INTRUSIVE STOP FORMATION IN ZULU: AN APPLICATION OF FEATURE GEOMETRY THEORY

By

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DECLARATION

I, the undersigned, hereby declare that the work contained in this thesis is my own original work and has not been previously in its entirety or in part been submitted at any university for a degree.

Signature……………………………….. Date………………...

SUMMARY

Key words:

Affricates, Intrusive Stop Formation, Duration, Feature Geometry, Phonetics, Phonology, Laboratory Phonology

This study investigates the Intrusive Stop Formation process in Zulu. In this process an intrusive stop arises when a nasal and fricative are juxtaposed resulting in the following seven affricate sounds /þf’, {v, ts’, dz, tñ’, dL, tS’/. These sounds are theoretically distinct from the four affricate phonemes which occur in Zulu, namely /kl’, dZ, ts’, tS’/. In this study the former are termed derived affricates and the latter pure affricates.

Two aspects of Intrusive Stop Formation are focused on - firstly, determining experimentally whether durational differences obtain between pure and derived affricates and secondly, using the results of the experimental investigation to facilitate a feature geometry description of the Intrusive Stop Formation process.

In the experimental investigation nine affricate sounds were examined. Words, containing these sounds, were recorded in frame sentences by five speakers, using PRAAT, a speech–processing platform. The duration of the pure and derived affricates were then determined. It was found that pure affricates are durationally longer than derived affricates.

The next progression in this study was the incorporation of the experimental results into a feature geometry description of Intrusive Stop Formation. Feature Geometry Theory has enjoyed acclaim because of its ability to retain Distinctive Feature Theory – the crux of Phonology – in a nonlinear framework. However, Feature Geometry Theory faces challenges with regard to the extent to which it includes phonetic detail; and its formalization technique. This study – *Intrusive Stop Formation in Zulu : An Application of Feature Geometry Theory* – brings a

new perspective to Feature Geometry Theory with the incorporation of the Duration tier – significant for the description of the Intrusive Stop Formation process. Furthermore the study introduces a more efficient formalization technique, which facilitates the explanation of the process.

It is always incumbent upon endeavours like this study, which examine specific phonological processes, to show relevance. In the concluding section the application of the experimental approach and Feature Geometry Theory is evaluated in terms of the contribution made to the disciplines of Human Language Technology and Speech Disorders.

A compact disk accompanies this thesis. It contains the sound files, spectrograms and textgrids of the recorded data.

OPSOMMING

Sleutelwoorde:

Afrikatale, Sluitklankinvoeging, Duur, Distinktiewe Kenmerke, Fonetiek, Fonologie, Laboratorium Fonologie

Hierdie studie ondersoek Sluitklankinvoeging as `n fonologiese proses in Zulu. In hierdie proses ontstaan ’n intrusiewe stop wanneer ‘n nasaal en ‘n frikatief naas mekaar geplaas word en lei tot die ontstaan van die volgende sewe affrikate /þf’, {v, ts’, dz, tñ’, dL, tS’/. Hierdie klanke is teoreties onderskeibaar van vier affrikate wat in Zulu voorkom, naamlik /kl’, dZ, ts’, tS’/. In hierdie studie word na die eersgenoemde groep verwys as “afgeleide” affrikate en na die laasgenoemde as “suiwer” affrikate.

Hierdie studie fokus op twee aspekte van Sluitklankinvoeging; eerstens, om op eksperimenteel fonetiese gronde die aanname te toets of daar duurverskille tussen suiwer en afgeleide affrikate voorkom en tweedens, om in die lig van die resultate van die eksperimentele ondersoek, ‘n distinktiewe kenmerk-beskrywing van die Sluitklankinvoegingsproses binne `n bepaalde raamwerk te fasiliteer.

In die eksperimentele ondersoek is nege affrikate foneties geanaliseer. Die uitspraak van woorde waarin hierdie klanke voorkom is opgeneem in raamsinne deur vyf sprekers dmv ‘n spraakverwerkingsplatvorm, PRAAT. Die fonetiese eienskappe van die suiwer en afgeleide affrikate is daarna bepaal met spesifieke aandag aan duurverskynsels. Die bevinding is dat die suiwer affrikate ‘n langer artikulasieduur as afgeleide affrikate het.

Die volgende stap in hierdie studie was die integrasie van die bevindinge van die eksperimentele ondersoek binne ‘n distinktiewe kenmerk-beskrywing van Sluitklankinvoeging. Kenmerk-geometrieteorie (Feature Geometry Theory) implementeer distinktiewe kenmerke binne `n nie-liniêre beskrywingsraamwerk,

en as sodanig skep dit besondere uitdagings met betrekking tot die insluiting van fonetiese detail binne die sisteem. Hierdie studie bied ‘n nuwe perspektief op Kenmerk-geometrieteorie met die insluiting van “duur” as ‘n distinktiewe kenmerk in die beskrywing van die Sluitklankinvoegingproses in Zulu. Verder stel die studie ‘n meer doeltreffende formaliseringstegniek voor, wat die verklaring van die proses vergemaklik.

Dit is altyd gebiedend vir ‘n studie van hierdie aard wat om blyke van relevansie te lewer. In die slotafdeling word die toepassing van die eksperimentele benadering asook Kenmerk-geometrieteorie geëvalueer in terme van die bydrae tot die dissiplines van Menslike Taaltegnologie (Human Language Technology) en Spraakpatologie.

‘n Kompakskyf (CD) word by hierdie tesis ingesluit. Dit bevat die klanklêers, spektrogramme en tekstabelle van die opgeneemde data wat in hierdie studie aangebied is.

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For Thatha
Who would have been so proud

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Chapter One
Orientation

Knowledge advances when many different ways of looking at the world are available,…, it advances cumulatively only when it is driven by the scientific method of reducing competing ways of looking to testable hypotheses and then designing and performing the appropriate experiments to test them.
Beckman (1988:234)

1.0. Introduction

Crystal (1997:12-13) explains that an affricate is a combination of plosion and friction, and defines the term as:

> …a sound made when the air-pressure behind a complete closure in the vocal tract is gradually released; the initial release produces a plosive, but the separation which follows is sufficiently slow to produce audible friction, and there is thus a fricative element in the sound also.

Affricate phonemes obtain in a large percentage of the world's languages[1]. However, of greater interest is the affricate that results from the juxtapositioning of a nasal and fricative. Sievers (1879:141) describes this as follows:

> *Hiermit betreten wir wieder das Gebiet des regelrechten Lautwandels.*
> We herewith encounter the area of proper sound changes.

This juxtapositioning is explained as "Affrication", where a fricative sound is changed into an affricate. Currently, the more popular terms are "Epenthesis" and "Intrusive Stop Formation[2]", alluding to the presence of the 'new sound' that surfaces between the nasal and fricative. Over the decades linguists have investigated this phenomenon but debates on the description and explanation of the process remain active.

While the process is typical of several Bantu languages[3] (cf. Nurse & Philippson, 2003:51), this study, *Intrusive Stop Formation in Zulu: An Application of Feature Geometry Theory,* concentrates on phonetic and phonological aspects of Zulu affricates, using an experimental framework to facilitate a phonological description of this occurrence of the intrusive or epenthetic stop.

The problematic nature of epenthetic or intrusive sounds in Zulu dates back to the early twentieth century. Wanger (1927:5) comments that Bryant's (1905) transcription of the word *inhliziyo* as intliziyo – no phonetic conventions were adhered to - is "unscientific" as it includes the /t/ sound and states:

> …because n which nasalizes hl, is of itself a dental nasal, wherefore n + hl, if not separated by an unnatural effort, automatically produces a slight connecting dental sound

Thus the issue of epenthesis or intrusion poses a challenge to phonetic transcription, and has implications for the phonetic description and phonological explanation of the nature and behaviour of affricates.

According to Fourakis & Port (1986:198) epenthesis is a "phenomenon that impacts on the interface between phonology, phonetics and physiology".

Warner (2002:1) reiterates this position and adds:

> …there are reasons to consider it a phonological alternation, part of the grammar, but it is clearly articulatorily motivated and closely related to language-specific phonetics. It is also a highly variable alternation, even within speakers, and there is evidence that **epenthetic stops are not phonetically equivalent to underlying stops**. (My emphasis: SN)

The following sections will expand on the complexity of the affricate in Zulu. It will become apparent that linguists have been hesitant in distinguishing among the affricate phonemes i.e. pure affricates versus derived affricates (nasal + fricative combination). Much of this cautiousness can be attributed to the lack of experimental evidence on the phonetic attributes of the affricate. Apart from obtaining experimental data on the nature of the affricate, this study seeks to find an appropriate phonological description of the Affrication/Intrusive Stop Formation/Epenthesis process.

1.1. The Problem

In Zulu, the nasal + fricative combination is the precondition for the occurrence of the intrusive stop. Meinhof (1932:92), while not using the terms Affrication, Epenthesis or Intrusive Stop Formation, identified the following “nasal compounds” in which the intrusive segment occurred:

Table 1.1 Nasal Compounds - Meinhof (1932)

N + s	n**t**s’
N + f	m**p**f’

Ziervogel et al. (1967, 1976) record that “nasal compounds” initiate a particular “pronunciation”. These are shown in Table 1.2.

Table 1.2 Nasal + Fricative Combination - Ziervogel, Louw & Ngidi (1967) and Ziervogel, Louw & Taljaard (1976)

Ns	nts (not normally heard)[4]
Nz	ndz
Mf	m-p-f
Mv	m-b-v
Nhl	n-t-hl

Ziervogel et al. (1976:19-23) and Canonici (1996:20) identify a class of affricate sounds which are distinct from the nasal + fricative combination. These are self-standing affricates (or what this study refers to as pure affricates) and are shown in Table 1.3:

Table 1.3 Pure Affricates

Ziervogel, Louw & Taljaard (1976)[5]	Canonici (1996)
ts’	ts [ts’]
tsh’	tsh [tS’]
j	j [dZ]
kl’	kl [kl][6]

Canonici (1996:30) also identifies affricates which arise from the nasal + fricative combination. But he describes these as “fricative allophones”. Table 1.4 shows the fricative allophones:

Table 1.4 Fricative Allophones - Canonici (1996)

N + fricative	Fricative Allophones
N + /f/	[φf']
N + /v/	[{v]
N + /s/	[ts']
N + /z/	[dz]
N + /hl/	[tñ']
N + /dl/	[dL]

Irrespective of the terms used, these linguists inadvertently identify the presence of an epenthetic or intrusive stop.

Of significance is the tentativeness of the linguists, Canonici (1996) excluded, to classify affricates. Meinhof (1932) and Ziervogel et al. (1967) do not use the term affricate. Ziervogel et al. (1976) use the term broadly to identify pure and derived affricates. Moreover, none of the linguists comment on the phonetic nature of the affricates. This may be attributed to the absence of conclusive phonetic data on the Zulu affricates as no experimental work has been conducted on this subject. This in turn has limited the description of the phenomenon to the linear Generative paradigm.

1.2. Motivation

While the linguists discussed in the previous section were cognizant of the phonological domain in which Affrication occurred, their recording of the intrusive stop was based on impressionistic observations. Such observations are no longer acceptable and it is incumbent upon the scholar to experimentally verify data. For English, experimental investigation has been ongoing - cf. Daly & Martin (1972), Harms (1973), Ohala (1974), Ali et al. (1979), Dorman et al. (1980), Wetzels (1985), Fourakis & Port (1986), Clements (1987), Blankenship (1992), Stevens (1993) and Yoo & Blankenship (2003). It is that perspective that provides the springboard for this study. As there is a paucity of experimentally obtained descriptions in Zulu and the African languages in general, cf. Doke (1926); Sands (1991), Ladefoged & Traill (1994), Ladefoged & Maddieson (1996); Roux & Ntlabezo (1996), it was deemed that such an investigation, which apart from ascertaining the correctness of classical observations, would also build the arsenal of experimental data on Zulu and open new possibilities for describing phonological processes. The latter point arises because experimental investigations have tended to be just that – experiments. Little was done to translate the results into phonological description. And that is the second factor that has motivated this study, namely the development of a phonological description of Intrusive Stop Formation in Zulu. The crux of the study is the introduction of a new tier – Duration – in the feature geometry structure, one that is experimentally informed and crucial to the description of the Intrusive Stop Formation process.

