variants occuring before uvulars. He also notes that vowels may be advanced before a coronal consonant, "[…]particularly if the vowel is also preceded by a corononal consonant. In such environmnents /u/ may be advanced so much that it lies somewhere between [ʉ] and [y] in quality" (op. cit., p. 136). Fischer-Jørgensen (1957, p. 474) transcribes /i/ and /a/ before uvulars as [a] and [ɑ], respectively, and elsewhere as [i] and [æ]. Fortescue (1984, p. 335f.) employs very fine-grained IPA notation, but in broad terms he discusses vowel ranges of /a, i, u/ similar to those of Rischel. It is worth mentioning that he cites [a̝], [i̞] and [u] as the "neutral realization" of the three vowels. Sadock (2003, p. 21) transcribes /a, i, u/ before uvulars as [a, e, o] and elsewhere as [æ, i, u], respectively. Finally, Wood (1971) makes a spectrographic study of vowel quality, presenting data in a manner described in the introduction to this chapter, i.e. with plots of F2, F1 values in Hertz in reverse order. He differentiates between two levels of prosodic prominence: "stressed vowels"[6] and "weak vowels" and also has

[6] I am uncertain as to what is meant by "stress" in this case. Jacobsen concludes that Greenlandic does not have lexically distinctive stress (2000, p. 64).

two levels of speech tempo: “carefully pronounced single word utterances” and “continous speech”, but only gives two contexts regarding place of articulation of surrounding segments, which are “pharyngal” and “non-pharyngal environments” as he labels them[7] (p. 68). The results he presents in figures 2b and 2e (loc. cit.) for “stressed vowels” in “continous speech” which he describes as “an average of 375 syllables per minute” (op. cit., p. 62) seem to be comparable with the data my informant produced (she had an average speech rate of approximately 250 syllables per minute). When it comes to transcription of vowel quality, Wood describes /a/ before a uvular as [ɑ], /u/ before a uvular ranging between [o] and [ɔ] and /i/ before a uvular as either [ɛ̈] or ranging between [ʌ] and [ɤ], also noting on the realisation of /i/ before a uvular that “The exact description of this allophone has been a matter of controversy.” (op. cit., p. 59). All in all, I feel the data in this chapter is more or less comparable to these other sources in terms of the acoustic quality of the allophones in question.

[7] Wood chooses to label what I am referring to as “uvulars” as “pharyngals” for phonetic considerations. I will stick to the term “uvular” so as not to cause any confusion in the text.

3 Vowel-to-consonant assimilation

3.1 Introducing the constraints

In this chapter I will analyse some of the changes in Greenlandic vowels described in the previous chapter. I will show that these should be categorised as assimilation, i.e. that one segment changes so as to me more alike another in terms of its featural makeup. I will begin this chapter by taking a closer look at the constraints that will be used in this chapter.

3.1.1 Constraints working for assimilation

One of the driving factors in my analysis of assimilation in Greenlandic is the *A-SPAN(F) constraint (McCarthy 2004, p. 4f.). The definiton of this constraint is: "Assign one violation mark for every pair of adjacent spans of the feature [F]" (op. cit., p. 5). The features I will be working with are the resonance elements of Element Phonology, as introduced in 1.3.3.3. To begin with, the *A-SPAN constraints that will be used are:

*A-SPAN(A): "No adjacent spans of [A]"

*A-SPAN(I): "No adjacent spans of [I]"

*A-SPAN(U): "No adjacent spans of [U]"

As mentioned in chapter 1, the assumption of Element Phonology is that [Ə] is present in each and every segment. Therefore we do not really need to concern ourselves with an *A-SPAN constraint for [Ə], as there is no need to spread this element from one segment to another. Recall from 1.3.3.3 though, that one element in a segment's structural description has a special function of being the "head" of that segment. It will be shown in 3.3 that we also need an *A-SPAN constraint that deals with spans of elements that function as heads. This constraint will be properly introduced when the need for it arises.

One problem that immidiately arises is the above definition of the *A-SPAN(F) constraint in relation to the theory of representation I will use use. McCarthy uses this constraint with a structures that are SPE-type representations, in other words a theory of representation where features are binary (with perhaps a few exceptions, such as [round]). This means that a feature [F] is always present, either as [+F] or [–F]. Not so in Element Phonology, here the features are exclusively unary, which means that under the definition of *A-SPAN(F) above, the spreading of features may not necessarily improve on the harmony of the candidate with respect to the *A-SPAN. This can be illustrated by the following example of vowel-to-consonant assimilation, where two output candidates for the input /tutːu/ n. "reindeer" are are considered (spans are marked by parentheses):

Figure 3-1: Spans of [A]*,* [I] *and* [U] *in candidates* [tutːu] *and* [tʉtːu]

IPA	t	u	tː	u		t	ʉ	tː	u
[A]									
[I][1]	(✓)		(✓)			(✓	✓	✓)	
[U]		(✓)		(✓)			(✓)		(✓)

For comparison, we can look at the spans of these candidates with some typical binary SPE features:

Figure 3-2: Spans of [back]*,* [high] *and* [low] *in candidates* [tutːu] *and* [tʉtːu]

IPA	t	u	tː	u		t	ʉ	tː	u
[low]	(–	–	–	–)		(–	–	–	–)
[back]	(–)	(+)	(–)	(+)		(–	–	–)	(+)
[high]	(–)	(+)	(–)	(+)		(–)	(+)	(–)	(+)

We see in figure 3-1 that the candidate [tʉtːu], whose first vowel is of the quality we would want according to the data in 2.3.1, is no more harmonic than [tutːu] as neither

[1] The presence of [I] in the structural description of /t/ is explained in 3.2.

of them violate the constraint *A-SPAN(I) under a strict interpretation of adjacency, i.e. the two spans of [I] in the candidate [tut:u] are not strictly speaking adjacent. This, in turn, means that the candidate [tʉt:u] would actually lose to [tut:u], as the latter candidate is fully faithful to the input /tutːu/. With binary features such as in figure 3-2 however, [tʉt:u] would be more harmonic than [tut:u] under the constraint *A-SPAN(back) as the former only has one pair of adjacent spans of [back] while the latter has three. To resolve this, we could instead of the *A-SPAN(F) constraint use a constraint such as *STRUCTURE, which is a constraint that can be used to penalise any kind of linguistic structure in the output. It could thus be used to favour candidates with fewer spans, i.e. candidates that maximise their spans as much as possible (or delete segments, depending on the ranking of faithfulness constraints), but this approach will not be pursued here. Some good reasons for not using a constraint such as *STRUCTURE comes from Gouskova, who notes that a) *STRUCTURE is redundant as an "economy constraint" as economy effects arise from constraint interaction anyway and b) The presence of *STRUCTURE in CON means that deletion processes could target unmarked structures for no real reason (2003, p. 18f.). So instead, I propose the following extension to the definition of *A-SPAN(F):

> For a phonological domain δ, the sequence of one or more segments with the absence of a unary feature [F] may be interpreted as a non-headed span that can be evaluated by *A-SPAN(F) iff there is one or more spans of [F] present in δ.

This comes quite close to saying that features should be binary rather than unary, but is not as I see it a refusal of the concept of unary features, as a "span of absence of [F]" is only possible as contrastive to the presence of a span of [F] in the same domain. This is not the same as saying that [F] is present in every segment even if the segment does not possess the trait F, as the case in binary feature representations. Meaning, in the candidates in figure 3-1, there is no "span of absence of [A]" in the word-level domain of either candidate as neither of them have any spans of [A], but there is now a difference in the performance of the two candidates under *A-SPAN(I). Since there is a span of [I] present in the word-level domain of both candidates, the absence of [I] may be interpreted as a span, so that [tutːu] receives three violation marks as it now has the spans[2] [(I)(x)(I)(x)]$_{I}$ that are evaluated by *A-SPAN(I), and [tʉtːu] receives just one violation mark as it now has the spans [(III)(x)]$_{I}$, cf. the tableau for this input in 3.2.

However, note that I claim that the "absence span" is headless, and that McCarthy assumes that GEN will not create such headless spans (McCarthy 2004, p. 4). The reason I do propose that the "absence span" is headless though, is twofold. Firstly because I feel that having a segment head an "absence span" of a unary feature [F] is conceptually problematic, because the segments in such a span may not have anything at all in common structurally, at least not formally speaking. Secondly, if such spans were to have heads then we will have gone too far in stretching the conceptuality of unary features and we might as well use binary features. It is of course quite possible to employ Element Phonology-like features with binary feature values. I will not pursue this approach here however, as the extended interpretation of *A-SPAN will suffice for my analysis.

3.1.2 Constraints working against assimilation

As explained above, it is the *A-SPAN constraints that will be the driving factor for vowel assimilation, as [tʉtːu] is more harmonic than [tutːu] by having fewer adjecent spans of [I] under the extended definition of *A-SPAN. As per usual in Optimality Theory, conforming to some constraints may come at the cost of violating others. Like many other cases, the constraints that make up the "opposing force" here are faithfulness constraints. These penalise all changes from the input made in output candidates, so the candidate [tʉtːu], whose first vowel has an [I] which is not present

---

[2] I will "x" use to mark skeletal slots in an "absence span". For convenience, I will not mark long segments in any way when using this notation.

in this vowel in the input, will violate a faithfulness constraint. Ideally, the *A-SPAN constraints want every segment in a word to have the same features, so if all faithfulness constraints for vowels were to be ranked below the *A-SPAN constraints in previous subsection, the output would be [titːi], as this would mean that there are no adjacent spans of either [A], [I] or [U]. To illustrate this, compare the following spans of [titːi] and [tʉtːu] (now with "absence spans" shown):

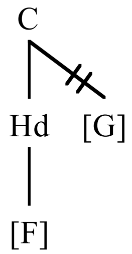
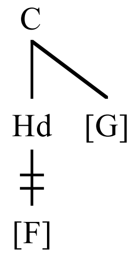
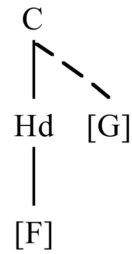
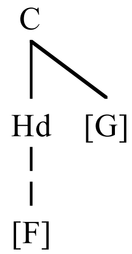
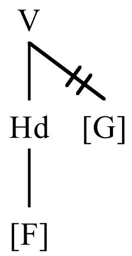
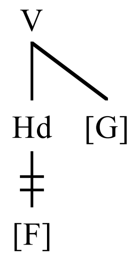
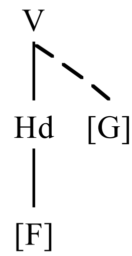
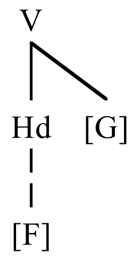
Figure 3-3: Spans of [A], [I] *and* [U] *in candidates* [titːi] *and* [tʉtːu]

IPA	t	i	tː	i		t	ʉ	tː	u
[A]									
[I]	(✓	✓	✓	✓)		(✓	✓	✓)	(x)
[U]						(x)	(✓)	(x)	(✓)

We see that [titːi] has both fewer adjacent spans of both [I] and [U]. In fact, this candidate has no adjacent spans at all and would be the most harmonic candidate possible under *A-SPAN. This assimilation pattern however, is not what is seen in the data in 2.3.1, so the goal of the analysis at this point is then to find out what ranking of *A-SPAN and faithfulness constraints produce output matching said data. The faithfulness constraints that will be used in this analysis are the familiar MAX(IMALITY-IO) and DEP(ENDENCE-IO) constraints[3]. These constraints can be specified for any feature and can also be specified so that they evaluate e.g. consonants or vowels. In addition I will need them to be specified to evaluate only the head (in terms of Element Phonology) of segments. At this point then, it seems proper to define how the features of Element Phonology should be arranged geometrically in an autosegmental model so that the property of headedness is captured in the structure of a segment. I will use the model shown in the figure below, which also shows how different constraints evaluate linking/spreading and delinking:

3 Since all features in Element Phonology are unary I will have no use for the faithfulness constraint IDENTITY-IO, as the identity of unary features are always the same.

Figure 3-4: Autosegmental processes that violate faithfulness

Autosegmental linking/spreading or delinking:				
Constraint violated:	MAXC(G)	MAXHDC(F)	DEPC(G)	DEPHDC(F)
Autosegmental linking/spreading or delinking:				
Constraint violated:	MAXV(G)	MAXHDV(F)	DEPV(G)	DEPHDV(F)

It is worth to note that the generic [F] and [G] here are features, but C, V and Hd are not, they are simply a part of the structure. C and V function as root nodes, coordinating features into segments like skeletal slots do. We need them in our structure as there are no features like [cons] and [syll] in element theory to distinguish consonants from vowels. A question that arises here is whether violating the more specific MAXHD/DEPHD constraints also constitutes a violation of the more general MAX/DEP constraints, but this is not crucial to the analyses. Therefore, for simplicity's sake I will consider the deletion/insertion of a feature under the node "Hd" to be just a violation of MAXHD/DEPHD, unless of course if the feature in question is deleted altogether, which does happen for some of the candidates under consideration in my analysis.

3.1.3 Constraints deciding span heads

As will be shown in the 3.4, there are cases where the *A-SPAN constraints, even under the extended interpretation proposed, are not enough to drive feature spreading, because a candidate may not improve harmonically under any *A-SPAN constraints even though features have been spread. In these cases the Span Theory notion of a span head and constraints deciding on the location of the span head must be brought out. In McCarthy's Span Theory each span of a feature [αF] is headed by one and one segment only that has the feature [αF] (McCarthy 2004, p. 3), and the selection of the head is decided by three constraint families: FTHHDSP, HEAD and SPHDL/R. The first is a faithfulness constraint for span heads, its definiton being:

> FTHHDSP(αF): If an input segment ς_I is [αF] and it has an output correspondent ς_O, then ς_O is the head of an [αF] span." (op. cit., p. 5).

The second is a markedness constraint that force certain features to be headed by segments of a certain featural makeup. It has the definition:

> HEAD([βG, γH, …], [αF]): Every [βG, γH, …] segment heads a [αF] span." (op. cit., p. 6).

The third constraint type evaluates the position of a span head in terms of its linear location in the span. SPHDR(αF) wants all [αF] span heads to be located at the right edge of the span and SPHDL(αF) wants all [αF] span heads to be located at the left edge of the span (op. cit., p. 11f.)[4]. For this analysis, the greek letter variables in all the constraint definitions can be dropped as they refer to binary feature values. The specific constraints will be introduced in the analysis as the need for them arises, but we have already looked at an example where McCarthy uses the HEAD constraint in 1.3.2.

3.2 Assimilation of /u/ between coronals

I will begin by analysing an example where the correct vowel quality is quite easily derived, in terms of the number of constraints that are needed. This is when the vowel /u/ is surrounded by coronals on both sides and surfaces as [ʉ], according to the data in 2.3.1. The fronting of /u/ between coronals is the reason I propose that [I] must be a

[4] Note that these two constraints are not gradient constraints like ALIGN, so they do not assign more violation marks to a span head situated further right/left than another (McCarthy 2004, p. 12).

part of the structural description of coronals, as this explains the origin of the element [I] inserted into the underlying vowel. We have already examined some output candidates for the input /tutːu/ n. "reindeer", namely [tʉtːu], [tutːu] and [titːi]. We could include the candidates [totːu] and [tʊtːu] as well, since the vowels [o] and [ʊ] are also thought to be allophones of /u/, as described in 2.3.1. I will include [totːu] in the tableaux in this section, but ignore the candidates with the allophone [ʊ] for now as we do not need to involve the notion of heads yet, neither in the Element Phonology or Span Theory sense[5]. Also, with the input /tutːu/ it is the first vowel we are primarily interested in, so we will just consider candidates with a faithful second vowel (hence [titːu] instead of [titːi]). The second vowel in this input is situated at a word edge where other phonological conditions apply, see section 4.5. I will begin by presenting the candidates in an table (not tableau) which shows the spans of [A], [I] and [U] for each candidate, as well as a what vowel faithfulness constraints are violated in each of the candidates:

/tutːu/	[A] spans	[I] spans	[U] spans	Violations of vowel faithfulness
tʉtːu	xxxx	(III)(x)	(x)(U)(x)(U)	DEPV(I)
tutːu	xxxx	(I)(x)(I)(x)	(x)(U)(x)(U)	None
titːu	xxxx	(III)(x)	(xxx)(U)	DEPHDV(I), MAXV(U)
totːʊ	(x)(A)(xx)	(I)(x)(I)(x)	(x)(U)(x)(U)	DEPV(A)

Outranking all of these constraints are consonant faithfulness constraints, protecting the consonants from changing to satisfy the *A-SPAN constraints. To rank these constraints so that [tʉtːu] wins, *A-SPAN(I) must outrank and DEPV(I), as this will allow the insertion of [I] into the structure of /u/ to improve this segment harmonically under *A-SPAN(I). Also it is clear that DEPHDV(I) and/or MAXV(U) outranks

[5] Recall that the structural difference between [u] and [ʊ] is that [U] heads the former and [ə] the latter. Otherwise they have the same features, since [ə] is present in every segment.

*A-Span(U) so the candidate [titːu], which is the most harmonic in terms of spans here, is eliminated. The resulting ranking of relevant constraints is presented in the tableau below, with the actual output form marked by a pointing hand as customary for the winning candidate. Refer to the table above to see how candidates violate the *A-Span constraints.

/tutːu/	DepHdV(I)	MaxV(U)	*A-Span(A)	*A-Span(I)	*A-Spn(U)	DepV(I)
☞ tʉtːu				*	***	*
tutːu				***	**!*	
titːu	*!	*		*	*	
totːu			**	***!	***	

As seen in the tableau, [tʉtːu] wins because it is more harmonic than [tutːu] and [toːtu] in terms of the number of adjacent spans, and more harmonic than [titːu] because it does not insert [I] into the head of /u/ or delete [U] from the vowel entirely. I have not included the constraint DepV(A) in the tableau as we cannot say where it ranks yet. The candidate [totːu] is eliminated by the *A-Span constraints anyway. Because of the ranking *A-Span(I) ≫ DepV(I), [I] will now also spread to /a/ when this vowel is between coronals. This is shown in 4.3.

3.3 Assimilation to a following uvular

We now turn to situations where vowel assimilation is triggered by a following uvular, regardless of the place of articulation of the preceding consonant. This process affects alle the three underlying vowels, short and long, as described in 2.3, where /a/ is retracted or tensed to [ɑ], /i/ is retracted and lowered to [ɐ] and /u/ is lowered to [o]. As the overview in figure 1-6 shows, the head resonance element of uvulars is [A], so what happens here in terms of Element Phonology feature spreading is the spreading of [A] from the uvular to the vowel. We will begin with an example with /a/, as the analysis of this will have consequences for the other two vowels. The case with /a/, is that if we accept the structural description /Ə, A/ for this vowel, this means that [A] needs to spread into the head in for the vowel to surface as [ɑ], i.e. [A] before uvulars. However, as will be shown, letting [A] spread to the head of /a/ means that it will have to be allowed to spread to the heads of /i/ and /u/ as well, to make the resulting candidates with [A]-headed vowels more harmonic under *A-SPAN(Head), which penalises adjacent spans of different head elements: "no adjacent spans of head elements". Since I am not considering the nodes labelled "Hd" in figure 3-4 to be features, this will be a slight deviation from the way the *A-SPAN constraint is supposed to be used, as it specified for features. Also, this will give some unwanted results, discussed in 5.1.3. A more proper way to do this would be to use one *A-SPAN(F_{Hd}) for each feature [F] that serves as head, but as this would clutter up the tableaux I will stick to the representation seen below. Let us have a look at the spans of some candidates for the input /qupːaq/ n. "crack", "fissure" (this time it is the second vowel we are interested in):

/qupːaq/	Spans of head elements	Spans of [A]	Spans of [I]	Spans of [U]
qupːaq	(A)(UU)(Ə)(A)	(A)(xx)(AA)	xxxxx	(x)(UU)(xx)
qupːɑq	(A)(UU)(AA)	(A)(xx)(AA)	xxxxx	(x)(UU)(xx)
qupːuq	(A)(UUU)(A)	(A)(xxx)(A)	xxxxx	(x)(UUU)(x)

From this tableau we see that the candidate we want to win, [qupːɑq], is only more harmonic than the faithful candidate [qupːaq] under *A-SPAN(Head), so obviously this constraint is needed to produce the output we want. Also, *A-SPAN(Head) must be ranked above DEPHDV(A) in order for this violation of faithfulness to be allowed. The other non-faithful candidate [qupːuq] also fares better than the fully faithful [qupːaq], but is not a wanted outcome according to 2.3.2, so this means that

DEPHDV(U) must be ranked above the *A-SPAN constraints, eliminating this candidate. In a tableau with ranked constraints then, [qupːɑq] now emerges as the winner:

/qupːaq/	DEPHDV(U)	*A-SPN(Hd)	*A-SPN(A)	*A-SPN(I)	*A-SPN(U)	DEPHDV(A)
qupːaq		***	**		**!	
☞ qupːɑq		**	**		**	*
qupːuq	*!	**	**		**	

Because of the ranking *A-SPAN(Hd) ≫ DEPHDV(A), [A] will now spread to the heads of /i/ and /u/, as seen below. One way to stop this would be to use local conjunction constraints such as [DEPHDV(A) & MAXHDV(I)]$_{\delta}$ and [DEPHDV(A) & MAXHDV(U)]$_{\delta}$, where δ = segment. The use of such constraints is discussed in 5.1.3.

However, I do not really see a problem with letting the resulting output structures for /i/+uvular and /u/+uvular be [A, I] and [A, U], respectively. The first reason is that the surface vowel quality of these two underlying vowels before a uvular, especially /i/, is in fact more like [ɑ] than [i] and [u] in terms of retracted articulation and openness. This can be seen in figures 2-4 and 2-8 (cf. also Appendix C and Wood 1971, p. 59, who uses mid back unrounded vowels to describe /i/ before a uvular). This corresponds well with having [A] as the head, as this element must then be considered more cognitively salient than [I] and [U]. The second reason is that there is not much that speaks *against* such structures here, as structures of Element Phonology are in general more open to interpretation than SPE features, since the latter are more to a further extent correspond to specific articulatory movements, while the former are abstractions of the actual acoustic traits of the sound. The only counterargument I can think of is that the “standard interpretation” of [A, I] and [A, U] is [æ] and [ɒ], respectively (Harris and Lindsey 1995, p. 57). From the data in figures 2-4 and 2-8, /i/+uvular seems more retracted and slightly less open than [æ] and /u/+uvular certainly does not seem to be quite as open as [ɒ]. Lastly, if [A] is not spread to the head of /i/ and /u/, the resulting structures would be [I, A] and [U, A]. While the latter has the standard interpretation of [o] (loc. cit.), which fits well with the data in figure 2-4, the former has [e] (loc.cit.) which does not fit well with the data in figure 2-8, as the allophone of /i/ before a uvular is clearly not a front vowel.

If we accept that the structure [A, I] may correspond to the vowel [ɐ], but wish to reject that [A, U] corresponds to [o] and that this structure should instead be interpreted as [ɒ], this will still work in the analysis with the final ranking derived, shown in 3.6. The way to do this is to exclude the candidate with [A, U] on the basis that such a vowel (i.e. [ɒ]) is unwanted for reasons of markedness (low/open vowels tend to be unrounded, cf. for example Roca 1994, p. 46). This is done by having an undominated constraint to ban the structure [A, U]. In 3.6, it is shown that the winning candidate then has the structure [U, A].

For now however, Let us look at how input with /i, u/+uvular, namely /piqut/ n. “piece of furniture” and /uːtːuq/ n. “sun-bathing seal” are treated, accepting [A, I] as the structure for [ɐ] and [A, U] as the structure for [o]. In this case, we are interested in the first vowel of /piqut/ and the second of /uːtːuq/. First let us have a look at how candidates for these input are spanned:

/piqut/	Spans of head elements	Spans of [A]	Spans of [I]	Spans of [U]
piqut	(U)(I)(A)(U)(Ə)	(xx)(A)(xx)	(x)(I)(xx)(I)	(U)(xx)(U)(x)
pɐqut	(U)(AA)(U)(Ə)	(x)(AA)(xx)	(x)(I)(xx)(I)	(U)(xx)(U)(x)
pyqut	(U)(I)(A)(U)(Ə)	(xx)(A)(xx)	(x)(I)(xx)(I)	(UU)(x)(U)(x)
pɑqut	(U)(AA)(U)(Ə)	(x)(AA)(xx)	(xxxx)(I)	(U)(xx)(U)(x)

/uːtːuq/	Spans of head elements	Spans of [A]	Spans of [I]	Spans of [U]
uːtːʉq	(U)(Ə)(U)(A)	(xxx)(A)	(x)(II)(x)	(U)(x)(U)(x)
uːtːuq	(U)(Ə)(U)(A)	(xxx)(A)	(x)(I)(xx)	(U)(x)(U)(x)
uːtːoq	(U)(Ə)(AA)	(xx)(AA)	(x)(I)(xx)	(U)(x)(U)(x)
uːtːɑq	(U)(Ə)(AA)	(xx)(AA)	(x)(I)(xx)	(U)(xxx)

I have also included candidates with [ɑ] here, and we see that these candidates, with the vowels fully assimilated to the uvular, are the most harmonic candidates under *A-SPAN in these cases, cf. the tableaux below. However, this is not the output we want. We have already seen in 3.2 that MAXV(U) ≫ *A-SPAN(U), this eliminates the candidate [uːtːɑq]:

/uːtːuq/	MAXV(U)	*A-SPN(Hd)	*A-SPN(A)	*A-SPN(I)	*A-SPN(U)	DEPHDV(A)
uːtːʉq		***	*	**	***!	
uːtːuq		***	*	**	***!	
☞ uːtːoq		**	*	**	***	*
uːtːɑq	*!	**	*	**	*	*

For the other input, MAXV(I) has to outrank *A-SPAN(I) to eliminate the candidate [pɑqut]:

/piqit/	MAXV(I)	*A-SPN(Hd)	*A-SPN(A)	*A-SPN(I)	*A-SPN(U)	DEPHDV(A)
piqut		****	**	***	***!	
☞ pɐqut		***	**	***	***	*
pyqut		****	**	***	***!	
pɑqut	*!	***	**	*	***	*

3.4 Assimilation of /i/ before labials

In the previous section I avoided examples that would bring about the need for additional constraints other than *A-SPAN(Head) that force expansion of spans and control the directionality of spreading, but if we want to analyse the possibility of rounding of /i/ before labials then we will need these constraints. The rounding of /i/ is a result of the labial spreading its [U] (cf. figure 1-6 for an overview of resonance elements for consonants) to the vowel. We can consider the input /qipik/ n. "blanket" which has an /i/ followed by a labial, for which we then would want the winning candidate to be [qypik], according to the data in 2.3.3. So far we have only been using *A-SPAN and faithfulness constraints and this is not sufficient any longer, as the candidate [qypik] ([(x)(UU)(xx)]$_U$) is no more harmonic than the faithful realisation [qipik] ([(xx)(U)(xx)]$_U$) under *A-SPAN(U). The difference in how the candidates span [U] is also the only structural difference between them. Each of the candidates have 3 adjacent spans of [U] and thus violate *A-SPAN(U) twice each, meaning that an optimal candidate is not decided by *A-SPAN. In turn this means that the more faithful [qipik] would be the better candidate of the two. To resolve this we need to investigate closer how the two candidates' spans differ from each other and bring in the notion of headedness into the domain of spans as well. This will enable us to set up a constraint ranking that prefers the [U] span of [qypik] to that of [qipik].