The incorporation of experimental data into phonological description comes to impact on the dichotomous relationship between Phonetics and Phonology, at the theoretical and practical level. Table 1.5 is a tabulation by Keating in Cohn (1998:29), illustrating the distinctions between Phonetics and Phonology:

Table 1.5 The Differences Between Phonetics and Phonology

Phonology	Phonetics
▪ Symbolic representations ▪ Allow idealization of segmentation, labels and timelessness ▪ Rules manipulate features and feature values, associations ▪ Phonological rules can be category changing, produce static changes over the whole segment; can be lexical, cyclic	▪ Physical representations ▪ Continuous in time and space ▪ Internal temporal structure allows overlap ▪ Quantitative values on multiple independent dimensions ▪ Rules interpret feature values in time and space, can be gradient

This dichotomy can be bridged using the so-called Laboratory Phonology approach, which is premised on integrating Phonetics and Phonology. In this approach these two disciplines are no longer considered as separate entities. To use the analogy of Ohala (1990:152) Phonology is the “software” and Phonetics the “hardware”. Roux (1991:49) uses a similar analogy espousing the more popular view of the integration, as opposed to the interfacing of Phonetics and Phonology:

> Phonetics and phonology are merely flip sides of the same coin without any interface involved. Although it is the right of proponents of each domain to determine their own specific objectives, useful and credible explanations can only be expected from studies effectively utilizing both sides of the coin.

Clark & Yallop (1990:4) also share that view:

> …the boundary need not be sharply drawn, nor should it be surreptitiously constructed on assumptions about the primacy of one kind of reality above others. In short, although we analyse speech by breaking it down into several aspects, we should not forget that the true reality is one of integration.

While Laboratory Phonology provides the experimental approach, a phonological description of Intrusive Stop Formation still requires a traditional theoretical framework. For this study Feature Geometry Theory is the chosen framework. Chapter Two is devoted to an explanation of this framework.

Thus, the absence of experimental work on intrusive stops in Zulu (as opposed to English) has motivated this experimental investigation of Intrusive Stop Formation. Furthermore, the integration of Phonetics and Phonology in a Feature Geometry description of the Intrusive Stop Formation process is a challenge that this study takes on.

1.3. Aims

In view of the preceding discussion this study is concerned with two broad aims:

- Experimentally obtaining data on the duration of Zulu intrusive stops
- Using the Feature Geometry framework, informed by the experimental results, to formalize a description of the Intrusive Stop Formation process.

In more specific terms the aims are as follows:

Phonetic Level

- Determining whether the acoustic phonetic parameter – Duration – is able to distinguish between pure and derived affricates in Zulu
- Determining whether voiceless affricates are ejected[7]

Phonological Level

- Assessing the traditional Generative Distinctive Feature description of affricates and the Affrication process
- Assessing the formalization of the Affrication/Intrusive Stop Formation process in the contemporary Feature Geometry framework

Integrated Level

- Examining theoretical perspectives on the relationship between Phonetics and Phonology
- Incorporating the experimental results into phonological description of Intrusive Stop Formation.
- Introducing two new perspectives to the feature geometry formalization of Intrusive Stop Formation, namely an acoustic tier Duration and a constraint-based approach.

1.4. Summary of Chapters

Chapter Two is a chronological exposition of Distinctive Feature Theory in the linear and nonlinear framework. The description of the Affrication process is examined in the Generative framework and the reasons for the move from the linear to the nonlinear are discussed. This is followed by a critique of the nonlinear Feature Geometry framework, wherein six feature geometry structures and their distinctive feature are compared and contrasted. Feature geometry structures have been designed on the basis of where on the hierarchy theorists locate Phonetics and Phonology. For example, some believe that feature geometry structures should depict the anatomical apparatus accurately, implying a Phonetic bias; while others believe that a consideration of Phonological criteria takes precedence. In comparing and contrasting these structures, the most efficient feature geometry structure and distinctive features, for the description of Intrusive Stop Formation, can be identified. And that structure is ultimately the anatomically based proposal of Halle, Vaux & Wolfe (2000). Given the Phonetic bias in this structure, it becomes incumbent to ensure the phonetic accuracy of the structure with regard to the description of Intrusive Stop Formation in Zulu. This acts as a catalyst to the experimental investigation in Chapter Three.

Chapter Three presents the experimental investigation into the affricates in Zulu, comparing the respective duration of the "assumed" pure affricates /kl', dZ, tS', ts'/ and derived affricates /φf', {v, ts', dz, tS', tñ', dL/ to ascertain whether the two types of affricates are indeed different. The chapter commences with an outline of the development of the experimental framework in Phonology. The experiment is then comprehensively explained and the results statistically analyzed.

Chapter Four is an application of the experimental results to the feature geometry formalization of Intrusive Stop Formation in Zulu. The chapter commences with a discussion on the principle of explanation in Phonology. It then proceeds onto the issue of integrating the acoustic dimension, which is quantitative and value-based, into Feature Geometry Theory. A proposal is then made for the introduction of a distinctive feature [±long], subsumed under the Duration tier. It is postulated that the use of this distinctive feature will provide an optimal description of the distinction between pure and derived affricates in Zulu. The formalization of the Intrusive Stop Formation process in Zulu is then presented. To bring greater clarity to the description of this process, a formalization technique incorporating a constraint-based framework is invoked and integrated into the feature geometry description of the process.

Chapter Five assesses how the original aims of this study and the results obtained relate. The chapter also looks at the practical implications of theoretical study by discussing the role of Phonetics and Phonology in the development of Human Language Technology systems and the study of language disorders.

NOTES

1. Using the UCLA Phonological Segment Inventory Database (UPSID), Hinskens & Van der Weijer (2004) conclude that of the 317 languages in the database, only one third or 105.2 languages do not contain affricates. Thus two-thirds or 211.80 languages contain affricates.
2. Intrusive Stop Formation is the preferred term in this study.
3. In the South African Bantu language family, Intrusive Stop Formation occurs in the Nguni, Sotho and Venda languages. While similarities are present, the process in Southern Sotho appears to be more complex than in Zulu. Guma (1971:31) explains the process as Nasal Strengthening where the preceding nasal causing the strengthening of continuants. This may result, not only in the occurrence of an intrusive stop but also in a complete sound change. For example:

   N + f → ph

   Doke & Mofokeng (1957:25) also note that the fricatives become aspirated during Affrication. Using their phonetic conventions, this is shown in Table 1.6.

   Table 1.6 Southern Sotho

N + fricative	Derived Affricate
N + f	mph
N +r	nth
N + s	ntsh
N + S	´tSh
N + ñ	ntñh
N + h	Nkxh
N + dZ	´tS’

   Ziervogel (1967:255-256), in a discussion of “nasalization”, documents a similar occurrence for Venda, where fricatives become aspirated during the Affrication process. Also complete sound changes occur in some instances. These are shown in Table 1.7:

Table 1.7 Venda

N + fricative	Derived Affricate
n + f [f]	pf [φfh]
n + v [v]	mbv [μ{v]
n + s [s]	ts [tsh]
n + z [z]	ndz [ndz]
n + sh [s]	tsh [tsh]
n + x [x]	kh [kh]
n + h [h]	kh [kh]

4. Impressionistic observations indicate that [t] is audible.
5. Ziervogel et al. (1976) do not differentiate clearly between phonetic and orthographic script. Therefore, their pure affricate phonemes occur in Table 1.3 in orthographic script but with ejective markings. The affricate phoneme /tsh/ [tS'] should not be read as an ejected aspirated sound but simply as a ejected sound. Ziervogel et al. (1976) are referring to the same sounds as Canonici (1996) but the former err in their transcription.
6. /kl/ is a peculiar affricate. While the other affricates are phonetically composed of a stop + fricative, /kl/ is composed of a stop + liquid. However, there is no experimental evidence to unequivocally prove that this is not an affricate (cf.3.4.5.1.).
7. Ejective affricates and fricative sounds have limited occurrence. The UPSID database contains only forty languages or 12.6% with ejective affricates. Ten languages or 3.2% contain ejective fricatives (Maddieson, 1984:108-109). With the exception of /kl/, the Zulu affricates and fricatives are not part of the UPSID inventory. Therefore it was deemed necessary to examine the ejective status of the Zulu affricates.

Chapter Two

Intrusive Stop Formation – From Linear to Nonlinear Description

…autonomous phonology has yet to develop a tradition of accountability: it has enlargened the list of causal factors which it can cite to account for given phonological behavior – but it has not enlargened its repertory of ways to ensure the quality of evidence in support of its claims.

Ohala (1991:9)

2.0. Introduction

Chapter Two focuses on the description of the Intrusive Stop Formation process within linear and nonlinear frameworks. The chapter commences with a review of the development of Distinctive Feature Theory in a linear framework. Problems with this framework are identified, and the factors that motivated for the move towards a nonlinear feature geometry framework are discussed.

The chapter then proceeds with a critique of Feature Geometry Theory. The critique takes the form of an application of six feature geometry structures to the Zulu Intrusive Stop Formation process. The six structures are a chronological presentation of the three major theoretical approaches to Feature Geometry Theory. These three have been termed the Phonological approach, the Unified Theory approach and the Anatomical Accuracy approach. Thereafter the Ladefoged & Maddieson (1996) proposal for a comprehensive, phonetically informed feature geometry structure and distinctive features is presented. A comparison between this proposal and the six structures is undertaken. This comparison assists in the selection of the relevant distinctive features and feature geometry nodes for the development of a language-specific feature geometry structure.

Finally, two nonlinear proposals for the formalization of the Intrusive Stop Formation process are critiqued (these focus exclusively on the Intrusive Stop Formation process as opposed to Feature Geometry Theory).

The aims of this chapter are as follows:

- Assess the Generative representation of affricates and the Intrusive Stop Formation process
- Critique the formalization of the Intrusive Stop Formation process proposed in the six feature geometry structures and those of Steriade (1993) and Schafer (1995)
- Critique the phonetically informed Ladefoged & Maddieson (1996) proposal and that of the six structures with the intention of establishing a language-specific distinctive feature inventory.

2.1. The Development of Distinctive Feature Theory: From *Preliminaries to Speech Analysis (PSA)* to *Sound Pattern of English* (*SPE*)

In 1951 Jakobson, Fant & Halle published a major work of the last century, *Preliminaries to Speech Analysis,* hereafter referred to as *PSA*. In this work the theory of the phoneme was taken a step further with the introduction of the concept of distinctive features, defined as:

> The ultimate distinctive entities of language since no one of them can be broken down into smaller linguistic units. The distinctive features combined into one simultaneous or,…, concurrent bundle form a phoneme.
>
> (1951:3)

In *PSA*, the authors produced an inventory of distinctive features. Three categories of features constituted the *PSA* distinctive feature inventory. These were Fundamental Source Features, Secondary Consonantal Features and Resonance Features. All features were defined in terms of acoustic and articulatory correlates. Jakobson, in Sangster (1982:26) notes:

> A listing of distinctive features in terms of their articulatory correlates without any acoustical correspondents inevitably remains an imprecise and inconclusive torso.

The features are shown in Table 2.1.

Table 2.1 *PSA* Inventory of Distinctive Features

CATEGORY	SUB-CATEGORY	FEATURES
Fundamental Source Features		Vocalic vs non-vocalic
		Consonantal vs non-consonantal
Secondary Consonantal Features	Envelope Features	Interrupted vs continuant Checked vs unchecked
		Strident vs mellow
Resonance Features		Compact vs diffuse
	Tonality Features	Grave vs acute Flat vs plain Sharp vs plain
		Tense vs lax
	Supplementary Resonator	Nasal vs oral

The successor to *PSA* was the work of Chomsky & Halle, entitled *The Sound Pattern of English* (1968) and hereafter referred to as *SPE*. The distinctive feature inventory of *SPE* is composed of 5 main categories (a Prosodic category was acknowledged but not developed) and twenty-two features. *SPE* was a development on the inventory of features presented in *PSA,* introducing the concept of binary features, extending the number of categories and features. All features are binary and are described in terms of their articulatory correlates[1]. Table 2.2 shows the distinctive feature inventory of *SPE*.