The question to be answered now is: what characterises the possible span heads of the [U] spans of [q(yp)$_U$ik] and [qi(p)$_U$ik]? In the latter candidate the spans consists of just one segment, so it must obviously be the head. In the former however, there is the choice of having either the segment [y] or the segment [p] to be head. In terms of the Theory of Representation we have been dealing with so far in this analysis, the differences between [y] and [p] is that the former is a vowel with the structural description [I, U] and the latter is a consonant with the structural description [U] (obviously [p] must have more features than just [U], but this is not an issue here). Remember that [I] and [U] (and of course also [A] and [Ə]) are resonance elements, i.e. abstractions of spectral characteristics. The type of segment that both a) relies the most on resonance elements and b) has the most salient spectral pattern for the resonance elements is a vowel, therefore, from a markedness point of view, any span of resonance elements should be headed by a vowel. This can be captured in a fixed ranking of the HEAD markedness constraints, where $\mathscr{R}$ is a variable for the four resonance elements:

HEAD(V, $\mathscr{R}$)		HEAD(C, $\mathscr{R}$)
"Assign one violation mark for every span of any resonance elements not headed by a vowel."[6]	$\gg$	"Assign one violation mark for every span of any resonance element not headed by a consonant."

Also, I have altered the definition of these constraints slightly so that they assign violation marks for spans with undesired heads instead of segments that are part of spans with undesired heads. For example, the hypothetical output [$(\text{pup})_{\text{U}}$] will receive one violation mark from the constraint HEAD(V, $\mathscr{R}$) and not three if the head of the [U] span is located on one of the consonants. I have done this to simplify the evaluation of the candidates, and I do not believe the altered definition to be a deviation to the purpose of the constraint HEAD.

The constraint FTHHDSP as introduced in 3.1.3 will not is not be used in the analysis, but its ranking relative to the constraints above needs to be clarified. If FTHHDSP($\mathscr{R}$) outranks HEAD(V, $\mathscr{R}$), then the latter constraint will have no effect, as all segments, whether they are vowels or consonants, would head the resonance elements in their own underlying structure. Therefore, FTHHDSP($\mathscr{R}$) must at least be ranked under HEAD(V, $\mathscr{R}$).

Under the ranking HEAD(V, $\mathscr{R}$) $\gg$ HEAD(C, $\mathscr{R}$), the head of the [U] span in [q$(\text{yp})_{\text{U}}$ik] must be the segment [y], since it is a vowel and more importantly, since there is no vowel in the [U] span in [qi$(\text{p})_{\text{U}}$ik], this candidate and all others with just

6 In element phonology, there is no [cons] or [syll] features, so I will not use any such notion here. I assume the identity of a segment as a vowel or a consonant lie in their geometrical structure, cf. 3.1.2. This is a slight deviation from the definition of HEAD([βG, γH, …], [αF]) seen in 3.1.3, which only refers to features.

the segment [p] in a [U] span will violate HEAD(V, $\mathscr{R}$). Therefore, [$q(yp)_U ik$] is more harmonic than [$qi(p)_U ik$] under HEAD(V, $\mathscr{R}$), or more specifically HEAD(V, U). We can now have a look at some possible spans of candidates for /qipik/, with span heads indicated when there is more than one possibility of the span head position (i.e. more than one segment in the span). The span head is marked by underlining the feature in the head position of the span.

/qipik/	Spans of head elements	Spans of [A]	Spans of [I]	Spans of [U]
qipik	(A)(I)(U)(I)(Ə)	(A)(xxxx)	(x)(I)(x)(I)(x)	(xx)(U)(xx)
$q(\underline{y}p)_U ik$	(A)(I)(U)(I)(Ə)	(A)(xxxx)	(x)(I)(x)(I)(x)	$(x)(\underline{U}U)(xx)$
$q(y\underline{p})_U ik$	(A)(I)(U)(I)(Ə)	(A)(xxxx)	(x)(I)(x)(I)(x)	$(x)(U\underline{U})(xx)$

I will rank HEAD(V, $\mathscr{R}$) above *A-SPAN for reasons that will be made clear below. The candidates in the table above are evaluated according to this tableau:

/qipik/	HEAD (V, $\mathscr{R}$)	*A-SPN(Hd)	*A-SPN(A)	*A-SPN(I)	*A-SPN(U)	DEPV(U)
qipik	*****!	****	*	****	**	
☞ $q(\underline{y}p)_U ik$	****	****	*	****	**	*
$q(y\underline{p})_U ik$	*****!	****	*	****	**	*

Since the candidate [$q(\underline{y}p)_U ik$] has one less span not headed by a vowel, it is more harmonic than the faithful candidate [qipik]. However, we encounter another problem if we take the candidate [qɐpik] into consideration in the tableau above. Since this candidate has the head element spans [$(A\underline{A})$[7]$(U)(I)(Ə)]_{Hd}$ it is actually more harmonic than [qypik] under *A-SPAN and would therefore win in the tableau. To find out how this candidate can be eliminated to the advantage of [qypik], we can consider another

[7] The head of this span is decided by HEAD($\mathscr{R}$, V).

input where the position of the span head will turn out to be important, namely /pisːut/ n. "reason", "opportunity". As there is little indication in figure 2-7 that a labial *preceding* /i/ should contribute to rounding, we would want the output [pisːʉt] for this input (ignoring lax vowels for now). However, HEAD(V, $\mathscr{R}$) would make the candidate [(p)$_{\mathrm{U}}$isːʉt] loose to [(py̲)$_{\mathrm{U}}$sːʉt] because the former candidate has one more span of resonance elements not headed by vowel than the latter. The candidates [(qɐ̲)$_{\mathrm{Hd}}$pik] and [(py̲)$_{\mathrm{U}}$sːʉt] have something in common in terms of how the head position in the span though, they both have heads situated on the right edge of a span. Enter McCarthy's directionality-controlling constraints SPHDR and SPHDL, who want the span heads to be positioned either at the right or left edge of that span. By ranking SPHDL($\mathscr{R}$) above HEAD(V, $\mathscr{R}$), [(py̲)$_{\mathrm{U}}$sːʉt] is eliminated because it does not have the head of the [U] span to the left. SPHDL($\mathscr{R}$) will also penalise [(qɐ̲)$_{\mathrm{Hd}}$pik] for the same reason, so by also ranking this constraint above *A-SPAN, we get the right winner for /qipik/:

/qipik/	SPHDL($\mathscr{R}$)	HEAD(V, $\mathscr{R}$)	A-SPAN(Hd)
qipik		*****!	**** (A)(I)(U)(I)(ə)
(qɐ̲)$_{\mathrm{Hd}}$pik	*!	***	*** (AA̲)(U)(I)(ə)
(q̲ɐ)$_{\mathrm{Hd}}$pik		*****!	*** (A̲A)(U)(I)(ə)
☞ q(y̲p)$_{\mathrm{U}}$ik		****	**** (A)(I)(U)(I)(ə)
q(yp̲)$_{\mathrm{U}}$ik	*!	*****	**** (A)(I)(U)(I)(ə)

As seen in the tableau, it is possible however, for [qɐpik] to avoid being eliminated by SPHDL($\mathscr{R}$) by having the position of the span head to accommodate this constraint, as in the candidate [(q̲ɐ)$_{\mathrm{Hd}}$pik], but this will lead to further violations of

HEAD(V, $\mathscr{R}$)[8], so this candidate will be eliminated anyway. This tableau also shows why HEAD(V, $\mathscr{R}$) must rank above *A-SPAN, as the winning candidate would be [(q̠ɐ)$_{Hd}$pik] by virtue of its fewer adjacent spans otherwise.

A problem with the constraint ranking now established, that enables [U] to spread to /i/, is that it will also permit [U] to spread to /a/ in the same contexts as /i/, so that /a/ also surfaces with [U] in its structure before a labial. As shown in 4.3 this will result in the output [ʊ] for /a/ before a labial. The data in 2.3.2 does not seem to indicate that this is a desired outcome, a possible solution to this is also discussed in 4.3 and 5.1.3.

3.5 Long vowels

When it comes to the long vowels, who do not seem to undergo any changes from the underlying form except before uvulars, they must be protected by specific faithfulness constraints for long vowels that outrank the constraints driving assimilation. As we have seen in the previous sections, the ranking of DEPV(I) and DEPV(U) below *A-SPAN allowed the spreading of [I] and [U] to vowels, so to protect long vowels from being assimilated in contexts with [I] and [U], we will need specific faithfulness constraints such as DEPVː(I) and DEPVː(U) ranked above HEAD(V, $\mathscr{R}$).

3.6 Additional considerations and summary

To summarise this chapter we can have a look at the complete ranking that has been derived (not included are consonant faithfulness constraints, which for the purpose of this analysis are assumed to be undominated):

8 One extra mark for the span of head element [A] seen in the tableau and an additional one for the span of [A] evaluated under *A-SPAN(A).

DEPHDV(I) DEPHDV(U) DEPHDV:(I) DEPHDV:(U) MAXV(I) MAXV(U) SPHDL($\mathscr{R}$)	≫	HEAD(V, $\mathscr{R}$)	≫	*A-SPAN(Hd) *A-SPAN(A) *A-SPAN(I) *A-SPAN(U)	≫	DEPV(I) DEPV(U) DEPHDV(A)

Let us first look at the case mentioned in 3.3, where we want the winning candidate for a sequence /u/+uvular to have the structure [U, A] (and not [A, U], as was the case in that section). As mentioned, we must first eliminate the candidate with [A, U], as this is the most harmonic candidate. We can look at the input /-puq/, which is the 3rd singular intranstive indicative inflection. As in the rest of the chapter, let us look at what spans the candidates have first. Remember that [ɒ] now represents [A, U].

/-puq/	Spans of head elements	Spans of [A]	Spans of [I]	Spans of [U]
-puq	($\underline{U}$U)(A)	(xx)(A)	xxx	($\underline{U}$U)(x)
-poq	($\underline{U}$U)(A)	(x)($\underline{A}$A)	xxx	($\underline{U}$U)(x)
-pɑq	(U)($\underline{A}$A)	(x)($\underline{A}$A)	xxx	($\underline{U}$U)(x)
-pɒq	(U)($\underline{A}$A)	(x)($\underline{A}$A)	xxx	($\underline{U}$U)(x)

As explained in 3.3, we can justify a constraint eliminating the candidate with [] for reasons of markedness. I will call this contraint *[A, U] in the following tableau:

/-puq/	*[A, U]	MAXV(U)	HEAD(V, ℛ)	*A-SPAN	DEPV(A)
-puq			****!	***	
☞ -poq			***	***	*
-pɑq		*!	**	***	*
-pɒq	*!		**	***	*

As can be seen, when the candidate with the structure [A, U] is eliminated, the optimal candidate has the structure [U, A], as the ranking HEAD(V, ℛ) ≫ DEPV(A) means that some form of assimilation is preferable to total faithfulness. An interesting effect of banning the candidate with [A, U] and using the constraint ranking derived at the end of the next chapter, is that the resulting structure for the second /u/ in /uːtːuq/, (the example for /u/ + uvular seen in 3.3) will in fact be [Ə, U, A]. If we presume that this structure consequently should be interpreted as [ɔ], this would be a welcome result. As seen in figure 2-3, realisations of /u/ in the context coronal_uvular seem to be more lax/centralised than realisations of /u/ in the context labial_uvular.

Before this chapter ends, there is another situation we have not looked at yet. As seen in 3.2, [I] will spread to a vowel when there are segments with [I] on both sides. However, with the constraint ranking above, [I] will spread regardless of the consonant preceding the vowel, which is not an outcome we want, at least the data for /u/ in figure 2-3 show this pretty clearly, with realisations of /u/ in the context coronal_coronal being much more fronted than in the context non-coronal_coronal. We can have a look at the two candidates for the input /putu/ n. 'hole' to see this happens:

/putu/	Spans of head elements	Spans of [A]	Spans of [I]	Spans of [U]
putu	(U̲U)(Ə)(U)	xxxxx	(xx)(I)(x)	(U̲U)(x)(U)
pʉtu	(U̲U)(Ə)(U)	xxxxx	(x)(I̲I)(x)	(U̲U)(x)(U)

Using the constraint ranking so far derived gives the following tableau:

/putu/	SpHdL(ℛ)	Head(V, ℛ)	*A-Span	DepV(I)
☹ putu		**!	*****	
☠ pʉtu		*	*****	*

Because of the undominated SpHdL(ℛ) constraint, all the spans need to have their heads to the left and as we see, now that we have introduced the Head(ℛ, V) constraint, we get assimilation to [I] in a context we do not want it according to the data in 2.3.1, hence a "wrong winner" marked. The reason for this is that Head(V, ℛ) does more work than it actually was meant to do, by forcing spreading of resonance elements from consonants in any context. What we really want with [I] is that this element should spread only to increase harmony under *A-Span(I), as seen in 3.2, and not for any other reason. The solution then is to separate out the constraint Head(V, I) ("Spans of [I] should be headed by a vowel.") from the cover constraint Head(V, ℛ) and rank this below DepV(I). To save space I will still use a cover constraint for the Head constaints other than Head(V, I), for this I will use the notation seen in the tableau below:

/putu/	Head(V, ℛ(–I))	*A-Span	DepV(I)	Head (V, I)
☞ putu	*	*****		*
pʉtu	*	*****	*!	