Table 2.2 *SPE* Inventory of Distinctive Features

CATEGORY	SUBCATEGORY	FEATURES
Major Class Features		Sonorant
		Vocalic
		Consonantal
Cavity	Primary Strictures	Coronal Anterior
	Tongue-Body Features	High Low Back
		Round
		Distributed
		Covered
		Glottal constriction
	Secondary Aperture	Nasal Lateral
Manner of Articulation		Continuant
		Delayed release
	Supplementary Movement	Suction Pressure
Source		Tense
		Heightened Subglottal Pressure
		Voice
		Strident

2.2. Distinctive Features in Generative Phonology

PSA and *SPE* shared a common purpose, namely the development of a system that described the phonetic content of sounds and allowed their classification into natural classes. Roca & Johnson (1999:90) succinctly describe this system as follows:

> …the system is maximally simple (it should only contain the features necessary to implement classification), clear (each value is immediately transparent:…) and unambigious…

Table 2.3, reproduced from Hyman (1975:242-243), is representative of the affricate distinctive features matrices[2] within the Generative paradigm.

Table 2.3 Distinctive Features for Affricates (Hyman:1975)

	t^s	c#	$j^{\#}$
cons	+	+	+
syll	-	-	-
son	-	-	-
high	-	+	-
back	-	-	-
low	-	-	-
ant	+	-	-
cor	+	+	+
voice	-	-	+
cont	-	-	-
nasal	-	-	-
strid	+	+	+
del rel	+	+	+
round	-	-	-
grave	-	-	-
lab	-	-	-
pal	-	+	+

However, *SPE* was not merely a catalogue of distinctive features for describing the phonetic content of phonemes or defining natural classes. It distinguished between levels in the grammar of language. The underlying (phonological) and surface (phonetic) levels were identified. The Structuralist trend of being exclusively descriptive now progressed to "explanation for the classification" (Smith, 1999:8). Massamba (1996:88) describes the intentions of Chomsky & Halle:

> It was necessary to show how the more underlying level (phonological) could be mapped onto the more surface level (phonetic). In their theory Chomsky & Halle, therefore, concentrate on making explicit principles that governed the association of the two levels of sound structure.

And, this was achieved through the development of rules, which were represented using various formalisms. Distinctive Feature Theory became located within this broader study of Phonology. From the time of publication, *SPE* came to dominate the linguistic field and Transformational-Generative Phonology, as expounded by Chomsky & Halle, continued to dominate thinking until the mid 1970s. According to Coleman (1998:3) *SPE* founded a trend in which linguists concentrated on

> …discovering the phonological rules of each language, the recurrent kinds of rules in the world's languages, and consequences of different ways of applying rules.

In the next section the phonetic motivation in rule formulation will be illustrated referring to the Zulu Vowel Raising and Nasal Assimilation processes.

2.2.1. Rule Formulation Using Distinctive Features

2.2.1.1. Vowel Raising

Vowel Raising occurs, in Zulu, when the mid-low vowels /E/ and /□/ are raised in the context of a following high vowel /i/ or /u/, as shown in the following examples:

(2.1)	theng + a	[t^hENga]	"buy"
	theng + ile	[t^heNgilE]	"bought"

Given that the phonemes /e, o/ form a natural class, the Vowel Raising process can be formulated using the distinctive features:

(2.2)
$$\begin{bmatrix}+\text{syllabic}\\+\text{mid}\\-\text{high}\end{bmatrix} \rightarrow [+\text{high}]/\_\_\_\_\_ \begin{bmatrix}+\text{syllabic}\\+\text{high}\end{bmatrix}$$

This rule states that a mid vowel changes to a high vowel when it precedes a consonant followed by a high vowel.

2.2.1.2. Nasal Assimilation

During the derivation of nouns from verbs, the homorganic nasal N assimilates to the place of articulation of the following phoneme.

(2.3)	iN + khulum + o	→	inkulumo	[iNk'ulumO]	talk
	iN + theng + o	→	intengo	[int'ENgO]	price/tax
	iN + phil + o	→	impilo	[imp'ilO]	life

The naturalness of this process is shown by the following formulation:

(2.4)
$$N \rightarrow [\propto \text{place}]/\_\_\_\_ \begin{matrix}[+\text{consonantal}]\\ \propto \text{place}\end{matrix}$$

This rule states that a nasal will assimilate to the place of articulation of a following consonant. Here again the phonetic motivation for the change is reflected in the formalism.

2.2.2. Problems with the Formulation of Rules

Robinson (1978:209) identifies two types of phonological rules that he terms 'phonological rules proper' and 'transformational rules'. The former alters an existing feature specification, as shown in examples (2.2) and (2.4). The latter, transformational rules, "create, delete or permute segments". And it is in the formulation of transformational rules in Zulu that the *SPE* framework encounters much difficulty. McCawley, in Massamba (1996:140), attributes this to the conventions used:

> Perhaps the biggest weakness of *SPE* analysis is the extent to which the ordering of rules rests ultimately on the conventions for the use of a highly questionable notational device.

McCawley's sentiment echoes that of Clements (1985). Clements (ibid.) found that the linear *SPE* rule formulation framework could not describe several phonological processes. Intrusive Stop Formation is one such process.

Explanations for Intrusive Stop Formation fall into one of two categories – phonological or phonetic. The latter is dealt with in 3.2. In this section three phonological explanations for the process are discussed.

Barnitz (1974:2) explains phonological epenthesis as the "abrupt insertion of a segment". He speaks of "phonetically unstable clusters," i.e. nasal-fricative cluster, which create the need for intrusive stops. Piggott & Singh (1985:415) attribute epenthesis to

> …certain properties of syllable structure and some universal principles of syllabification interacting with (phonotactic) constraints….

They (op.cit.:3) identify the epenthetic processes as blocking devices, which prevent the "surface occurrence of certain sequences of segments."

While Barnitz (1974) and Piggott & Singh (1985) view Intrusive Stop Formation in terms of unstable clusters and blocking, respectively, Schafer (1995) see this process as one of strengthening. Schafer (op.cit.:71) explains Intrusive Stop Formation in Tswana as being "morphologically conditioned," where "continuants become stops or affricates after specific (nasal) morphemes."

All of these explanations have realizations in the Generative formalization of the process.

Using the *SPE* framework, the rule can be formulated, as per Schafer, as:

(2.5) $\begin{bmatrix} +\text{cons} \\ -\text{son} \\ +\text{cont} \end{bmatrix} \rightarrow$ [+delayed release]/[+nasal]______

Alternatively, to specify the presence of the intrusive stop, as per Barnitz and Piggott & Singh, the rule can be formulated as:

(2.6) $\varnothing \rightarrow$ [-cont]/N__ $\begin{bmatrix} -\text{son} \\ +\text{cont} \end{bmatrix}$

Three different *SPE* categories are engaged during Intrusive Stop Formation Manner of Articulation, Source and Cavity. The juxtapositioning of the nasal and fricative creates an intrusive [-continuant] segment. The [-continuant] segment assimilates the place of articulation of the nasal and the voice feature of the fricative. But, two rules have been provided in examples (2.5) and (2.6) and neither is able to encapsulate all the changes, i.e. the linear structure is unable to show overlapping and the hierarchy of categories engaged.

The Generative framework used the feature [+delayed release] to specify affricates. *SPE* (1968:318) defined this feature as follows:

> There are basically two ways in which a closure in the vocal tract may be released, either instantaneously as in the plosives or with a delay as in the affricates. During the delayed release, turbulence is generated in the vocal tract so that the release phase of the affricates is acoustically quite similar to the cognate fricative. The instantaneous release is normally accompanied by much less or no turbulence.

The definition above raises concern for two issues. Firstly, [delayed release] is not an economical distinctive feature, as its use is limited to affricate description. Hyman (1975:52) notes:

> The feature Delayed Release contrasts only in sounds produced with a complete closure in the vocal tract, that is, stops vs affricates.

Secondly, while Chomsky & Halle (1968:318-319) offer a comprehensive phonetic description of the feature [delayed release], no mention is made of the differing types of affricates and the potential for differing qualities of that feature. For example, two types of affricates have been identified for Zulu, pure and derived (cf. 1.1). Implicit in this differentiation is not only a phonological contrast, but also a phonetic one. Thus, there is a possibility that having an all-inclusive feature like [delayed release], may not be capturing all relevant phonetic contrasts. This type of supposition can only be resolved through an experimental assessment of the two types of affricates and this is undertaken in Chapter Three.
Such inadequacies led to the desire to find an improved framework, one that could provide phonetic description and also explain phonological patterns in a consistent manner.

2.3. The Shift from the Linear to the Nonlinear

2.3.1. General Issues

While the rule formulation issue was one weakness within the Generative framework, there were other challenges to be faced. Noam Chomsky contributed to several sub-disciplines in Linguistics and within the sub-discipline of Phonology there were a range of issues that were challenged.

Perhaps at the top of the list was that of the relationship between Phonetics and Phonology. For many linguists from the pre-Generative period, there was a perception that Phonetics was an independent discipline and the Generative trend of mapping the phonological onto the phonetic (vice versa) revealed interdependence between these two sub-disciplines. Many linguists, inter alia Anderson (1976, 1981); Donegan & Stampe (1979); Lindblom (1980); Huffman (1990); Pierrehumbert (1990); Ohala (1990, 1991); Kohler (1991) and Wetzels (2002), wanted to further develop this principle which Generative Phonology had initiated. So the role of Phonetics in Phonology became an issue for debate.
Secondly, the Generative framework acknowledged and identified, through cross-linguistic survey, the universal principles that exist in language. But the proposal that the distinctive feature inventory could be universal came under challenge. Keating (1990:333) states:

> …since languages differ in phonetic detail, some account of those differences must be provided for by the grammar.

Akmajian et al. (2001:120) counter that argument stating:

> The set of universal distinctive features is a set that is *available* to all languages; not all features and combinations of features are actually found in each individual language.

Thirdly, the accuracy of the phonetic and phonological descriptions, provided by the Generative framework were challenged, particularly by proponents of Laboratory Phonology, inter alia Ohala & Jaeger (1986); Beckman (1988); Fujimura (1990); Ohala (1995a & 1995b); Lindblom (2000); Hume & Johnson (2001). The latter believed (and rightly so) that the Generative paradigm was based on impressionistic observations and therefore the conclusions proposed were fundamentally unscientific. Distinctive Feature Theory, in particular, was subject to much scrutiny. Debates have centred on several issues, inter alia:

- the phonetic correctness of features, given that there is no experimental authentication
- how many features should constitute an inventory
- is the inventory indeed universal i.e. can all languages be described using the same set of features
- the naturalness of classes
- contrasts permitted by the features
- the articulatory bias in the description of features
- the use of binary features as opposed to unary and scalar features

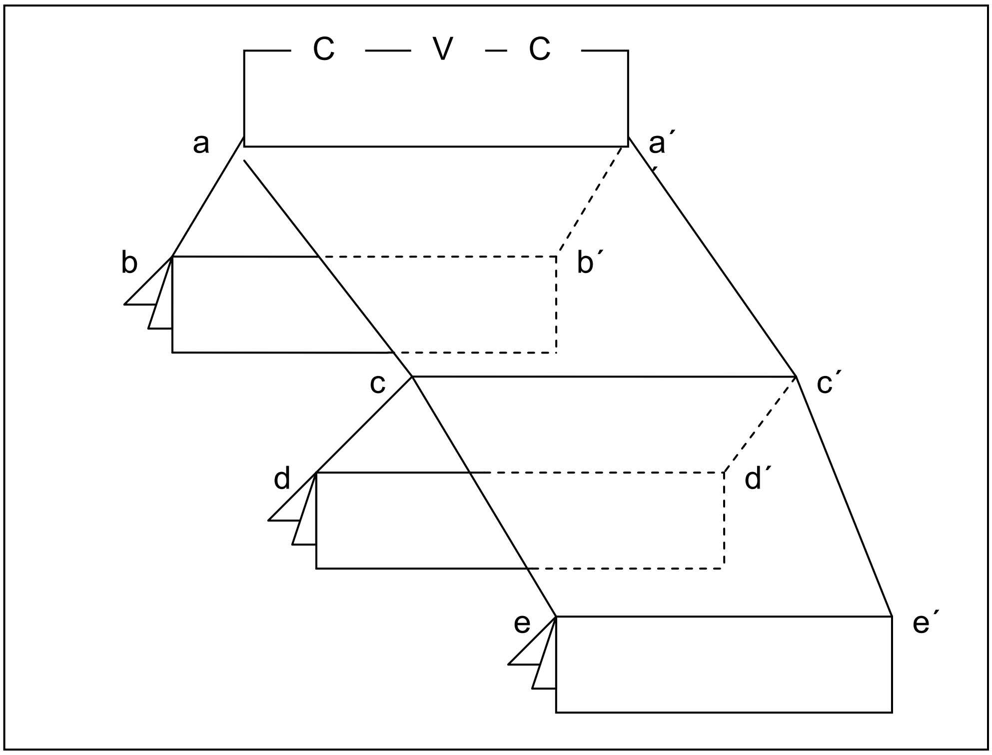
A fourth major issue in the Generative framework was that of the matrix structure. This is expanded on in the next section.

2.3.2. The Linear Matrix Structure Issue

In the *PSA* and *SPE* framework phonemes were described using a linear matrix structure, shown in Table 2.3, and further exemplified in examples (2.2) and (2.4).

While sharing the *PSA* and *SPE* perspective that phonemes were indeed composed of smaller units, i.e. features, Clements (1985:225) identified two main problems with the matrix structure. Firstly, the feature columns convey the impression that features do not “overlap”. Secondly, “internal hierarchical organization” is not evident in the matrix structure. Clements (op.cit.:226) therefore proposed the use of a nonlinear hierarchical structure to describe phonemes and phonological processes. This structure came to be called the Feature Geometry structure and will be discussed in greater detail in the next section. Shown in Figure 2.1 (op.cit.:229) is the model on which Clements’ feature geometry structure came to be based.

Figure 2.1 – The Basis for the Clements feature geometry structure



aa´ = root tier, bb´ = laryngeal tier, cc´ = supralaryngeal tier,
dd´ = manner tier, ee´ = place tier

This model was favoured because it displayed the “componential” characteristic i.e. all the tiers, a-e, are linked and associated with each other and the main CVC tier in the model. This corresponded to actual speech production, where all the structures jointly co-ordinate to create and execute a sound. Furthermore, Clements (op.cit.:226) maintained that the hierarchical structure allowed, “the sequential ordering of features into higher-level units.” And, features could be grouped into sets. This was efficient in rule formulation as certain processes affect selected features. According to Clements (op.cit.:227)

> By grouping together entire sets of features on single tiers, we in effect make it possible for them to behave as a functional unit with regard to rules of deletion, assimilation and so forth.

Thus Feature Geometry Theory was born. It was an attempt to integrate anatomical structure, phonetic detail and phonological representation. Broe and Pierrehumbert (2000:1) summarize this as using the phonetic data "to shape as well as execute the phonological theory". In the next section, feature geometry structures are introduced.

2.4. Feature Geometry

This section presents a critique of six feature geometry structures and their application to the Intrusive Stop Formation process in Zulu. Table 2.4 shows the formation of the intrusive stop (indicated in bold) during the derivation of nouns from verbs. Noun formation, in Zulu, occurs by prefixing the class 9-10 prefix iN onto the verb. The juxtapositioning of the nasal + fricative results in Intrusive Stop Formation or Affrication. In this chapter, the feature geometry representations of the process, use only the /iN + s/ example.

Table 2.4 Zulu Noun Derivation

iN + Verb		**Derived Noun**		
iN + *fanel* + *o*	be suitable	*imfanelo*	[iμφf'anElO]	suitability
iN + *vakaz* + *i*	make spots	*imvakazi*	[iμ**{**vakazi]	hair-fringe
iN + *sangan* + *o*	be confused	*insangano*	[in**t**s'aNganO]	confused state of mind
iN + *zal* + *a*	bear	*inzala*	[in**d**zala]	grass seed
iN + *hlab* + *a*	slaughter	*inhlaba*	[in**t**ñ'aºa]	good-for-nothing person
iN + *dloz* + *i*	seize violently	*indlozi*	[in**d**Lozi]	tiger-cat
iN + *shumayel* + *o*	preach	*intshumayelo*	[i´**t**S'umajElO]	sermon

The complexity of the Intrusive Stop Formation process revolves around two issues, namely the identification of distinctive features to specify the affricates and the formalization of the process.

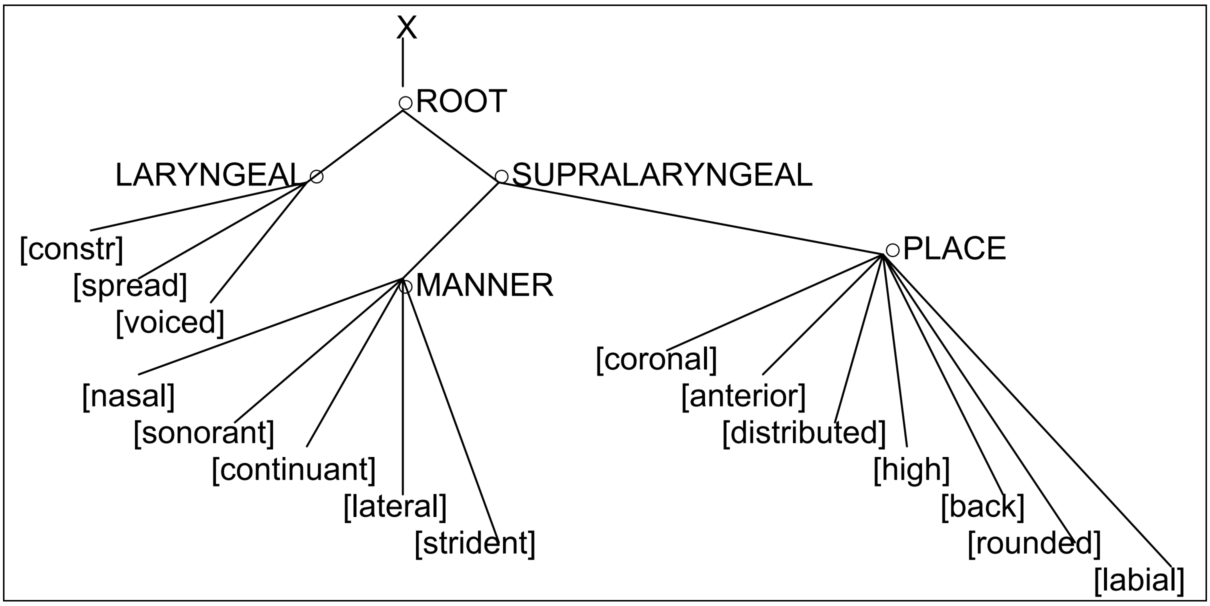
The following description of the process by Laver (1994:363-364) captures, from a phonetic perspective, the physiology of the process:

> …affrication is a co-ordinatory property of a relationship either between two segments, or between a segment and utterance-final silence. The first element in both cases must be an oral stop. If another full segment follows, then it must be a resonant. This follows from the requirement that the friction in the overlap phase between the two segments should be only momentarily audible…
> More traditional analysis has conceptualized the process of Affrication as a unisegmental property of stop articulation, perhaps because of the fact that the affrication necessarily involves friction during the offset phase of the stop being made at the same place of articulation as the stop. In this more traditional approach, the stop and its affricated release together are conventionally said to form an affricate.

Regarding the two issues, the Generative paradigm used the feature [+del release] to identify affricates or the null segment ø, to indicate the insertion of the intrusive stop. The nonlinear framework rejected these on the basis of the limited occurrence of the distinctive feature [+del release] as the principle of economy is always an issue in distinctive feature theory. Also the null segment offers no explanation on the relationship between the juxtaposed segments (cf.2.7). The following sections expand on the nonlinear feature geometry alternatives to the Generative Phonology[3].

Feature Geometry Theory originates from the work of Clements (1985), who retained the *SPE* features and to an extent the categories, and proposed the feature geometry structure shown in Figure 2.2.

Figure 2.2 Clements (1985)



This structure adapts the existing *SPE* distinctive features into the nonlinear form. In an attempt to acknowledge the articulators, the structure is divided into the Laryngeal and Supralaryngeal tiers, with the former containing the traditional voice features and the latter, the traditional manner of articulation and place of articulation features. *SPE* had separate features to describe vowels and consonants. Clements (op.cit.:241) retains this and specifies that the primary features [coronal], [anterior] and [distributed] are used for consonant description and the secondary features [high], [back], [round] and [labial] are used for vowel description.

The Clements (1985) structure was the foundation for Feature Geometry Theory. However, succeeding structures moved away from this representation and from the influence of *SPE.*

In the following discussion the six feature geometry structures listed will be presented and their application to Intrusive Stop Formation critiqued:

- Clements (1987)
- Dogil (1988)
- Padgett (1995)
- Clements & Hume (1995)
- Keyser & Stevens (1994)
- Halle, Vaux & Wolfe (2000)

The six have been selected primarily because of the differences that they exhibit, and their development on preceding structures. The structures delineate the discussion in this chapter into three broad sections. In 2.4.1 the feature geometry structures of Clements (1987), Dogil (1988) and Padgett (1995), which are informed by phonological criteria, are presented. In 2.4.2 the Clements & Hume (1995) structure, where consonant and vowel place features are unified, is introduced.

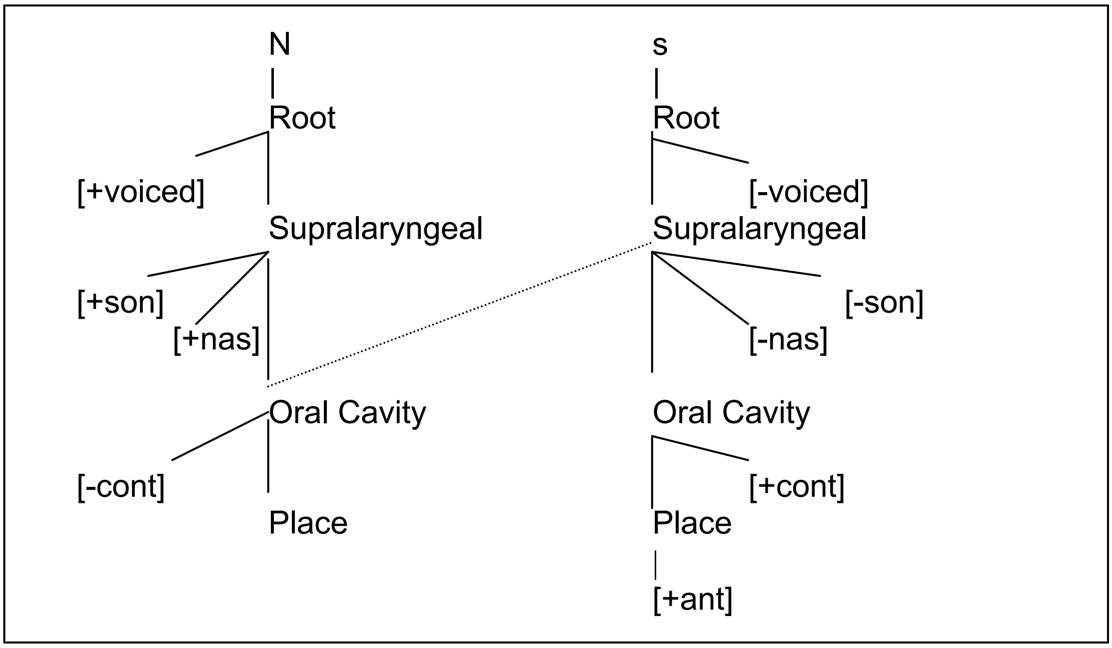
2.4.3 focuses on feature geometry structures that are based primarily on anatomical accuracy. These include the structures of Keyser & Stevens (1994) and Halle, Vaux & Wolfe (2000).

2.4.1. Phonological Criteria: An Assessment of the Feature Geometry Structures of Clements (1987), Dogil (1988) and Padgett (1995)

2.4.1.1. Clements (1987)

The Clements (1987) description of Intrusive Stop Formation is shown in Figure 2.3.