This gives us the following relevant constraint ranking for this chapter:

DEPHDV(I)								
DEPHDV(U)				*A-SPN(Hd)				
DEPHDV:(I)		HEAD(V,A)		*A-SPN(A)		DEPV(I)		
DEPHDV:(U)	≫	HEAD(V,U)	≫	*A-SPN(I)	≫	DEPV(U)	≫	HEAD(V,I)
MAXV(I)		HEAD(V,Ə)		*A-SPN(U)		DEPHDV(A)		
MAXV(U)								
SPHDL(ℛ)								

This overview does not include the local conjunction constraints discussed, these would be ranked above the highest-ranked faithfulness constraints, as conjoined constraints as thought to universally outrank their component constraints (Kager 1999, p. 393).

4 Vowel reduction

4.1 Introduction

In this chapter I will analyse changes in the Greenlandic vowels that traditionally are charaterised as vowel reduction, in that the vowels' prominence in certain position is reduced. Again I will use McCarthy's Span Theory and Element Phonology structures to analyse these processes, and show that the mechanism of these are in fact the very same as the ones seen in the previous chapter, and that "vowel reduction" may therefore not be a fitting term for this process. Before I continue the analysis I will shortly explain what the term "reduction of prominence" means. There are several patterns of vowel changes that have been characterised as vowel reduction. Crosswhite (2004) recognises two basic patterns, namely that of prominence reduction (p. 203ff.) and contrast-enhancing reduction (p. 192ff.). In the former reduction pattern, mid vowels arise as the result of reducing corner vowels, while in the latter corner vowels arise as the result of reducing mid vowels (p.225f.). However, the latter pattern is not used in Greenlandic, so it will not be discussed here. The former pattern is an example of prominence reduction, where it is the prominence in terms of sonority of vowels that are reduced. In Greenlandic this is accomplished by a centralised realisation of the underlying dispersed vowels /a, i, u/ as [ə, ɪ, ʊ], respectively. This type of pattern is appealing to Element Phonology as it can be formalised in the structural changes of the vowels. The structural change seen in /i, u/ → [ɪ, ʊ] is a demotion of the elements [I] and [U] from head position (promoting the ever-present neutral element [Ə] to head position), while the structural change in /a/ → [ə], where the element [A] is already not in the head position in the underlying form, is a deletion of [A] from the segment entirely. So in both cases, the cognitive concept of this type of structural change is toning down the most salient property of the segment. The driving factors (i.e. constraints) in Crosswhite's analyses of vowel reduction patterns are constraints which penalise a mismatch between the features of a certain vowel in a certain prosodic environment. In my analyses I will be using any constraints with reference to prosody other than faithfulness constraints protecting long vowels. This chapter will be structured so that word-internal reduction of each underlying vowel is first investigated in its own section, with reference to the data in chapter 2 and to the constraint ranking derived in 3.2, and then section 4.5 is devoted to investigating the pattern seen at word edges, where some additional modifications to the constraint hierarchy may be needed.

4.2 Reduction of /u/

As seen by the data in 2.3.1, the vowel /u/ surfaces as [ʊ] before a coronal (except in between two coronals), before a velar, and word-finally (see 4.5). As described in 1.3.3.3, velars have [Ə] as their only resonance element (Harris and Lindsey 1995, p. 67), and my analysis of the change in the vowel is thus that this causes the vowel to promote [Ə] to its head so as to be more harmonic under *A-Span(Head). In chapter 3 I did not consider any candidates with the allophone [ʊ] for /u/, but now we can have a look at the input /pukiq/ n. "reindeer pelt", adding a candidate with this lax vowel. We can also examine a candidate with [ə], as this is an even more reduced vowel in terms of prominence. Keep in mind that the span heads are all to the left due to the undominated ranking of SpHdL(ℛ).

/pukiq/	Spans of head elements	Spans of [A]	Spans of [I]	Spans of [U]
pukɐq	($\underline{\text{U}}$U)(Ə)($\underline{\text{A}}$A)	(xxx)($\underline{\text{A}}$A)	(xxx)(I)(x)	($\underline{\text{U}}$U)(xxx)
pʉkɐq	($\underline{\text{U}}$U)(Ə)($\underline{\text{A}}$A)	(xxx)($\underline{\text{A}}$A)	(x)(I)(x)(I)(x)	($\underline{\text{U}}$U)(xxx)
pʊkɐq	(U)($\underline{\text{Ə}}$Ə)($\underline{\text{A}}$A)	(xxx)($\underline{\text{A}}$A)	(xxx)(I)(x)	($\underline{\text{U}}$U)(xxx)
pokɐq	(U)(A)(Ə)($\underline{\text{A}}$A)	(x)(A)(x)($\underline{\text{A}}$A)	(xxx)(I)(x)	($\underline{\text{U}}$U)(xxx)
pəkɐq	(U)($\underline{\text{Ə}}$Ə)($\underline{\text{A}}$A)	(xxx)($\underline{\text{A}}$A)	(xxx)(I)(x)	(U)(xxxx)

Since reduction is what we want, clearly DEPHDV(ə) must be ranked below *A-SPAN. This gives the following tableau, using the final constraint ranking from 3.6:

/pukiq/	MAXV(U)	HEAD(V, ℛ(–I))	*A-SPAN	DEPHDV(ə)
pukɐq		***!	*******	
pʉkɐq		***!	********	
☞ pʊkɐq		**	******	*
pokɐq		***!	*********	
pəkɐq	*!	**	******	*

Even though the winning candidate is also the most harmonic one under *A-SPAN, it is actually the combination of SPHDL(ℛ) and HEAD(V, ℛ(–I)) that decide the winner in this tableau. According to the data in 2.3.1, [ʊ] is the vowel that surfaces in the context non-coronal_coronal as well, this means the analysis points to [ə] also being the head of coronals, justifying the complete proposed resonance structure of coronals as [ə, I]. Using the resonance element [R] for coronals as described in 1.3.3.3, would not explain anything about how neighbouring vowels are affected by coronals in Greenlandic, as [R] is not found in vowels. Therefore I see no place for this proposed resonance element in my analysis.

The ranking in the tableau above has some implications for the analysis in 3.2. In the context coronal_coronal as analysed in 3.2, candidates with the lax (i.e. [ə]-headed) vowel [ᵿ] (structurally [ə, U, I]) would be more harmonic than [ʉ] under *A-SPAN(Hd)[1], meaning that the winning output of the sequence /-tut-/ will be [-tᵿt-] because *A-SPAN(Hd) ≫ DEPHDV(ə). It is difficult to assess whether this is at odds with the data in 2.3.1 or not. In figure 2-4, the tokens of realisations of /u/ in the context coronal_coronal seem to be approximately as close as faithful realisations of

[1] Compare the head element spans of [-tᵿt-]: $[\text{-(əəə)-}]_{\mathrm{Hd}}$, to that of [-tʉt-]: $[\text{-(ə)(U)(ə)-}]_{\mathrm{Hd}}$.

/u/ though, this could indicate that this allophone is tense. Again this possibly unwanted outcome could be avoided using a local conjunction constraint, this time it would have to be [DepHdV(Ə) & DepV(I)]$_{\delta}$ where δ = segment. See 5.1.3 for a further discussion of using a such constraint.

4.3 Reduction of /a/

Unlike /u/, which is not reduced to [ʊ] before a labial, /a/ is reduced to [ə] before any non-uvular. We can have a look at the input /tapiq/ n. “addition”, “supplement”:

/tapiq/	Spans of head elements	Spans of [A]	Spans of [I]	Spans of [U]
tapɐq	(ƏƏ)(U)(AA)	(x)(A)(x)(AA)	(I)(xx)(I)(x)	(xx)(U)(xx)
tɑpɐq	(Ə)(A)(U)(AA)	(x)(A)(x)(AA)	(I)(xx)(I)(x)	(xx)(U)(xx)
təpɐq	(ƏƏ)(U)(AA)	(xxx)(AA)	(I)(xx)(I)(x)	(xx)(U)(xx)
tʊpɐq	(ƏƏ)(U)(AA)	(xxx)(AA)	(I)(xx)(I)(x)	(x)(UU)(xx)

In this case I have also included the candidate [tʊpɐq], as this will be shown to be a problematic candidate in the tableau below:

/tapiq/	Head (V, ℛ(–I))	*A-Spn(Hd)	*A-Spn(A)	*A-Spn(I)	*A-Spn(U)	MaxV (A)	DepV (U)
tapɐq	**!	**	***	***	***		
tɑpɐq	**!	***	***	***	***		
☹ təpɐq	**!	**	*	***	***	*	
☠ tʊpɐq	*	**	*	***	***	*	*

The winner in this tableau, again decided by Head(V, ℛ(–I)), is [tʊpɐq], and even though there are not so many tokens of realisations of /a/ in the context coronal_labial in the figure 2-5, it does not seem to be the case that /a/ should be realised as [ʊ] in this context. Again the solution may be a conjoined constraint, here [MAXV(A) & DEPV(U)]$_{\delta}$. In any case, MAXV(A) must rank below *A-SPAN to allow reduction to take place. Looking at an example with /a/ before a coronal we can see that the constraint ranking derived in 3.6 works better. We can consider the input input /katu/ n. "drumstick".

/katu/	Spans of head elements	Spans of [A]	Spans of [I]	Spans of [U]
katu	(ə̲əə)(U)	(x)(A)(xx)	(xx)(I)(x)	(xxx)(U)
kɑtu	(ə)(A)(ə)(U)	(x)(A)(xx)	(xx)(I)(x)	(xxx)(U)
kətu	(ə̲əə)(U)	xxxx	(xx)(I)(x)	(xxx)(U)
kɪtu	(ə̲əə)(U)	xxxx	(x)(I̲I)(x)	(xxx)(U)

Here I have included the candidate [kɪtu], which we see is eliminated either because it is in sum less faithful to the input or because DEPV(I) outranks MAXV(A). The crucial difference between this example an the one above is that HEAD(V, I) is not ranked above DEPV(I) as shown in 3.6.

/katu/	HEAD (V, ℛ(–I))	*A-SPAN	MAXV(A)	DEPV(I)	HEAD(V, I)
katu	*	******!			*
kɑtu	**!	********			*
☞ kətu	*	*****	*		*
kɪtu	*	*****	*	*!	

Returning to the analysis in 3.2 however, the ranking *A-SPAN ≫ DEPV(I), MAXV(A) does become a problem, as it will mean that the output of /a/ with coronals on both sides will be [ɪ]. Since *A-SPAN(I) is ranked above DEPV(I) inserting [I] is permitted to reduce the number of adjacent [I] spans, and since *A-SPAN(A) is ranked above

MAXV(A) then deleting [A] is permitted to reduce the number adjacent [A] spans. Cf. the spans of /tat:ak/ n. “fish scale”:

/tat:ak/	Spans of head elements	Spans of [A]	Spans of [I]	Spans of [U]
tat:ək	(Ə̲ƏƏƏƏ)	(x)(A)(xxx)	(I)(x)(I)(xx)	xxxx
tıt:ək	(Ə̲ƏƏƏƏ)	xxxxx	(I̲II)(xx)	xxxx
tət:ək	(Ə̲ƏƏƏƏ)	xxxxx	(I)(x)(I)(xx)	xxxx

As we see in a tableau with ranked constraints, [tıt:ək] is the winner because it is the most harmonic under *A-SPAN:

/tat:ak/	HEAD (V, ℛ(–I))	*A-SPN(Hd)	*A-SPN(A)	*A-SPN(I)	*A-SPN(U)	MAXV (A)	DEPV (I)
tat:ək	*		**!	***			
☠ tıt:ək	*			*		**	*
☹ tət:ək	*			**!*		**	

The data in 2-5 does not seem to support this winning candidate in this case. Yet again it seems we must use a local conjunction constraint, in this case [MAXV(A) & DEPV(I)]$_\delta$ where δ = segment. This constraint would be ranked above *A-SPAN. The use of conjoined constraints is discussed in 5.1.3.

4.4 Reduction of /i/

When it comes to the reduction of /i/, the ranking established in 4.2 will mean that this vowel will reduce before coronals and velars as well. If the allophones I propse for /i/ in 2.3.3 are correct, then there is not much more to say, as the constraint ranking derived will do fine. However, it is not so easy to interpret whether there is reduction of /i/ or not in figure 2-7, but it is worth noting that all the word-initial tokens of /i/ have F1 and F2′ values that indicate that these realisations are at least more tense than many of the other realisations (cf. the next section). If we do not want the output from words with /i/ to have [ɪ], then the question is how to avoid this. We will need some constraint ranked above *A-SPAN eliminating candidates with [ɪ], but motivating such a constraint theoretically is not so easy. If two constraints ban two types of segments, then it usually implies that the segment banned by the highest-ranked constraint is the most marked. As the required ranking to allow [ʊ], but ban [ɪ] in the same context would be *[ɪ] ≫ *[ʊ], this would subsequently mean that [ɪ] is more marked than [ʊ]. I am uncertain as to if this can be defended from a markedness perspective. Again the solution could be to employ a local conjunction constraint, in this case [DEPHDV(Ə) & MAXHDV(I)]$_{\delta}$ where δ = segment. As seen in the tableau with the input /tikiq/ n. "index finger", "thimble" below, this allows us to favour candidates with [i] over candidates with [ɪ], if this is a wanted outcome:

/tikiq/	Spans of head elements	Spans of [A]	Spans of [I]	Spans of [U]
tikɐq	(Ə)(I)(Ə)(A̲A)	(xxx)(A̲A)	(I̲I)(x)(I)(x)	xxxxx
tɪkɐq	(Ə̲ƏƏ)(A̲A)	(xxx)(A̲A)	(I̲I)(x)(I)(x)	xxxxx

/tikiq/	[DEPHDV(Ə) & MAXHDV(I)]$_{\delta}$	HEAD(V, $\mathscr{R}$(–I))	*A-SPAN	DEPHDV(Ə)
☞ tikɐq		**	*******	
tɪkɐq	*!	*	*****	*

As mentioned towards the end of 4.2, the reranking *A-SPAN(Head) ≫ DEPHDV(Ə) causes a promotion of [Ə] to the head of /u/ between coronals that may not be justified in the data in 2.3.1. This problem occurs for /i/ before labials as well, if the preceding consonant is a coronal or velar (in both cases a consonant with [Ə] in its head). This means that the input /tipi/ n. "smell", "aroma" will surface as [tʏpɪ], not [typɪ], because the former candidate has one less adjacent span of head elements: $[(ƏƏ)(U)(Ə)]_{Hd}$ versus $[(Ə)(I)(U)(Ə)]_{Hd}$. Again, it is hard to say whether this is at odds with the data in figure 2-7 or not. Should the ouput with a lax vowel be unwanted, we will need the local conjunction constraint $[\text{DEPHDV(Ə) \& DEPV(U)}]_{\delta}$ where δ = segment, to eliminate the candidate [tʏpɪ].

4.5 Vowel reduction and faithfulness at word edges

As seen in the data, at word edges, the realisations of the vowels may differ from how they are realised word-internally. When a vowel is word-initial it is generally more faithful than when it is word-internal, except when followed by a uvular. This is captured in the analysis by having faithfulness constraints specific for initial vowels. The types of changes we have seen the vowels undergo in chapter 3 and this chapter are insertion of [I] and [U] as non-head elements, insertion of [A] and [Ə] as head elements and lastly deletion of [A]. Word-initially then, we will need faithfullness constraints for each of these processes except the insertion of [A] as head element, because we see that this happens even in this position. Partially following the notation of Kager (1999, p. 409), this means that the following constraints are undominated: DEPV(I, [ω), DEPV(U, [ω), DEPHDV(Ə, [ω) and MAXV(A, [ω), with the "[ω" part meaning "at the left edge of a phonological word". Kager lists up some positions known to be more faithful (op. cit., p. 408), but does not mention word-initial vowels. He mentions vowels in initial syllables however, and it would be interesting to see if this applies to Greenlandic. Unfortunately, I do not have data that may support or discredit whether vowels (other than word-initial vowels) in initial syllables are more faithful than vowels word-internally.

When a vowel is realised at the end of a word, /a/ and /i, u/ again differ slightly on how they are realised. The vowels /i/ and /u/ seem to be realised as lax ([ɪ] and [ʊ]), while /a/ is realised faithfully. Again this is captured with ranking certain positional faithfulness constraints above the constraints working for assimilation, in this case DEPV(I, ω]), DEPV(U, ω]) and MAXV(A, ω]), here "ω]" at the right edge of a phonological word. The question to be answers is what the driving forces behind the lax realisation of /i/ and /u/ are. When a coronal or velar consonant precedes word-final /i/ and /u/ the lax realisation or spreading of [Ə] to the head position of the final vowel follows the basic workings of the constraints working to minimise spans as can be seen with the input /putu/ n. 'hole':

/putu/	Spans of head elements	Spans of [A]	Spans of [I]	Spans of [U]
putu	(<u>U</u>U)(Ə)(U)	xxxx	(xx)(I)(x)	(<u>U</u>U)(x)(U)
pʊtʊ	(U)(<u>Ə</u>ƏƏ)	xxxx	(xx)(I)(x)	(<u>U</u>U)(x)(U)

/putu/	HEAD(V, ℛ(–I))	*A-SPAN	DEPHDV(Ə)
putu	***!	******	
☞ pʊtʊ	**	****	*

When it comes to final /i/ and /u/ preceded by labials or uvulars, who do not have [Ə] as their head element there is unfortunately a lack of convincing data again. For /i/ there is generally scarce data for this vowel in the word-final positions.

To get [ɪ] and [ʊ] as the output for a word-final /i/ and /u/ with a preceding labial or uvular we will need additional constraints, as labials uvulars do not have [Ə] as their head element, they cannot be a source of spreading of this element in the head position, forced by the assimilation-driving constraints. We could use an approach such as Crosswhite uses, that is crossing prominence scales to get constraint families that ban various degrees of vowel prominency in non-prominent positions (2004, p. 205). However, there are two problems with this. First of all, the constraint family obtained from crossing prominence scales are supposedly ranked so that in a non-prominent position, such as word-final, a constraint banning a more prominent vowel outrank a constraint banning a less prominent vowel. In this case it would mean that a constraint such as *WORD-FINAL/a 'no [a] word-finally' would outrank

*Word-final/i, u ‘no [i] or [u] word-finally’, since [a] is a more prominent vowel than [i] and [u]. But this is not the pattern we see, as the data in 2.3.2. indicats that a word may well end in [a]. Also, since we have [u] and probably [i] in a word-internal position, which is an even less prominent position than word-final, it would then be strange that [i] and [u] would be permitted there, but not word-finally. Because of the lack of data I will not use to much time discussing what constraint could cause the lax realisation of word-final /i/ and /u/ preceded by a labial or uvular.

4.6 Long vowels and summary

As with the vowel assimilation processes analysed in chapter 3, the long vowels resist change and are not reduced in the same contexts as the short. And just as in the previous chapter this is captured using faithfulness constraints for long vowels, in this case it would mean that DepHdV:(ə) and MaxV:(A) outrank Head(V, $\mathcal{R}$). Summed up now, the ranking to derive all word-internal changes made to the three underlying vowels in Greenlandic is the following (excluding the conjoined constraints mentioned throughout (but cf. 3.6), the use of these are discussed in 5.1.3):

DepHdV(I)								
DepHdV(U)								
DepHdV:(I)				*A-Spn(Hd)		DepV(I)		
DepHdV:(U)		Head(V,A)		*A-Spn(A)		DepV(U)		
DepHdV:(ə)	≫	Head(V,U)	≫		≫	DepHdV(A)	≫	Head(V,I)
MaxV:(A)		Head(V,ə)		*A-Spn(I)		DepHdV(ə)		
MaxV(I)				*A-Spn(U)		MaxV(A)		
MaxV(U)								
SpHdL($\mathcal{R}$)								

5 Discussion and conclusion

5.1 Discussion of the analysis

To begin the final chapter I will discuss some of the aspects of the analysis in chapters 3 and 4. First I will go through some of the merits I believe my analysis to achieve, followed by a comparison of my analysis with McCarthy's use of Span Theory as described in 1.3.2. Finally in this section I will look at the unresolved issue of the need for local conjunction constraints in my analysis.

5.1.1 Merits of the analysis

The merits I believe my analysis achieves stems from its individual components: Optimality Theory, Span Theory and Element Phonology. Some of the aspects of these have already been discussed in chapter 1, but here I will briefly discuss how these components used to analyse the problem at hand, namely vowel allophony in Greenlandic, appear to be a good combination.

The first merit I wish to mention is a quality that all Optimality Theory analyses have: they show how structurally different processes in a language are related, in the sense that they can all be explained as arising from the same set of certain demands on phonological structure, be it language-specific or universal. In other words, how changes that in classic generative phonology would be formalised by a set of rules may conspire to work toward a common goal as dictated by a constraint hierarchy. In the case of this analysis, how rules[1] such as "u → ʉ / t_t", "a → ɑ / _q", "i → y / _p" etc. conspire to enlarge the spans of the resonance elements, so as to better satisfy the constraints HEAD(V, ℛ) and/or *A-SPAN.

Another appeal of my analysis, that stems from both the combined use of Span Theory and Element Phonology is that it unifies what may be viewed as two types of changes in the structure of Greenlandic vowels, namely vowel-to-consonant

[1] I am using very superficial and naïvely formulated rules here just to drive the point home.

assimilation and what could be seen as vowel reduction. In my analysis, both these processes are the result of candidates conforming to the constraints HEAD(V, $\mathscr{R}$) and/or *A-SPAN, either by having surface vowels that have inserted features from neighbouring consonants into their structure (as seen in chapter 3) or by surface vowels that have promoted a feature already in their underlying structure to be more prominent in the surface structure so as to be more like a neighbouring consonant (as seen in chapter 4 and in the case of /a/+uvular). That the analysis is able to accomplish this is also to the credit of the structures of Element Phonology, as this theory of representation has a unified approach for the featural makeup of vowels of consonants, cf. the discussion in 5.2.

In fact, the analysis could quite easily be extended to cover some alternations seen in the consonants of Greenlandic as well, using *A-SPAN constraints specified for the consonantal elements [ʔ] (closure) and [h] (noise). These alternations fall into the category of consonant lenition. For example, the plosive /q/ is realised intervocalically as [χ][2] (Fortescue 1984, p. 333, but mostly preceding /a/ according to my data), which would be a result of conforming to *A-SPAN(ʔ) as the surrounding vowels do not have this element and it would reduce the number of adjacent spans of [ʔ], as seen in the tableau below with the partial input /-uqa-/:

/-uqa-/	*A-SPAN(ʔ)	MAXC(ʔ)
-(o)(q)$_{ʔ}$(a)-	*!*	
☞ -(oχa)-		*

Also, the underlying fricatives /v, ɣ, ʁ/ become approximants intervocalically and plosives are realised with no audible release burst word-finally, both of which could be results of conforming to *A-SPAN(h) as vowels generally do not have this element

[2] This does not happen for the other plosives, but I believe this could be captured in the geometric structure of these segments. If the resonance elements for /p, t, k/, but not /q/, somehow were dependent on the [ʔ] element, then deletion of this would lead to deletion of the resonance elements as well, leading to more violation of faithfulness for /p, t, k/ than for /q/ when deleting [ʔ].

either, so it would reduce the number of adjacent spans of [h] as seen in the tableau below with the partial input /-uɣut#/:

/-uɣut#/	*A-SPAN(h)	MAXC(h)
-(ʊ)(ɣ)$_h$(ʊ)(t)$_h$#	*!**	
-(ʊɰʊ)(t)$_h$#	*!	*
-(ʊ)(ɣ)$_h$(ʊt˺)#	*!*	*
☞ -(ʊɰʊt˺)#		**

There are also some underlying segments that have been analysed as morpho-phonemes that could fit well into this analysis as well, an example of this is /P/[3], seen in the intransitive indicative marker /Pu/, which has allomorphs with both [p] after a consonant, and [w] after a vowel. Intervocalically, /P/ would improve harmonically under both *A-SPAN(ʔ) and *A-SPAN(h) by surfacing as [w][4], as seen in the tableau below with the partial input /-uPu-/:

/-uPu-/	*A-SPAN(ʔ)	*A-SPAN(h)	MAXC(ʔ)	MAXC(h)
-(u)(p)$_{h,ʔ}$(u)-	*!*	**		
-(u)(f)$_h$(u)-		*!*	*	
-(u)(p˺)$_ʔ$(u)-	*!*			*
☞ -(uwu)-			*	*

3 The most common symbol for this segment is /V/ (e.g. Sadock 2003, p. 3), but using such notation would imply that the element [ʔ] is not present in the underlying form, which for my analysis must be the case. Therefore I use the symbol /P/ for this segment. Other segments found in derivation and inflection that alternate in a similar manner are /K/, e.g. in the politeness marker /-Kaluaʁ-/, which surfaces as [k] after a non-uvular consonant and [ɰ] after a vowel and /T/, e.g. in the intransitive participle ending /-Tuq/, surfacing as [t] after a consonant, but [s] after a vowel.

4 Voicing would presumably be spontaneous as the segment structurally would just consist of [U]. The realisation [w] would of course also be an improvement of harmony after a consonant, but what happens here is that the preceding consonant assimilates giving a long [pː], which would then presumably be protected by positional faithfulness.

The structural difference between /p/ and /P/ could then be something akin to what is sketched out for /p, t, k/ versus /q/ in footnote 2 of this chapter.

Finally, I wish to constrast two interpretations of the effects of the constraints HEAD(V, $\mathcal{R}$) and *A-SPAN. One interpretation could be that they conserve articulatory effort by spreading features to span over more segments, in other words could be taken to support a proposed constraint such as Kirchner's LAZY constraint (1997, p. 26), a constraint penalising any attempt to refrain from conserving effort for the speaker. The constraint LAZY is critisised by Hale and Reiss (2008 pp. 184f.) as they are of the opinion that such a notion is as much dysfunctional as functional, and have no place directly encoded in a grammar. However, the effects of HEAD(V, $\mathcal{R}$) and *A-SPAN can be interpreted in another way as well. For one thing, while it is true that HEAD(V, $\mathcal{R}$) and *A-SPAN do minimise articulatory effort in my analysis, they do so at the cost of computational effort, in that they bring about a fair amount of redundancy in the grammar. The purpose of this added redundancy can be seen as an example of system-level redundancy management (Dahl 2004, pp. 9-11), where a system (here a grammar) could demand certain duplication of information as a safeguard to ensure the correct transmission of this information. I do not believe that an analysis using the LAZY constraint implies this sort of system-level redundancy management.