Figure 2.3 Intrusive Stop Formation - Clements (1987)



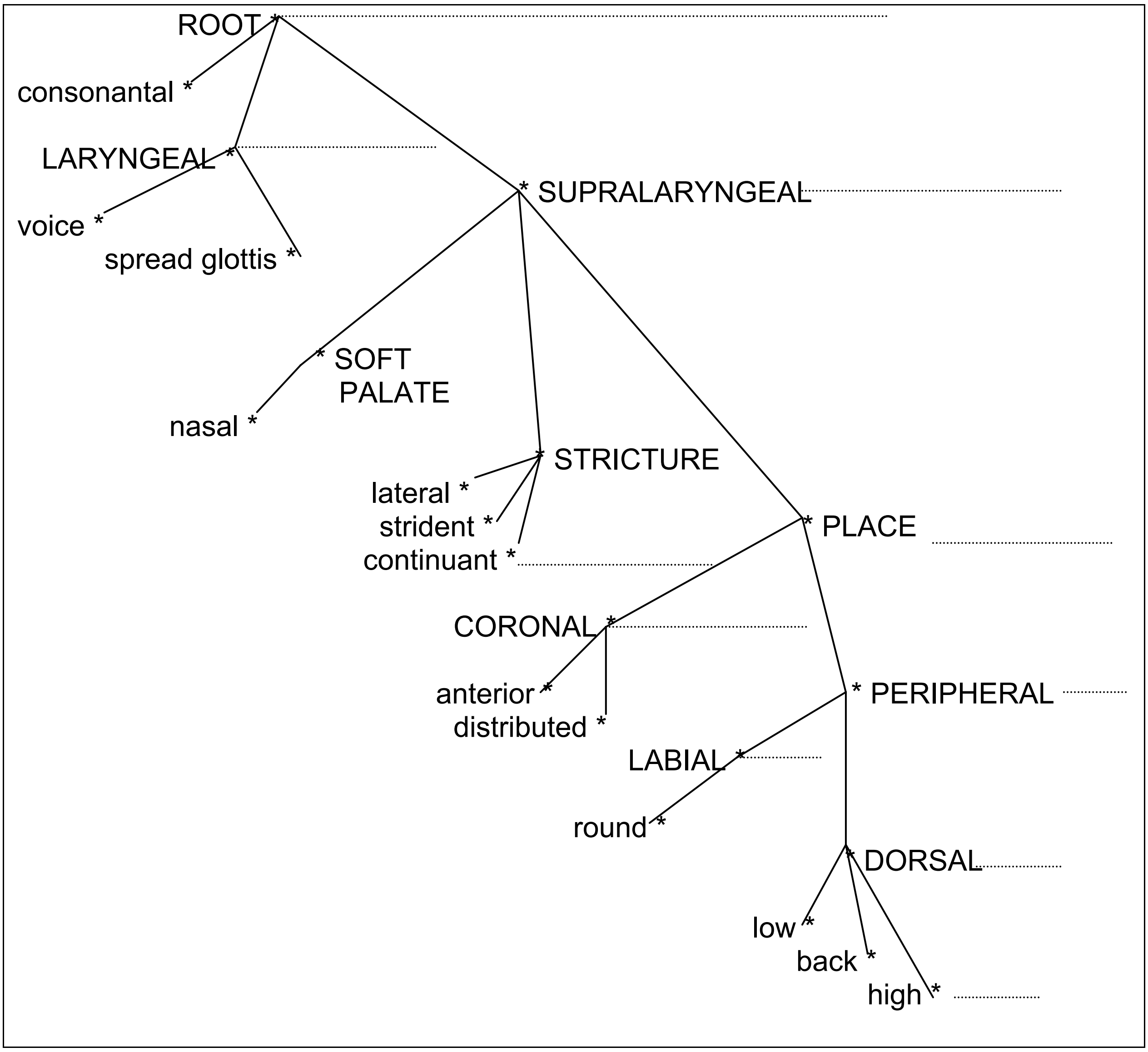
It is evident from this proposal that significant rethinking has transpired since 1985. Clements (1987) introduces the Oral Cavity node, specifically to accommodate the feature [continuant] and the Place features. The other Stricture features [sonorant][4] and [nasal] are attached directly to the Supralaryngeal node. Clements

(1987:28) describes Intrusive Stop Formation as the spreading of the Oral Cavity node of the nasal onto the Supralaryngeal node of the consonant /s/. This converts /s/ into a contour segment, /ts/, with the manner of articulation features [-cont,+cont]. The representation also implies that the homorganic nasal assimilates the place feature of the fricative, i.e. [+anterior]. According to Warner (2002:4) the Clements description, which illustrates the formation of the contour segment, "allows for the phonetic differences between epenthetic and underlying stops" i.e. whereas an underlying stop will have an independent Oral Cavity node, an epenthetic or intrusive stop shares an Oral Cavity node with the following segment. Warner's observation mirrors a focal point of this study, namely the distinction between underlying or pure and derived affricates, both phonetically and phonologically.

2.4.1.2. Dogil (1988)

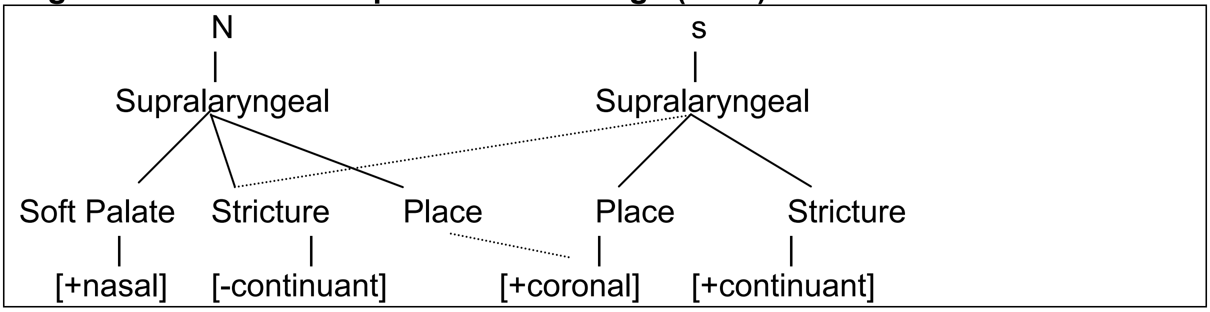
Dogil (1988) proposes the feature geometry structure shown in Figure 2.4.

Figure 2.4 Dogil (1988)



The Dogil (1988) structure introduces the Stricture node, which subsumes the traditional manner of articulation or Stricture features. Using the Dogil (1988) structure, Zulu Intrusive Stop Formation can be described in Figure 2.5.

Figure 2.5 Intrusive Stop Formation - Dogil (1988)

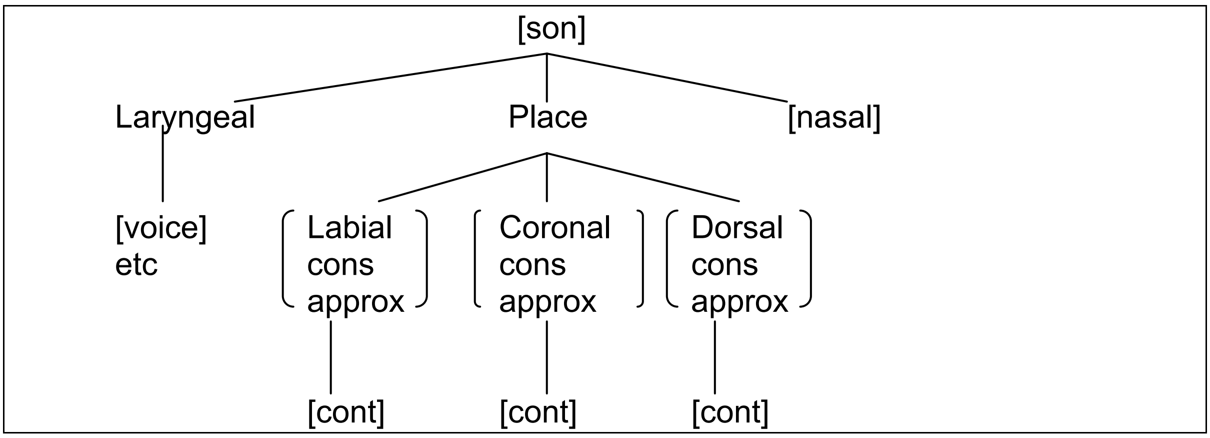


In this representation the Stricture node of the nasal spreads onto the Supralaryngeal node of the fricative, indicating that /s/ now has the Stricture features [-cont,+cont]. Nasal assimilation is depicted by assimilating the Place node feature of the fricative, [+coronal], onto the nasal, implying that both nasal and fricative have the specification [+coronal].

2.4.1.3. Padgett (1995)

The Padgett feature geometry structure differs from the preceding structures in that it does not pay too much attention to replicating the vocal tract. This was one of the major concerns of Feature Geometry Theory, and the bias was that phonetic detail should constrain phonological description. Padgett (1995:12), while conceding that phonetics has a vital role, states, “as a theory of phonological processes, Feature Geometry is first responsible to phonological data”. Hence, the structure in Figure 2.6, which is visually quite different.

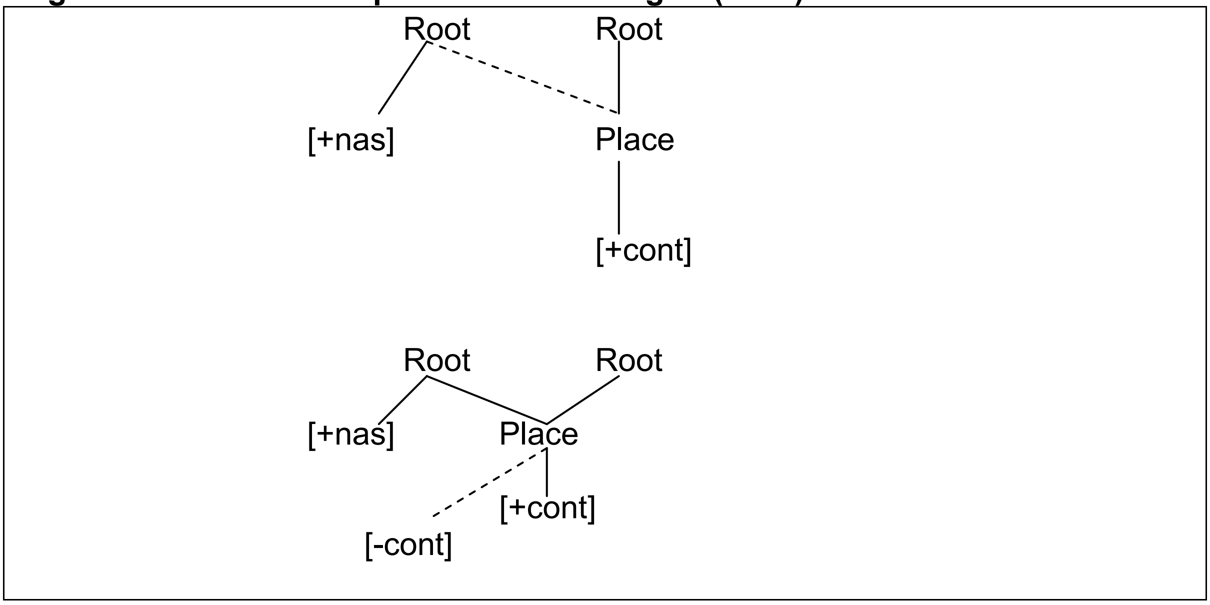
Figure 2.6 Padgett (1995)



The Padgett structure differs from that of Clements and Dogil in that at the level of the Root Node, only the feature [sonorant] is used. The traditional Laryngeal and Place categories are retained on the same level as the feature [nasal]. The Place node is then divided into the following Articulator Groups - Labial, Coronal and Dorsal. The traditional major class features [consonantal] and [approximant][5] are subsumed under the Articulator Group and in turn, they subsume the feature [continuant].

Apart from differing physically from the preceding structures, Padgett introduces new rules and representational conventions, marking a new rule formalization strategy. Linguists had been critical of the conventions of the Generative paradigm. For example, according to Lacharité & Paradis (1993:128) a fundamental problem with Generative representation is that "although it may be descriptively adequate, it is overly powerful and lacks predictive power". In the Padgett (1995) structure, repairs are permitted and depicted. Following Myers (1991:316), Padgett subscribes to the notion that languages do not only block ill-formed structures, they change such structures. Therefore, constraint and repair rules (cf. 4.4) operate. Relating this to Intrusive Stop Formation in Zulu, it is evident that the sequence nasal + fricative is not permitted i.e. their occurrence is blocked. The change i.e. the repair arises with the creation of the intrusive stop. Padgett (1994:470) describes the assimilation of the nasal to a fricative as one of hardening where the "nasal assimilates but simultaneously hardens the fricative to a stop or affricate." Padgett (1995:55) formalizes Intrusive Stop Formation in Figure 2.7.

Figure 2.7 Intrusive Stop Formation - Padgett (1995)



Applying this to Zulu, the first portion of the diagram depicts Nasal Assimilation and illustrates the Place node of the nasal assimilating to the [+coronal] feature of the phoneme /s/. The second diagram illustrates the Nasal Hardening process where a [-cont] 'segment', unattached to any root node, is inserted. By locating [-cont] 'outside' the nasal and /s/ phonemes, Padgett attempts to show that the intrusive stop is an intrusive and new addition to the process. In so doing, a constraint is shown, i.e. the /N + s/ sequence is not permissible. Therefore, a repair, in the form of an intrusive stop, is effected.