5.1.2 Comparison with McCarthy's use of Span Theory

In this section I will briefly compare some differences between my analysis of Greenlandic vowel allophony with McCarthy's analysis of nasal spreading, which is used to demonstrate Span Theory in 1.3.2. The constraint HEAD has a different function in McCarthy's analysis, as it is used as to block spreading (McCarthy 2004, p. 7), while I am using this constraint as an instigator for spreading. The different uses of HEAD arise from the way it is specified, in McCarthy's analysis this constraint want different classes of segments to head nasal spans with a *negative* feature value, while my HEAD constraints are cannot be specified for negative values as I am using unary features. However, even though I am using the HEAD constraints for a different purpose than McCarthy, I do not believe that I am abusing the HEAD constraint in the respect that I am using it for something it is not meant for. It is after all a markedness constraint, and I believe the hierarchy[5] I have set up in 3.4 to be well grounded in universal markedness.

5.1.3 Unresolved issues in the analysis

In this section I will discuss some of the problems encountered in the analysis in chapters 3 and 4, where the solution proposed is a local conjunction constraint. A local conjunction constraint works by assign a violation mark only if both of the constraints conjoined are violated in some local domain δ, all the local conjunctions I will be discussing have the domain δ = segment.

In chapter 3 I proposed the local conjunction constraints [DEPHDV(A) & MAXHDV(I)]$_{\delta}$ and [DEPHDV(A) & MAXHDV(U)]$_{\delta}$. They were proposed to ban candidates for the inputs /i, u/+uvular with the structures [A, I] and [A, U], in favour of the structures [I, A] and [U, A], respectively. However, as argued for in 3.3, the structure [A, I] seems more appropriate than [I, A] based on the phonetic data, and in 3.6 an alternative way of deriving [U, A] for the vowel in the input /u/+uvular was shown. Therefore, I think we can dismiss the need for these local conjunction constraints.

In chapter 4, local conjunction constraints were proposed in three cases to deal with possible unwanted output. In 4.4 I proposed [DEPHDV(Ə) & MAXHDV(I)]$_{\delta}$ as a possibility to ensure that /i/ surfaces as non-lax, if that is what the data in 2.3.3 points to. As this is not clear, I will leave this matter unresolved.

Another case was pointed out in 4.4 and 4.2, where it was shown that the ranking *A-SPAN(Hd) ⪢ DEPHDV(Ə) would produce the output [ʊ] rather than [ʉ] for /u/ between coronals and [ʏ] rather than [y] for /i/ after a coronal or velar and before a

[5] I.e. HEAD(V, $\mathscr{R}$) ⪢ HEAD(C, $\mathscr{R}$), this hierarchy could of course be more finely grained by differentiating between different classes of consonants, but I see no need for this in the analysis.

labial. As mentioned in 1.3.3.3 I have also chosen to remain agnostic to whether Element Phonology structures with more than two elements have additional structure for the non-head elements, in other words, if there is a difference between [Ə, U, I] and [Ə, I, U]. These structures do not arise as output if we use the more space-consuming, but probably more accurate analysis of spans of head elements as explained in 3.3, as the candidates with [ʉ] and [ʏ] no longer would be any more harmonic than their tense counterparts under *A-SPAN($Ə_{Hd}$). In that case the need for the local conjunction constraints proposed to deal with this problem, namely [DEPHDV(Ə) & DEPV(I)]$_δ$ and [DEPHDV(Ə) & DEPV(U)]$_δ$, would evaporate.

Lastly, there were two cases in 4.3 where /a/ would surface with the wrong vowel quality in the analysis. Due to the constraint ranking set up to spread [I] to /u/ between coronals in 3.2 and [U] to /i/ before labials in 3.4, [I] and [U] would also spread to /a/ in the same contexts, giving the surface forms [ɪ] and [ʊ] due to the fact that [A] was permitted to delete to increase harmony under *A-SPAN(A). Here, the local conjunction constraints [MAXV(A) & DEPV(I)]$_δ$ and [MAXV(A) & DEPV(U)]$_δ$ were proposed as a possible solution. Unlike the other local conjunction constraints proposed however, these two might find support in typological data, as the structural change they protect against is a quite radical change for the vowel /a/: I do not believe it is common for a corner vowel to completely change its "corner affilation", at least not in any reduction pattern[6], as is the case with the change seen in /a/ → [ɪ] or [ʊ]. In Element Phonology terms, this would be the same as saying that it is not common for a vowel that has just one of the resonance elements in its structure [A], [I] or [U] to exchange this for another. The only example of such a change I am acquainted with is in Old Norse rounding harmony, where /a/ surfaces as [u] in unstressed positions when an inflectional suffix with initial /u/ is added (Haugen 1993, p. 74). It is interesting to note in this respect that Icelandic, the modern decendant of Old Norse, now has [ɔ] in this position, which lends support to the idea that there could be a

[6] For example, none of the reduction patterns described in Crosswhite 2004 include such a change.

constraint protecting corner vowels from completely changing their corner affilation. I choose therefore to use a constraint called CORNERAFFILATION, which in Element Phonology terms would be a cover constraint for the following local conjunction constraints: [MAXV(A) & DEPV(I)]$_{\delta}$, [MAXV(A) & DEPV(U)]$_{\delta}$, [MAXV(I) & DEPV(A)]$_{\delta}$, [MAXV(I) & DEPV(U)]$_{\delta}$, [MAXV(U) & DEPV(A)]$_{\delta}$ and [MAXV(U) & DEPV(I)]$_{\delta}$. Ranking this constraint alongside the other non-violable vowel faithfulness constraints seen in the summarised constraint hierarchy in 4.6 would prevent the unwanted outputs for /a/ seen in 4.3.

5.2 Comparison of different Theories of Representation

In this section I will compare the structural inventory of Element Phonology to that of two other theories of representation and show that by using the structures assumed none of these would be completely adequate to describe the allophonic variation of vowels in Greenlandic in an analysis such as presented in chapters 3 and 4. I must clarify that I am not claiming the Element Phonology is “better” than these theories of representation, just that for the analysis as I have performed it, the features of Element Phonology will adequately describe the allophonic variation, but the structures assumed in the two other theories of representation will not be adequate to use in the analysis, with a possible implication that different structures for segments of Greenlandic must be proposed in these theories of representation. The different theories of representation discussed in this section are introduced in 1.3.3.

5.2.1 Textbook SPE-type

For this theory of representation, I will be using feature matrices for consonants as described in figure 1-4. The main problem these structures is that there is not necessarily a match between the interpretation of the place features shared by vowels and consonants. If we first look at the fronting of /u/ between coronals, then this would have to be analysed as a spreading of the feature [–back] to the structure of /u/, since the structural change seen in /u/ → [ʉ] is changing the feature [+back] to

[–back]. This would presumably be motivated by a constraint *A-SPAN(back), cf. figure 3-2. However since there are other segments, such as labials, which are not coronal, but still have the feature [–back], the analysis would then predict that /u/ should be fronted between labials as well, which is clearly not the case according to figure 2-3.

Similar problems are encountered with the assimilation of vowels before uvulars. Here, the situation is further complicated by the fact that the three vowels in question would go through three different structural changes. For /u/ the case is pretty clear, here it would be the feature [–high] from the uvular that replaces [+high] in the underlying structure of /u/. For /a/, however, if we accept this underlying form, the allophone [ɑ] is impossible to derive through an analysis such as the one in 3.3, as consonants do not have the feature [+tense]. It is possible to have /æ/ (cf. 2.4) as the underlying form though, or more precisely that this vowel has an underlying structure with [–back]. The alternation seen before a uvular, which is [+back], would then be a change from [–back] to [+back]. Finally, for /i/ it seems the structural change before a uvular is both changing the value of [+high] to [–high] and [–back] to [+back]. Again, trying to analyse these three different structural changes we will run into trouble, as uvulars are not the only consonant which is [+back], this value would presumably also be true for velars, or [–high], which is true for labials and coronals as well. Using the constraints *A-SPAN(back) and *A-SPAN(high) would therefore not yield the results we want, because we would get assimilation patterns that are not compatible with the data in chapter 2, such as retraction before velars and lowering before coronals and labials.

For the rounding of /i/ before labials the analysis would work though, as no other consonantal segments but labials have the feature [(+)round]. But turning to the alternations of /u/ and /i/ seen in chapter 4, an analysis such as this with textbook SPE-features would fail, again because [+tense] is not a feature found in consonants. Using *A-SPAN(low) as well as *A-SPAN(back) and *A-SPAN(high) we would partially get the results we want for /a/, before labials and coronals, which have negative values for all their place features, we would end up with a feature matrix for the vowel that could correspond to the data in figure 2-5, but before velars, who are [+high] and [+back], the analysis would predict /a/ to surface as [ɯ].

All in all, the structures assumed in this theory of representation would not give satisfying results in an analysis such as the one in chapters 3 and 4. The main reason for this is, as is mentioned above, that this theory of representation has not got a unified representation for the place features of vowels and consonants. Another reason is partially because of the binary approach to features in this theory of representation. For example, as shown with the feature [A] in Element Phonology, the vowel assimilation to a following uvular should not be considered a full assimilation to the negative feature [–high] of uvulars, but rather a partial assimilation to the positive feature [+low]. Also, when compared to a SPE-type theory of representation, the elements of Element Phonology can be described as “bundled”, so that [A] can be interpreted as both the articulatory qualities low/open and back. Inserting this feature into a segment will therefore cause both a more open and more retracted realisation of this segment, as seen with /i/ before a uvular, but for the textbook SPE-type theory of representation, this corresponds to at least two changes in the structure of /i/.

5.2.2 Morén’s Parallel Structures Model

As described in 1.3.3.2, Morén’s Parallel Structures Model of Feature Geometry (2003) would seem more promising as to work in an analysis such as the one proposed here, as this theory of representation has a unified structure for the place features of consonants and vowels (op. cit., p. 222). As the place feature [cor] for coronals is now compatible with vowels (place features for consonants and vowels reside under different nodes in the geometry, but this has presumably no ill effects on the analysis), the fronting of /u/ between coronals is possible to analysis using the constraint *A-SPAN(cor). This constraint spread [cor] to /u/ which has an underlying structure consisting of the place features [lab] and [vel] and the manner feature [close], and I see no trouble in interpreting the resulting structure as corresponding to [ʉ].

As for the case of vowel assimilation before uvulars, matters are not quite as simple. Uvulars have the place feature [vel] and [post] where presumably only the former is compatible for vowels. Spreading [vel] to /a/, which has the underlying structure consisting of the place feature [phar] and the manner feature [open] would presumably yield a structure that may correspond to [ɑ], but it is not enough to spread [vel] to the vowels /i/ (which has an underlying structure consisting of the place feature [cor] and the manner feature [close]) and /u/, since these would still be correspond to closed vowels since they only have the manner feature [close] present. Perhaps the “uvulars” in Greenlandic *should* rather be characterised as “pharyngals” as Wood does (cf. 2.4). The place feature [phar] in Morén’s model corresponds roughly to [A] in Element Phonology, and presumably this element is incompatible with a close vowel, forcing a lowering of the vowel.

Again, the case of rounding of /i/ before a labial should be easy to derive as both labial consonants and round vowels have the feature [lab]. But turning to the allophones analysed in chapter 4, matters become more difficult again. In this theory of representation there is a manner feature [lax] which can be present in both consonants and vowels. But as plosives are supposedly not [lax] it is hard to analyse the lax realisations of the vowels before coronal and velar plosives in Greenlandic as resulting from the demands of the constraint *A-SPAN(lax). Here I must admit that the manner of the consonants is something I have not taken into consideration in the study in chapter 2, but the majority of consonants in this study were plosives, as can be seen in Appendix B. In these cases though, it is of course quite possible that the reduced allophone of the vowels arises du to some other constraint interaction.

5.3 Summary and concluding remarks

In this thesis I have performed an informal investigation of vowel quality in Greenlandic, and performed a phonological analysis that analyse the vowel allophones described in this investigation. I how shown how two different structural changes in the vowels, one that could be labelled as assimilation and one that could be labelled as vowel reduction, arise from the same constraint interaction. Due to the fronting of /u/ between coronals and the reduction of /u/ before coronals, I was able to propose a structure for the resonance of coronals to replace the proposed [R] resonance. I have used a novel combination of a grammatical framework and representational structures, and also compared the adequacy of these structures to others using the same framework, showing that the choice of the phonological structure is very important to the results of an analysis. I have also in 5.1.1 sketched an extension to the analysis using the *A-SPAN constraint to analyse patterns of consonant lenition, and also, how this could be combined with some special structural considerations to analyse some changes that previously would fall under the heading of “morphophonology” as a purely phonological phenomenon. I shall admit to the slightly weak foundation of my analysis however, as the investigation in chapter 2 ignores many phonetic considerations, and lacks a statistical treatment of the results. Therefore it would be interesting to see a more extensive and precise phonetic study of vowel quality in Greenlandic, that perhaps could yield more unambiguous results than mine.

References:

Clements, George N. (1991): "Place of articulation in consonants and vowels: A unified theory." In *Working Papers of the Cornell Phonetics Laboratory*, vol. 5, pp. 77-123.

Crosswhite, Katherine M. (2004): "Vowel reduction". In Hayes, Bruce; Kirchner, Robert and Steriade, Donca (eds.): *Phonetically Based Phonology*, pp. 191-231. Cambridge University Press.