2.4.1.4. Comments

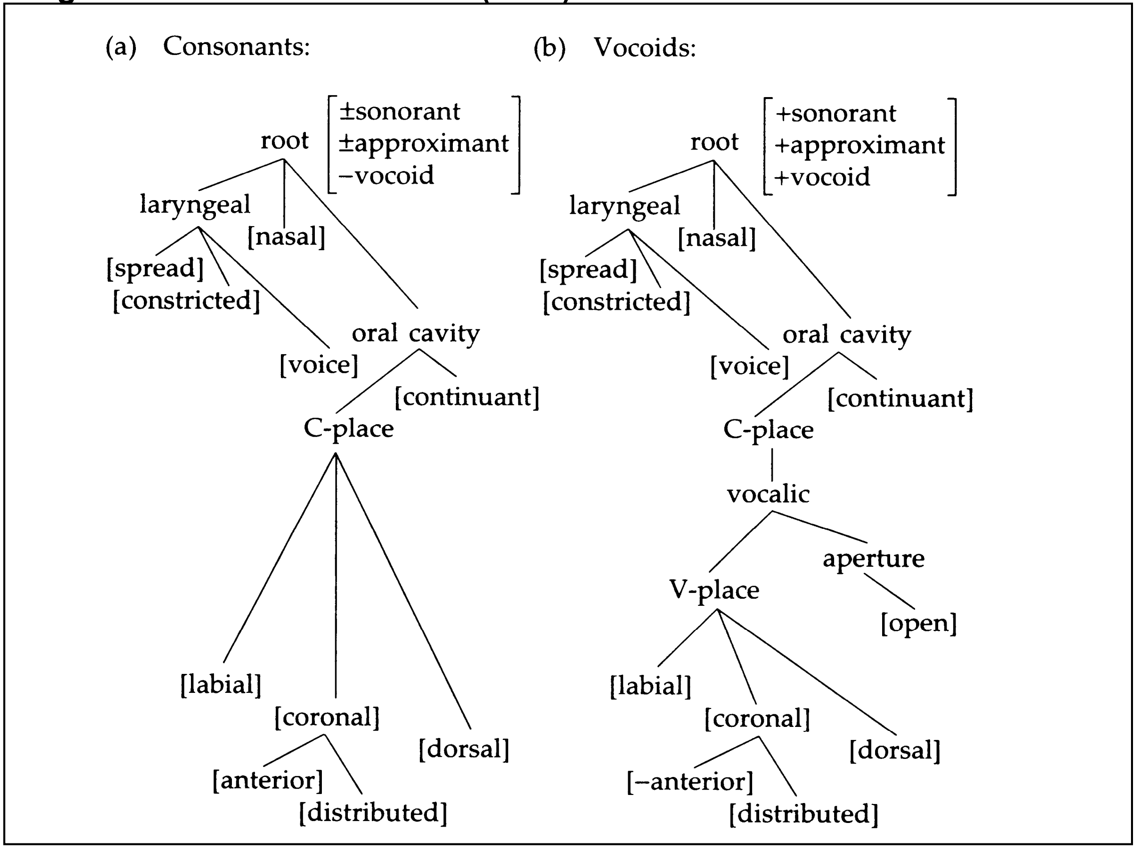
Intrusive Stop Formation is composed of two steps. Firstly, Nasal Assimilation occurs when the nasal phoneme assimilates to the place of articulation of the fricative. Secondly the manner of articulation feature of the nasal spreads onto that of the fricative, creating a [-cont,+cont] segment.

Both Clements (1987) and Dogil (1988) show these. In the Clements structure the Oral Cavity node subsumes the Place node and the manner feature [-cont]. The Oral Cavity node links to the fricative. The Dogil structure has separate Place and Stricture nodes, which link the nasal and fricative phonemes. The problem with the Dogil structure is that the no-crossing lines convention is violated. The Padgett (1995) structure shows Intrusive Stop Formation in two steps - Nasal Assimilation and Hardening. Padgett (1995) worked within the framework of constraint and repair, thus the new representational convention of the inserted [-cont].

2.4.2. Unified Theory: An Assessment of the Feature Geometry Structure of Clements & Hume (1995)

The term Unified Theory simply means that the same distinctive features are used for the description of vowels and consonants. Clements (1991b) motivated for the unified place node by using supporting examples of assimilatory, dissimilatory, strengthening and weakening processes in a variety of languages[6]. The traditional vowel features [high], [low], [back] are discarded, and the features [coronal], [dorsal] and [labial] are used in the description of both vowels and consonants. A comprehensive feature geometry structure was realized in Clements & Hume (1995) and is shown in Figure 2.8.

Figure 2.8 Clements & Hume (1995)

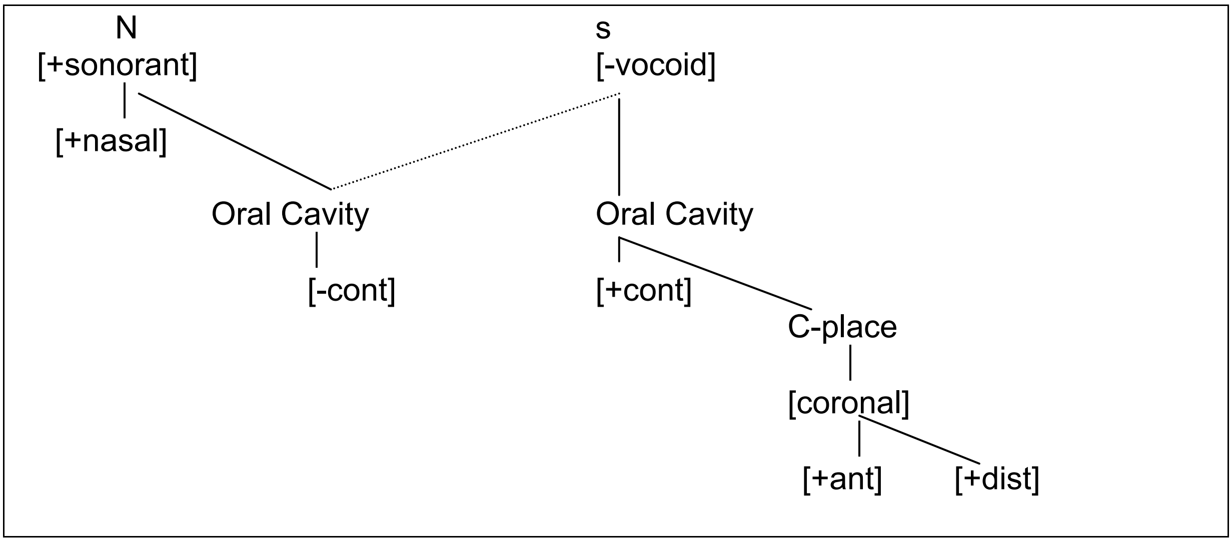


Of significance in the Clements & Hume (1995) structure is the introduction of the [labial], [coronal] and [dorsal] nodes in the description of vowels. According to Clements (1991b:79) Labial identifies rounded vowels; Coronal distinguishes between front and retroflex vs central and back vowels; Dorsal differentiates back vowels vs front and central. Clements (op.cit.:80) introduces a new notion to the binarity principle. The articulator features for consonants are “one-valued” while those for vowels and glides are “two-valued”. Clements (ibid.) motivates this because

> …rules which cause the negative values of these features to spread from one segment to another are rare, if not entirely unattested.

Using the Clements & Hume (1995) model, Zulu Intrusive Stop Formation is presented in Figure 2.9.

Figure 2.9 Intrusive Stop Formation – Clements & Hume (1995)



2.4.2.1. Comments

The description above is similar to that of Clements (1987) in Figure 2.3, except that the Supralaryngeal node has been dispensed with. Figure 2.9 must be read as the Oral Cavity node of the nasal assimilating to the Root node of the fricative /s/. This implies the creation of an affricate segment with the features [-cont,+cont]. Also implicit from this linking is that the nasal assumes the place of articulation features of the fricative /s/, namely [+anterior].

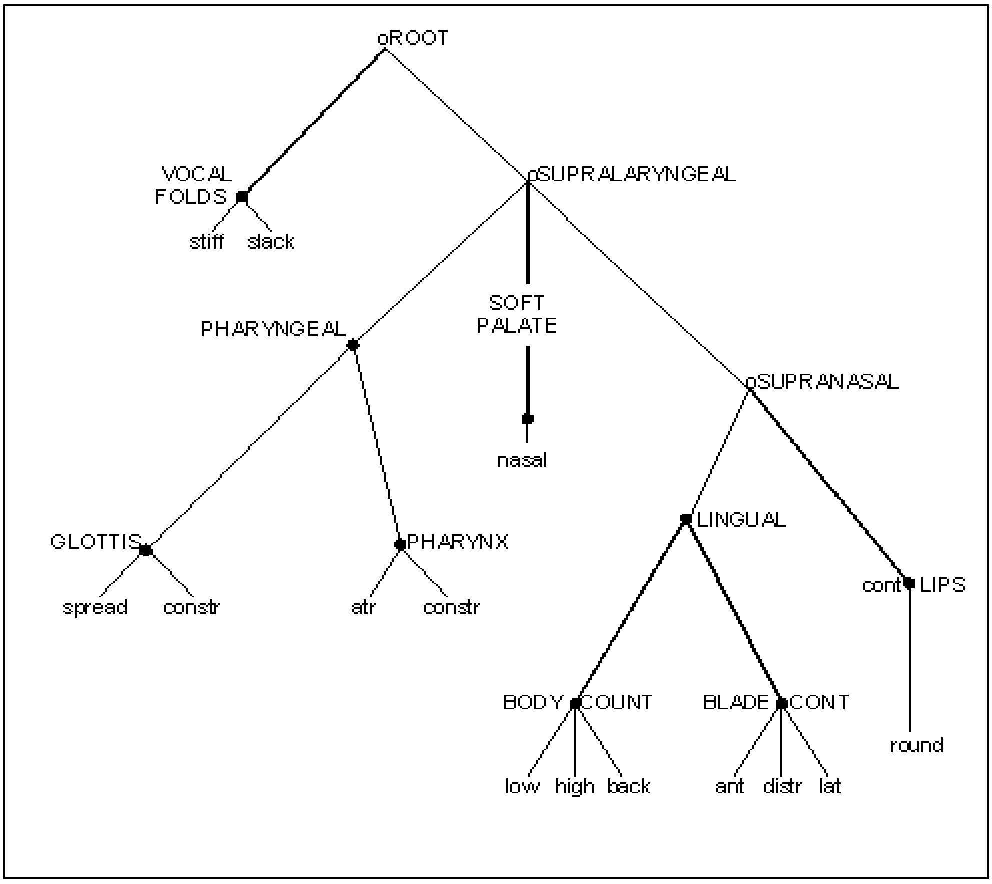
2.4.3. Anatomical Accuracy: An Assessment of the Feature Geometry Structures of Keyser & Stevens (1994) and Halle, Vaux & Wolfe (2000)

The feature geometry structures discussed in the preceding sections were motivated primarily by phonological considerations. In this section the structures of Keyser & Stevens (1994) and Halle, Vaux & Wolfe (2000) are intended to be as anatomically accurate as possible.

2.4.3.1. Keyser & Stevens (1994)

The Keyser & Stevens feature geometry structure, shown in Figure 2.10 is based on the anatomical structure of the vocal tract.

Figure 2.10 Keyser & Stevens (1994)



Keyser & Stevens (1994:209) identify four regions "which are controlled more-or-less independently":

- Stiffness of the vocal folds
- Airways in the laryngeal and pharyngeal areas
- Soft palate
- Oral cavity

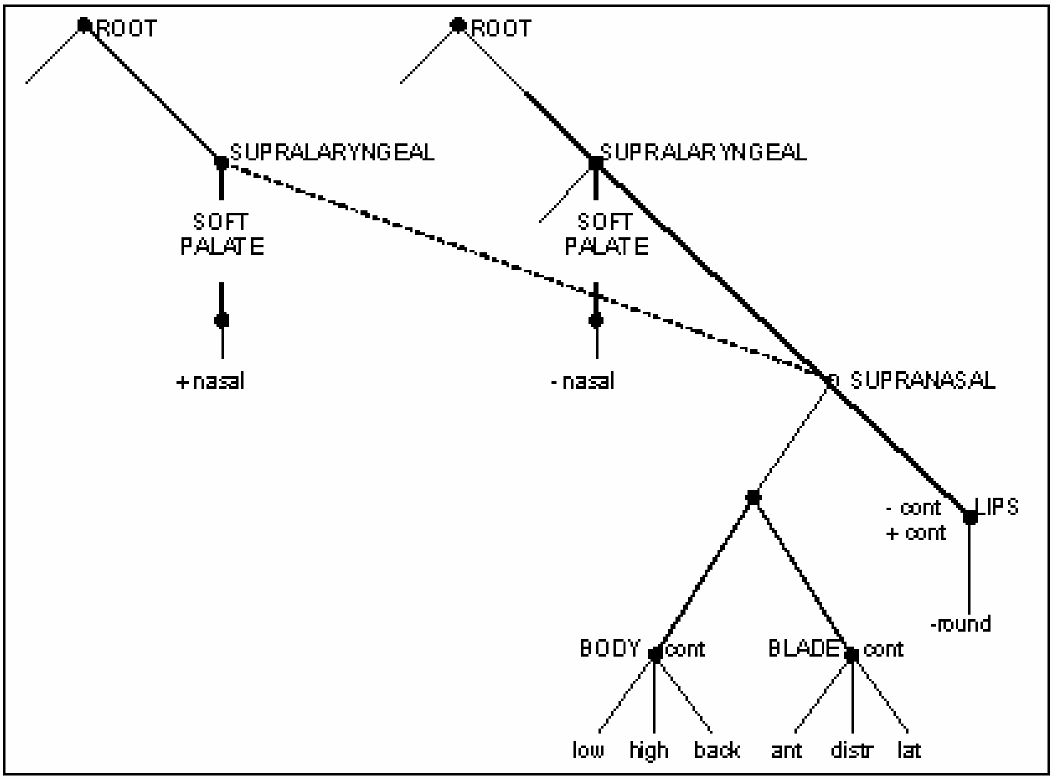
These regions are equivalent to the Vocal Folds, Pharyngeal, Soft Palate and Supranasal levels, respectively, on Figure 2.10. The four regions are dominated by the Supralaryngeal and Supranasal nodes, which in turn are dominated by the Root node. Keyser & Stevens (op.cit.:216-217) also provide the acoustic correlates for the Supralaryngeal and Supranasal nodes.

In any feature geometry structure the primary distinction is between consonants and vowels. In the Keyser & Stevens (1994) structure the Root Node is dominant for vowels, the Supralaryngeal for glides and the Supranasal for consonants. The feature [consonantal] is viewed as a redundant feature because all consonants will dominate either the Supranasal or the Supralaryngeal nodes. On the point of representational conventions, Keyser & Stevens add a new item, that of the open and closed circles, indicated by o and •, respectively. When the circle is open it indicates that the particular node is dominant.

The Keyser & Stevens structure sees the return of the term Supralaryngeal, after several years. The Supralaryngeal node dominates the Pharyngeal, Soft Palate and Supranasal nodes. These nodes are then further divided into their phonetic components. The Pharyngeal node subsumes the Glottis and Pharynx. The Supranasal node subsumes Lingual and Lips, with the former further divided into Body and Blade. The traditional manner features are not accorded a separate node. Instead, [continuant], [sonorant] and [strident] can be attached onto any of the articulators that execute the feature. The implementation of this has been seen already in the Padgett (1995) structure, which supports the position of Keyser & Stevens.

Keyser & Stevens (1994:225) provide the tree structure for /mf/. In Figure 2.11 this structure is modified for the /N+s/ example.

Figure 2.11 Intrusive Stop Formation – Keyser & Stevens (1994)

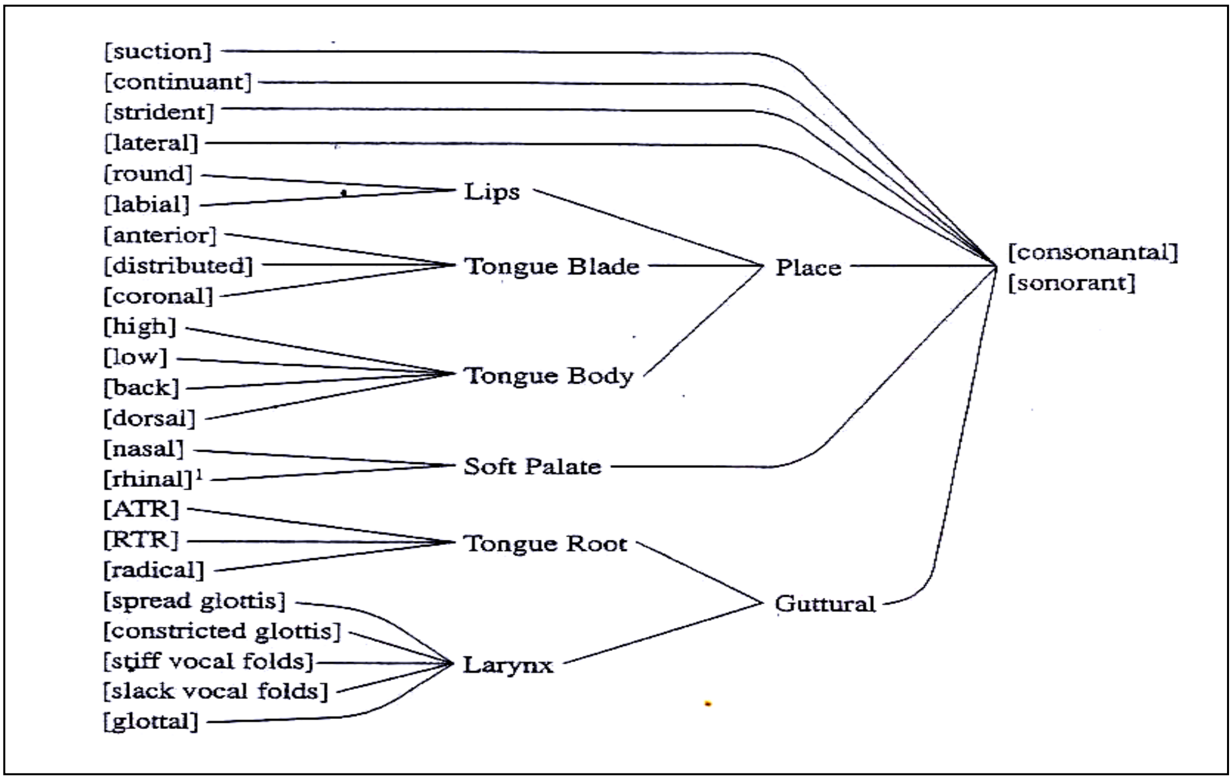


Keyser & Stevens (1994) link the nasal and fricative by using a “connector” i.e. an association line between the supranasal node of the fricative /s/ to the supralaryngeal node of the nasal /n/. The two portions, /n/ and /s/, now share a common supranasal node, and the features [-cont,+cont] are assigned at the Lips node.

2.4.3.2. Halle, Vaux & Wolfe (2000)

The feature geometry structure shown in Figure 2.12 forms the basis of the Halle, Vaux & Wolfe theoretical perspective, which they name Revised Articulator Theory, hereafter referred to as RAT.

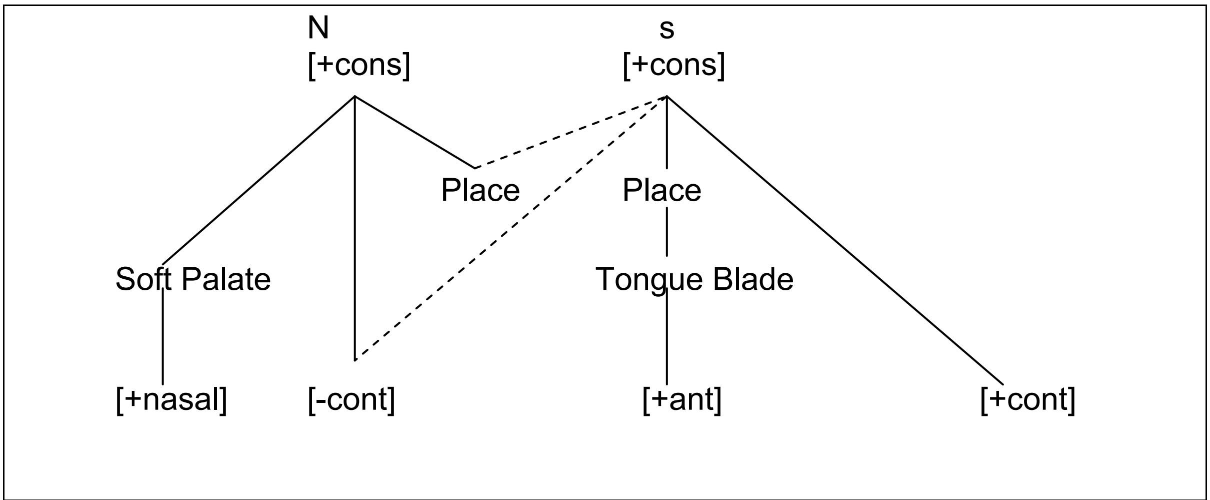
Figure 2.12 Halle, Vaux & Wolfe (2000)



The Root node, represented by the features [consonantal] and [sonorant], is divided into two articulator groups - Place and Guttural. These subsume the five articulators, namely the Lips, Tongue Blade, Tongue Body, Tongue Root and Larynx. The sixth articulator, the Soft Palate is not linked to either the Place or Guttural nodes. The six articulators, in turn, subsume the distinctive features. And, it is only at the level of the terminal node, i.e. the features, that spreading is depicted. The traditional manner of articulation features are attached directly to the Root node.

Figure 2.13 is an application of the RAT structure to Zulu Intrusive Stop Formation.

Figure 2.13 Intrusive Stop Formation – Halle, Vaux & Wolfe (2000)



By assimilating the Place node and the terminal feature [-cont] onto the Root node of the fricative /s/, the RAT structure depicts assimilation of both place of articulation and manner of articulation.

2.4.3.3. Comments

Keyser & Stevens (1994) and Halle, Vaux & Wolfe (2000) stress anatomical accuracy in their feature geometry structures. And as anatomical structures are not language-specific – in fact the anatomical arrangement of the vocal tract is universal - the expectation is one of very similar looking structures. But, this is not so. From the choice of nodes to the identification of articulators to the selection of terminal features, the theorists differ. And this speaks volumes. Although theorists may identify the same criterion on which to base the construction of their feature geometry structure, the resultant structures may be completely different. In fact the Keyser & Stevens (1994) structure resembles the Padgett (1995) structure, even though the former is based on anatomical and the latter on phonological criteria.

In addition to the articulatory correlates, Keyser & Stevens (1994) also offer a brief description of the acoustic correlates of the segments dominated by the Supralaryngeal and Supranasal nodes. The problem with the acoustic descriptions is that these are broad definitions and there will be acoustic variation among the segments occurring under these nodes. As with articulatory description, acoustic description should be segment specific or else its function in the feature geometry structure is limited.

The Keyser & Stevens (1994) description of Intrusive Stop Formation, in Figure 2.11, shows the assimilation of the Supranasal node to the adjacent Supralaryngeal node. The manner feature for both the nasal and the fricative is placed on one tree. In other structures, each tree retained its respective [cont] value. The advantage of the Keyser & Stevens configuration is that under the /s/ node, it is explicit that an affricate, with the features [-cont,+cont], occurs. Nasal Assimilation is implicit as the nasal now subsumes the Lingual Node with the features [+ant] and [-dist].

The RAT structure attaches the feature [cont] directly onto the Root node. By linking the Root node of the nasal to that of the adjacent fricative, the implication is the creation of a [-cont,+cont] segment. Unlike other feature geometry structures where distinctive features occur at various positions, RAT has a strict hierarchy and features always occur at the terminal position. By focussing on the spread of the feature as opposed to nodes, RAT is reinforcing the role of the feature as it is the distinctive feature that embodies the quality, not an abstract node.

Anatomical terms are used for the identification of the articulators and this makes the structure user-friendlier. But, apart from that the feature geometry structure used for RAT is much like all other structures, particularly when it comes to the description of Intrusive Stop Formation.

From an examination of the feature geometry structures of Keyser & Stevens (1994) and RAT (2000) it is evident that basing a feature geometry structure primarily on anatomical factors is as complex as basing it on phonological factors.