Bergsland, Knut (1955): *A Grammatical Outline of the Eskimo Language of West Greenland*. Skrivemaskinstua, Oslo.

Dahl, Östen (2004): *The Growth and Maintanance of Linguistic Complexity*. John Benjamins Publishing Company.

de Boer, Bart (2001): *The Origins of Vowel Systems*. Oxford University Press

Boersma, Paul and Weenink David (2010): Praat: doing phonetics by computer (computer program). Downloaded from www.fon.hum.uva.nl/praat/.

Fischer-Jørgensen, Eli (1957): "What Can the New Technique of Acoustic Phonetics Contribute to Linguistics?" in Fischer-Jørgensen, Eli (1979): *25 Years' Phonological Comments*, pp. 156-162. Wilhelm Fink Verlag München.

Fortescue, Michael D. (1984): *West Greenlandic*. Croom Helm.

Fortescue, Michael D. (1985): "The degree of interrelatedness between Inuit dialects as reflected by percentages of shared affixes". In *International Journal of American Linguistics*, vol. 51, no. 2, pp. 188-221.

Fortescue, Michael D. (2004): "West Greenlandic (Eskimo)". In Booij, Geert E. et al. (eds.): Morphologie/Morphology, volume 2, pp. 1389-1399. Mouton de Gruyter.

Goldsmith, John Anton (1976): *Autosegmental Phonology* (PhD dissertation). Massachusetts Institute of Technology.

Gouskova, Maria (2003): *Deriving Economy: Syncope in Optimality Theory* (PhD dissertation). University of Massachusetts Amherst.

Hale, Mark and Reiss, Charles (2008). *The Phonological Enterprise*. Oxford University Press.

Harris, John and Lindsey, Geoff (1995). The elements of phonological representation. In Durand, Jacques and Katamba, Francis (eds.): *Frontiers of Phonology: Atoms, Structures, Derivations*, pp. 34-79. Longman.

Jacobsen, Birgitte (2000): "The Question of 'Stress' in West Greenlandic". *Phonetica*, vol. 57, pp. 40-67

Johnson, Keith (1997, 2003): *Acoustic & Auditory Phonetics*. Blacwell Publishing.

Kager, René (1999): *Optimality Theory.* Cambridge University Press

Katamba, Francis (1989): *An Introduction to Phonology*. Longman.

Kirchner, Robert Martin (1998): *An Effort-Based Approach to Consonant Lenition* (PhD dissertation). University of California.

Langgård, Karen (2003): "Magt og demokrati – og sprog". In Winther, Gorm (ed.): *Demokrati og magt i Grønland*, pp. 215-235. Aarhus universitetsforlag.

Langgård, Per (1995): "Er Grønland tosproget – og hvorfor ikke?". In Thorleifsen, D. (ed.): *Festskrift i anledning Ilinniarfissuaqs 150-års jubileum*, pp.

McCarthy, John J. (2004): "Headed Spans and Autosegmental Spreading". Linguistics Department Faculty Publication Series [at the University of Massachusetts – Amherst], paper 42.
Downloaded from: http://scholarworks.umass.edu/linguist_faculty_pubs/42/

Morén, Bruce (2003): "The Parallel Structures Model of Feature Geometry". In *Working Papers of the Cornell Phonetics Laboratory*, vol. 15, pp. 194-270.

Nagano-Madsen, Yasuko (1992): *Mora and prosodic coordination – a phonetic study of Japanese, Eskimo and Yoruba*. Lund University Press.

Olsen, Carl Christian (2004): "Kalaallisut – grønlandsk". In Sletten, Iben Stampe (ed.): *Nordens språk med røtter og føtter*, pp. 113-127. Nordisk Ministerråd, København.

Plichta, Bartlomiej (2010): Akustyk (Praat script). Downloaded from http://akustyk.org.

Rischel, Jørgen (1974): *Topics in West Greenlandic Phonology – Regularities Underlying the Phonetic Appearance of Wordforms in a Polysynthetic Language* (PhD dissertation). Akademisk Forlag, Copenhagen.

Roca, Iggy (1994): *Generative Phonology*. Routledge.

Sadock, Jerrold M. (2003): *A Grammar of Kalaallisut*. Lincom Europa.

Traunmüller, Hartmut (1990): "Analytical expressions for the tonotopic sensory scale". *Journal of the Acoustical Society of America*, vol. 88, pp. 97-100.

Wood, Sydney A. J. (1971): "A spectrographic study of allophonic variation and vowel reduction in West Greenlandic Eskimo". *Working Papers at the Phonetics Laboratory, Department of General Linguistics*, vol. 4, pp. 58-94. Lund University Press.

Appendix A: List of figures

Appendix B: Values from the vowel quality investigation

/a/:

Previous segment	Previous category	Next segment	Next category	F1 (Hz)	F2 (Hz)	F3 (Hz)	F4 (Hz)	F1 (Bark)	F2′ (Bark)
l	cor	#	#	599	1454	1961	2746	5.7	11.3
l	cor	#	#	652	1590	2453	4033	6.2	11.7
t	cor	#	#	585	1520	1683	2781	5.6	11.5
t	cor	#	#	838	1634	2681	3971	7.5	11.8
t	cor	#	#	822	1610	2695	4194	7.4	11.6
t	cor	#	#	546	1942	2774	4128	5.3	13.2
p:	lab	#	#	809	1451	2461	3882	7.3	10.9
q:	uvu	#	#	757	1458	2790	4027	6.9	10.9
k:	vel	#	#	789	1580	2380	4026	7.2	11.7
#	#	s:	cor	694	1945	2829	4217	6.5	13.2
#	#	t	cor	791	1700	2797	3890	7.2	12.0
#	#	t	cor	596	1248	2344	3464	5.7	9.9
#	#	t	cor	558	1292	2187	3377	5.4	10.1
#	#	t	cor	793	1689	2722	4061	7.2	12.0
#	#	t	cor	732	1722	2729	4045	6.8	12.2
s	cor	t	cor	547	1107	1709	2772	5.3	9.4
s	cor	t	cor	510	1060	1850	2730	5.0	8.9
s:	cor	s	cor	487	1951	2797	4406	4.8	13.2
t	cor	ɬ:	cor	469	1576	2281	3421	4.6	11.8
t	cor	ɬ:	cor	444	1281	1914	2819	4.4	10.4
p	lab	l	cor	594	1369	2110	2812	5.7	10.8
p	lab	s	cor	634	1701	2620	4346	6.0	12.2
p:	lab	l	cor	497	1439	2519	3670	4.9	10.8
p:	lab	l	cor	492	1392	2222	3311	4.8	10.8
p:	lab	l	cor	529	1405	2497	3797	5.2	10.7
p:	lab	ɬ:	cor	526	1730	2750	4309	5.1	12.2
q	uvu	l	cor	602	1264	2484	3523	5.8	10.0
q	uvu	l	cor	716	1252	2100	3317	6.6	10.0
q:	uvu	ɬ:	cor	584	1525	2306	3595	5.6	11.5

q:	uvu	t	cor	507	1668	1873	2997	5.0	12.1
x:	vel	t	cor	456	1712	2520	2798	4.5	13.7
k	vel	s	cor	540	2077	2482	3978	5.3	13.7
k	vel	s	cor	565	1720	2667	3993	5.5	12.2
k	vel	s	cor	501	1539	2392	3844	4.9	11.5
#	#	p	lab	692	1695	2591	3974	6.5	12.2
#	#	p	lab	915	1600	2653	3734	8.0	11.6
#	#	p	lab	786	1649	2673	3878	7.1	11.8
#	#	p	lab	514	1334	2320	3475	5.0	10.3
#	#	v	lab	546	1821	2695	4172	5.3	12.7
l	cor	p	lab	421	1600	2513	3890	4.2	11.7
l	cor	p	lab	558	1281	1563	2751	5.4	10.5
l	cor	p	lab	582	1807	2568	3980	5.6	12.7
ɬ:	cor	p:	lab	544	1607	2515	3937	5.3	11.8
s:	cor	p:	lab	526	1475	2508	3967	5.1	11.0
p	lab	p:	lab	411	1137	1964	2487	4.1	9.3
f:	lab	v	lab	576	1180	2479	3926	5.6	9.5
k	vel	p:	lab	548	1237	2583	4110	5.3	9.8
k	vel	p:	lab	502	1155	2442	3844	4.9	9.4
k	vel	v	lab	642	1560	2480	4097	6.1	11.5
#	#	q	uvu	867	1466	2887	3864	7.7	10.9
l	cor	q	uvu	855	1420	2392	3695	7.6	10.7
l	cor	χt	uvu	885	1307	2167	3229	7.8	10.3
ɬ:	cor	χt	uvu	804	1356	2264	3757	7.3	10.5
s	cor	χf	uvu	724	1338	2672	3926	6.7	10.3
s	cor	χf	uvu	832	1422	2695	4014	7.5	10.7
s	cor	χs	uvu	745	1395	2600	3841	6.9	10.6
s:	cor	q	uvu	765	1409	2507	3833	7.0	10.7
ɬ:	cor	χs	uvu	604	1092	2236	3614	5.8	9.1
s:	cor	χp	uvu	819	1271	2646	3893	7.4	10.0
q	uvu	χf	uvu	837	1261	2458	3671	7.5	10.0
q	uvu	χɬ	uvu	733	1230	2525	3438	6.8	9.8

q	uvu	χp	uvu	830	1205	2597	3456	7.4	9.7
q	uvu	χp	uvu	821	1244	2404	3658	7.4	9.9
q	uvu	χp	uvu	871	1317	2343	3454	7.7	10.2
q	uvu	χp	uvu	755	1199	2423	3559	6.9	9.6
q	uvu	χp	uvu	693	1135	2327	3622	6.5	9.3
q	uvu	χp	uvu	843	1171	2418	3651	7.5	9.5
q:	uvu	χs	uvu	869	1346	2642	3692	7.7	10.4
q:	uvu	χs	uvu	720	1281	2484	3639	6.7	10.1
k	vel	χp	uvu	695	1321	2386	3968	6.5	10.3
k	vel	χs	uvu	728	1498	2450	3947	6.7	11.2
k:	vel	χɬ	uvu	812	1493	2394	3844	7.3	11.2
k:	vel	χp	uvu	800	1385	2404	3756	7.2	10.6
k:	vel	χt	uvu	665	1369	2126	3685	6.3	10.7
#	#	x:	vel	665	1579	2219	3712	6.3	11.8
#	#	x:	vel	574	1722	2617	3883	5.5	12.3
#	#	k	vel	466	1073	2262	2880	4.6	9.0
#	#	k	vel	673	1652	2597	4116	6.3	11.9
#	#	k	vel	547	1481	2322	2709	5.3	11.2
#	#	k	vel	749	1673	2443	4074	6.9	12.2
#	#	k	vel	764	1825	2928	4264	7.0	12.6
#	#	k:	vel	656	1766	2505	4010	6.2	12.6
#	#	k:	vel	806	1691	2663	3669	7.3	12.1
#	#	k:	vel	689	1666	2304	4051	6.4	12.2
l	cor	k	vel	593	1778	2485	4248	5.7	12.6
l	cor	k:	vel	541	1547	2150	2967	5.3	11.7
l	cor	k:	vel	435	1680	2564	3103	4.3	12.1
l	cor	k:	vel	509	1868	2815	3865	5.0	12.9
l	cor	k:	vel	445	1678	2429	3133	4.4	12.2
t	cor	k	vel	461	2111	2769	4382	4.6	13.8
t	cor	k	vel	500	1678	2521	4318	4.9	12.1
t	cor	k	vel	547	1129	2133	2518	5.3	9.3
t	cor	k	vel	490	2128	2434	4133	4.8	13.8

p	lab	k	vel	521	1584	2316	4030	5.1	11.8
v	lab	k:	vel	518	1543	2433	3915	5.1	11.5
q:	uvu	k:	vel	737	1463	2597	3938	6.8	10.9

/i/:

Previous segment	Previous category	Next segment	Next category	F1 (Hz)	F2 (Hz)	F3 (Hz)	F4 (Hz)	F1 (Bark)	F2′ (Bark)
l	cor	#	#	396	1986	2158	2917	4.0	12.4
l	cor	#	#	430	1390	2134	2919	4.3	10.9
l	cor	#	#	406	2181	2957	4346	4.1	14.0
s	cor	#	#	457	1972	2483	3491	4.5	13.3
s	cor	#	#	374	2208	2838	4413	3.8	14.1
l	cor	#	#	455	1955	2420	3628	4.5	13.3
l	cor	#	#	459	2062	2754	4196	4.6	13.6
l	cor	#	#	434	2119	2905	4198	4.3	13.8
#	#	s	cor	387	2333	2745	4262	3.9	14.4
#	#	s	cor	355	1548	2627	3623	3.6	11.3
#	#	t	cor	360	1988	2848	4153	3.6	13.4
#	#	t	cor	401	2393	3025	4304	4.0	14.6
l	cor	s:	cor	368	1610	2511	3443	3.7	11.8
s	cor	l	cor	428	1880	2508	3638	4.3	13.0
s	cor	s:	cor	397	2197	2902	4379	4.0	14.1
t	cor	l	cor	433	1488	2233	2843	4.3	11.3
t	cor	ɬ:	cor	409	2049	2759	4260	4.1	13.6
t	cor	s:	cor	409	2186	2839	4248	4.1	14.0
t	cor	t	cor	459	1903	2829	4388	4.6	13.0
t	cor	t	cor	387	2050	2832	4326	3.9	13.6
s:	cor	ɬ:	cor	420	2039	2833	4291	4.2	13.6
t:	cor	ɬ:	cor	424	1981	2912	4208	4.2	13.3
t:	cor	ɬ:	cor	439	1974	2703	4252	4.4	13.3
p	lab	s	cor	364	2207	2869	4060	3.7	14.1
p	lab	t	cor	423	2122	2762	4100	4.2	13.8
p	lab	t	cor	442	2100	2580	3636	4.4	13.8
p	lab	t:	cor	405	2036	2781	3804	4.1	13.6

v	lab	s:	cor	401	2206	2719	3873	4.0	14.1
ɣ	vel	t	cor	487	2483	2859	4342	4.8	14.2
ɣ	vel	t	cor	493	2269	2449	4158	4.9	14.1
k	vel	l	cor	432	1498	2651	3587	4.3	11.1
k	vel	s	cor	412	2355	2876	4267	4.1	14.5
k	vel	s	cor	419	2276	2768	4171	4.2	14.3
#	#	p	lab	384	2401	2844	4133	3.9	14.1
#	#	p:	lab	375	2170	2790	3955	3.8	14.0
t	cor	p	lab	396	1791	1956	2878	4.0	11.7
t	cor	p	lab	419	1940	2649	4671	4.2	13.2
t	cor	p	lab	460	1917	2582	3405	4.6	13.2
t	cor	p	lab	434	1863	2571	3563	4.3	12.9
t	cor	p	lab	422	1996	2673	3596	4.2	13.4
t	cor	p	lab	487	2029	2540	3377	4.8	13.5
l	cor	p:	lab	393	2210	2959	4256	3.9	14.1
l	cor	p:	lab	473	2076	2844	4320	4.7	13.7
ɬ:	cor	p	lab	422	1923	2478	3514	4.2	13.2
s	cor	p	lab	417	2043	2800	4320	4.2	13.6
s	cor	p:	lab	452	2181	2823	4268	4.5	14.0
ts	cor	p	lab	445	1938	2529	3671	4.4	13.2
ts	cor	p	lab	418	1861	2508	4091	4.2	13.0
ts	cor	p:	lab	393	1960	2598	3392	3.9	13.3
s:	cor	v	lab	483	1939	2821	3521	4.8	13.2
p	lab	p:	lab	377	2315	2826	3957	3.8	14.1
p	lab	v	lab	415	2087	2571	3798	4.2	13.7
p	lab	v	lab	412	2079	2563	3785	4.1	13.7
q:	uvu	p:	lab	493	1964	2760	3631	4.9	13.3
k	vel	f:	lab	408	2352	2660	4320	4.1	14.4
k	vel	f:	lab	447	2315	2559	4010	4.4	13.4
k	vel	p:	lab	384	2302	2799	4210	3.9	14.4
#	#	q:	uvu	580	1213	2238	3639	5.6	9.7
#	#	q:	uvu	562	1640	2785	3852	5.4	11.7

#	#	q:	uvu	492	1485	3041	4432	4.8	11.0
s	cor	q	uvu	505	1377	1672	2864	5.0	10.9
s	cor	q	uvu	602	1357	2765	3630	5.8	10.4
s	cor	q	uvu	545	1394	2932	4237	5.3	10.6
s	cor	q	uvu	607	1351	2563	3696	5.8	10.4
t	cor	q	uvu	641	1344	2678	4067	6.1	10.4
t	cor	q	uvu	543	1410	2893	3861	5.3	10.7
t	cor	q	uvu	530	1256	2661	3859	5.2	9.9
l	cor	q:	uvu	460	1419	2782	4010	4.6	10.7
l	cor	q:	uvu	602	1484	2794	4064	5.8	11.0
t	cor	q:	uvu	589	1340	2752	4255	5.7	10.4
l	cor	χɬ	uvu	703	1511	2719	4084	6.5	11.1
s	cor	χ:	uvu	652	1513	2925	4258	6.2	11.1
ɬ:	cor	χt	uvu	597	1346	2716	3672	5.7	10.4
l	cor	χp	uvu	778	1532	2814	4187	7.1	11.2
l	cor	χp	uvu	654	1437	2832	4011	6.2	10.8
l	cor	χp	uvu	600	1340	2723	3951	5.8	10.4
l	cor	χp	uvu	606	1630	2520	3892	5.8	11.9
ɬ:	cor	χp	uvu	644	1327	2759	3929	6.1	10.3
s	cor	χp	uvu	559	1371	2767	3950	5.4	10.5
t	cor	χp	uvu	551	1230	2934	4050	5.4	9.8
p	lab	q:	uvu	573	1410	3015	3234	5.5	10.7
p	lab	χɬ	uvu	596	1378	2729	3722	5.7	10.5
#	#	ɣ	vel	411	2459	3008	4098	4.1	14.6
#	#	k	vel	410	2446	3013	4332	4.1	14.8
#	#	k	vel	417	2498	2801	3673	4.2	14.1
l	cor	k:	vel	369	2110	2775	4332	3.7	13.8
s	cor	x:	vel	403	2356	2686	4262	4.0	14.4
s	cor	k:	vel	358	2189	2609	4215	3.6	14.0
s	cor	k:	vel	393	2479	2839	4226	3.9	14.1
t	cor	ɣ	vel	405	1605	2306	2707	4.1	13.2
t	cor	k	vel	381	2366	2697	4208	3.8	14.5

t	cor	k	vel	425	2373	2531	4236	4.2	14.3
t	cor	k:	vel	426	2206	2827	4090	4.3	14.1
p:	lab	k	vel	467	2127	2484	3821	4.6	13.8
p:	lab	k	vel	429	2164	2700	3962	4.3	14.0
p:	lab	k	vel	421	2145	2603	3878	4.2	13.9
p:	lab	k	vel	408	2067	2496	2616	4.1	13.6
f:	lab	k:	vel	531	1925	2368	3635	5.2	13.2
f:	lab	k:	vel	456	2177	2561	3246	4.5	13.6

/u/:

Previous segment	Previous category	Next segment	Next category	F1 (Hz)	F2 (Hz)	F3 (Hz)	F4 (Hz)	F1 (Bark)	F2′ (Bark)
l	cor	#	#	512	1378	2409	3535	5.0	10.5
l	cor	#	#	492	1316	2343	3697	4.8	10.2
l	cor	#	#	555	1529	2429	3541	5.4	11.4
l	cor	#	#	536	1519	2283	3501	5.2	11.5
l	cor	#	#	495	1322	2392	3723	4.9	10.3
l	cor	#	#	509	1222	2453	2977	5.0	9.8
l	cor	#	#	541	1434	2243	3672	5.3	11.0
l	cor	#	#	505	1430	2461	3617	5.0	10.8
l	cor	#	#	545	1464	2335	3744	5.3	11.1
ɫ:	cor	#	#	426	1212	2282	3821	4.3	9.7
ɫ:	cor	#	#	506	1388	2414	3700	5.0	10.6
ɫ:	cor	#	#	525	1288	2280	4018	5.1	10.1
ɫ:	cor	#	#	537	1229	2356	3938	5.2	9.8
ɫ:	cor	#	#	402	1665	2631	3889	4.0	12.0
ɫ:	cor	#	#	424	1555	2566	3273	4.2	11.4
ɫ:	cor	#	#	442	1152	2514	2611	4.4	9.4
ɫ:	cor	#	#	455	1203	2376	2561	4.5	9.7
ɫ:	cor	#	#	450	1307	2415	3441	4.5	10.2
ɫ:	cor	#	#	507	1188	2340	4015	5.0	9.6
ɫ:	cor	#	#	446	1271	2309	3429	4.4	10.0
k:	vel	#	#	401	1051	2462	4208	4.0	8.8
k:	vel	#	#	541	1049	2465	4182	5.3	8.8

k:	vel	#	#	479	1077	2415	4269	4.7	9.0
k:	vel	#	#	436	1616	2571	3127	4.3	11.8
#	#	l	cor	411	1238	2448	2896	4.1	9.8
l	cor	t:	cor	388	1702	2542	2665	3.9	13.7
l	cor	t:	cor	413	1631	2707	3614	4.1	11.7
l	cor	t:	cor	395	1356	2098	2932	4.0	10.7
s	cor	l	cor	429	1819	2274	3270	4.3	12.8
s	cor	t	cor	389	1819	2569	3550	3.9	12.8
s	cor	t	cor	410	1309	2019	2748	4.1	10.5
s:	cor	t	cor	394	1863	2717	3769	4.0	12.9
s:	cor	t	cor	400	1854	2663	3324	4.0	12.9
t	cor	s	cor	391	1915	2655	3738	3.9	13.1
t	cor	s	cor	384	1869	2777	3511	3.9	12.9
t:	cor	s:	cor	375	1903	2713	3379	3.8	13.1
t:	cor	t	cor	459	1873	2558	3934	4.6	13.0
t:	cor	t	cor	448	1431	2387	3581	4.5	10.8
p	lab	t	cor	432	1304	2433	3641	4.3	10.2
p:	lab	t	cor	495	1249	2394	3076	4.9	9.9
k:	vel	t	cor	415	1352	2601	3974	4.2	10.4
k:	vel	t	cor	414	1031	2536	4101	4.1	8.7
k:	vel	t	cor	422	1461	2457	4069	4.2	10.9
k:	vel	t	cor	502	1268	2328	3710	4.9	10.0
k:	vel	t	cor	434	1351	2524	3874	4.3	10.4
#	#	p:	lab	388	906	2448	4362	3.9	7.9
#	#	p:	lab	405	1073	2498	4338	4.1	9.0
#	#	p:	lab	418	1033	2402	4173	4.2	8.7
#	#	p:	lab	392	976	2374	4166	3.9	8.4
#	#	p:	lab	434	933	2346	4299	4.3	8.1
#	#	p:	lab	435	994	2449	4254	4.3	8.5
#	#	p:	lab	386	1017	2426	4125	3.9	8.6
#	#	p:	lab	428	1049	2437	4065	4.3	8.8
t	cor	p	lab	383	1271	2407	3569	3.9	10.0

t	cor	p	lab	384	1201	2454	3799	3.9	9.7
t	cor	p	lab	361	1233	2551	3557	3.6	9.8
t	cor	p:	lab	399	1107	2496	3871	4.0	9.1
ts	cor	p	lab	507	1579	2519	3369	5.0	11.6
q	uvu	p:	lab	462	957	2613	3751	4.6	8.3
k:	vel	p:	lab	455	1051	2559	3974	4.5	8.8
k:	vel	p:	lab	427	911	2631	4214	4.3	8.0
#	#	q	uvu	506	997	2821	3853	5.0	8.5
#	#	q	uvu	517	1099	2647	3655	5.1	9.1
#	#	q	uvu	586	1112	2497	3799	5.6	9.2
#	#	q	uvu	433	1066	2203	3603	4.3	8.9
#	#	q	uvu	640	1146	2374	3826	6.1	9.4
s:	cor	q	uvu	589	1240	2531	2701	5.7	9.9
t	cor	q:	uvu	374	1151	2624	3784	3.8	9.4
t:	cor	q	uvu	582	1195	2611	3697	5.6	9.6
t:	cor	χt	uvu	464	1179	2743	3645	4.6	9.5
t:	cor	χt	uvu	542	1198	2463	3636	5.3	9.6
s:	cor	q	uvu	590	1189	2749	3569	5.7	9.6
t:	cor	q	uvu	639	1186	2661	3705	6.1	9.6
t:	cor	χɬ	uvu	602	1211	2772	3465	5.8	9.7
pp	lab	q	uvu	566	1136	2621	3641	5.5	9.3
pp	lab	q	uvu	500	1123	2361	3616	4.9	9.2
pp	lab	q	uvu	605	1217	2451	3811	5.8	9.7
v	lab	q	uvu	483	1079	2350	3729	4.8	9.0
v	lab	q	uvu	571	1062	2430	3863	5.5	8.9
p:	lab	q	uvu	537	1059	2364	3558	5.2	8.9
p:	lab	q	uvu	584	1089	2542	3690	5.6	9.0
q:	uvu	χs	uvu	390	1128	2380	3378	3.9	9.3
x:	vel	χs	uvu	472	1007	2484	3478	4.7	8.6
x:	vel	χs	uvu	479	1153	2168	3624	4.7	9.4
x:	vel	χs	uvu	517	1071	2078	3789	5.1	8.9
k	vel	χf	uvu	710	1140	2327	3862	6.6	9.3

s	cor	k:	vel	395	1376	2485	3828	4.0	10.5
s	cor	k:	vel	461	1241	2310	3624	4.6	9.9
s	cor	k:	vel	458	1309	2425	3616	4.5	10.2
s	cor	k:	vel	353	1239	2215	3395	3.6	9.9
t	cor	ɣ	vel	450	1417	2447	4001	4.5	10.7
t	cor	k	vel	403	1434	2389	3381	4.0	10.8
t	cor	k:	vel	413	1353	2422	3946	4.1	10.4
t	cor	k:	vel	420	1260	2462	4007	4.2	10.0
t	cor	k:	vel	409	1224	2516	3499	4.1	9.8
ɬ:	cor	ɣ	vel	478	1208	2451	4117	4.7	9.7
ɬ:	cor	ɣ	vel	498	1479	2462	4029	4.9	11.1
ɬ:	cor	k	vel	498	1262	2460	3643	4.9	10.0
r	uvu	k	vel	509	1096	2441	3545	5.0	9.1
k	vel	k	vel	404	1040	2488	4269	4.1	8.8

Appendix C: All vowel realisations from chapter 2 sorted by allophone