2.5. General Evaluation of the Six Feature Geometry Structures & Distinctive Features

2.5.1. Purpose of the Evaluation

One of the aims, which this study is arguing for, is the integration of Phonetics and Phonology in the description of the Intrusive Stop Formation process in Zulu. The preceding discussion on the six feature geometry structures has revealed biases towards either a phonetic or a phonological description. Nevertheless the proposed integrated feature geometry structure will evolve from these six structures. With regard to the distinctive features, the traditional ones still have a vital function. As the experimental investigation in Chapter Three concentrates on only one factor of Acoustic Phonetics, namely Duration, the experiment in itself is, to use the term coined by Hargus & Beavert (2002:232) “instrumental but not exhaustive”. Thus, several traditional distinctive features will reappear in the new integrated structure. On account of these reasons the following evaluation is undertaken – to determine which structures and features justify retention. Given that interfacing Phonetics with the Phonology is an aim in this thesis, it is deemed necessary to examine a truly comprehensive account of a phonetically informed structure. Therefore, the use of the Ladefoged & Maddieson (1996) structure as a point of departure.

2.5.2. Ladefoged & Maddieson (1996)

In *The Sounds of the World’s Languages* Ladefoged & Maddieson (1996:369) identify the “major phonetic categories that languages employ”. They do not propose a formal feature geometry structure. Instead, based on a survey of approximately four hundred languages, Ladefoged & Maddieson identify the categories, that they believe, should be used to inform feature theories. Hence their ‘structure’ is a not in the usual mode of binary features. But, given the comprehensive nature of their proposal and its relevance from a phonetic and anatomical perspective, their feature geometry structure informs the evaluation in this section.

Figures 2.14 – 2.19 show the breakdown given by Ladefoged & Maddieson (1996: 370-373).

Figure 2.14 The Division of the Root Node

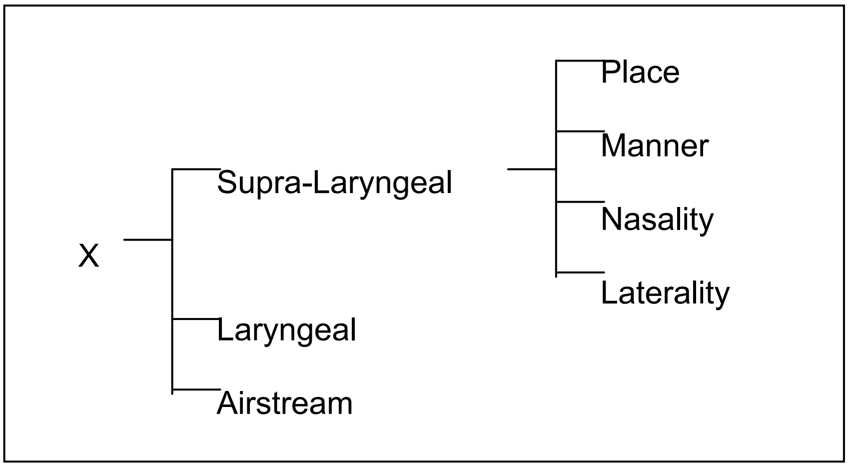


Figure 2.15 The Place Node

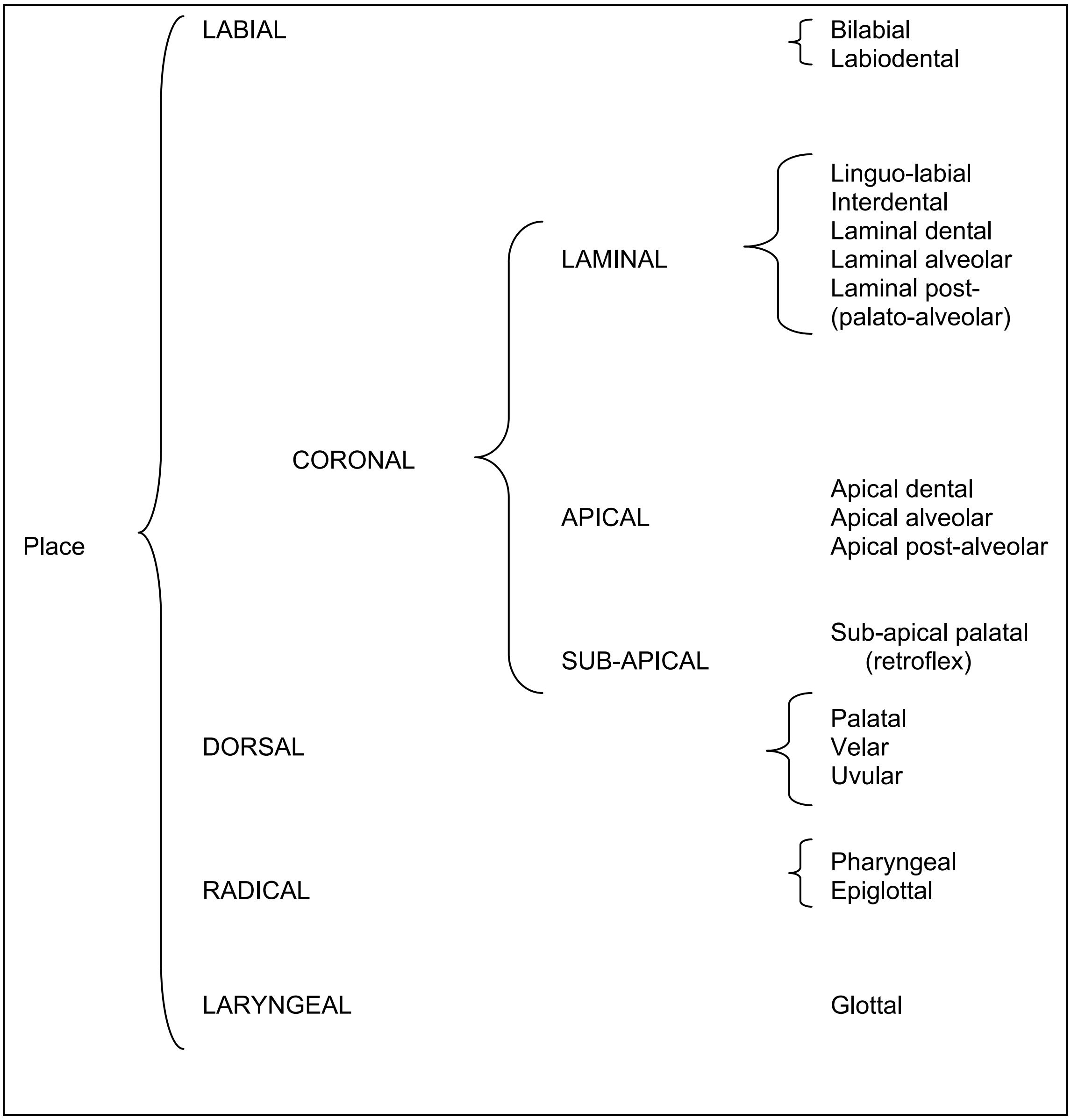


Figure 2.16 The Manner Node

- MANNER
  - STRICTURE
    - STOP
    - FRICATIVE
      - Sibilant
      - Non-Sibilant
    - APPROXIMANT
    - VOWEL
  - TAP
  - TRILL

Figure 2.17 The Description of Vowels and Approximants

- APPROXIMANTS AND VOWELS
  - HEIGHT
    - High
    - Mid-high
    - Mid
    - Mid-low
    - Low
  - BACKNESS
    - Front
    - Central
    - Back
  - ROUNDING
    - PROTRUSION
      - Protruded
      - Retracted
    - COMPRESSION
      - Compressed
      - Separated
  - TOUNGE ROOT
    - +ATR
    - -ATR
    - (Pharyngealized)
  - RHOTIC
    - Rhotacized

Figure 2.18 The Laryngeal Node

- LARYNGEAL
  - GLOTTAL STRICTURE
    - Voiceless
    - Breathy voice
    - Modal voice
    - Creaky voice
    - Closed
  - GLOTTAL TIMING
    - Aspirated
    - Unaspirated
  - GLOTTAL MOVEMENT
    - Raising
    - Lowering

Figure 2.19 The Airstream Node

- AIRSTREAM
  - PULMONIC
    - Fortis
    - Lenis
  - VELARIC
    - Click

Ladefoged & Maddieson (1996) were cognizant of the great variability that exists in sound production. Their concerns to incorporate such variability have been echoed by other linguists. Schmidt (1994:289) explains that if the anatomical arrangement of the vocal tract is supposedly universal, and if the feature geometry structure (nodes and features) is intended to mirror this, then it follows that the feature geometry structure should also be considered universal. But, according to Schmidt (op.cit.:290) cross-linguistic examples indicate that the same features[7] do not behave in the same manner across languages. For example, the feature [low] in Arabic does not display the exact articulatory and acoustic patterns as [low] in Nupe. The same is applicable to the feature [voice] in English and French. Kingston & Diehl (1994), based on evidence from an experimental investigation of the distinctive feature [voice], conclude that there is considerable variability in the implementation of the same feature. These are often dependent on the position of, in this instance, the stop i.e. does it occur in the utterance initial, intervocalic or utterance final position. These points are reflected in Ladefoged & Maddieson (1996) proposal. They highlight the existence of several phonetic variables. Consider that apical has three variables – dental, alveolar and postalveolar. The implication is that the features [coronal] and [anterior] have limitations and are not reflective of the choices that speakers may have.

2.5.3. A Comparison of Feature Geometry Structures

In the following discussion, when undertaking a comparison of the six feature geometry structures, the extent to which the very comprehensive Ladefoged & Maddieson (1996) study is incorporated, will be assessed.

The three primary nodes in the Ladefoged & Maddieson (1996) structure, identified in Figure 2.14, are the Supralaryngeal, Laryngeal and Airstream nodes. All six feature geometry structures, to some extent, include these nodes. The Ladefoged & Maddieson (1996) proposal was already implemented by Clements (1985) and Dogil (1988). Clements & Hume (1995) identify the Laryngeal and Oral Cavity nodes. Keyser & Stevens (1994) use the term Vocal Folds to subsume the Laryngeal features but still retain the Supralaryngeal node. And, RAT (2000) uses the Place and Guttural nodes with the latter subsuming the traditional Laryngeal features. Although not giving prominence to the manner of articulation features, Padgett (1995) nevertheless splits the Root node into Laryngeal and Place nodes. Thus, broadly speaking, all feature geometry structures are similar.

There are two categories of features used by Ladefoged & Maddieson (1996) that have limited occurrence elsewhere. Firstly, the Airstream node, shown in Figure 2.19, does not occur on any of the other feature geometry structures. Secondly, Ladefoged & Maddieson (1996) give prominence to the Stricture node, shown in Figure 2.16. Albeit that other structures identify stricture features, only Dogil (1988) specifies a Stricture node.

The other development on the Ladefoged & Maddieson (1996) proposal is the extent to which phonetic detail is included. For example, under the Laryngeal node, a range of voicing possibilities is accounted for. These are probably lacking

in the other feature geometry proposals because those voicing issues may not have phonological relevance. Similarly, Ladefoged & Maddieson (1996) also take into account a range of place of articulation possibilities for both consonants and vowels. Also, like Clements (1995), Ladefoged & Maddieson (1996) accord special status to the Vowel Place node and extend the class nodes to include not only Height and Backness but also Rounding, Tongue Root and Rhotic.
The Ladefoged & Maddieson (1996) proposal, while clearly identifying the phonetic correlates at the level of the terminal feature, is somewhat extensive. Designed to have universal application, this structure would need to be précied for language-specific use, as intended in this thesis.

2.5.4. A Comparison of Distinctive Features

Distinctive features are the basis of feature geometry structures. In the quest to establish an appropriate feature geometry structure for Zulu, the essential features must be identified. In this section, by way of comparison[8] of distinctive features, an appropriate inventory is developed.

Since its appearance in *PSA* and *SPE,* there has been a proliferation of distinctive features, many of them being language-specific. Hume & Odden (1996:346) propose that for a feature to exist, it must fulfill the following functions:

- Describe phonemic contrasts
- Describe sound or sound class changes
- Describe sounds as a natural class

In this section, distinctive features are discussed under the traditional categories of Major Class, Laryngeal, Place of Articulation and Manner of Articulation Features. The extent to which these features fulfill the functions identified by Hume & Odden above, will be critically examined.

2.5.4.1. Major Class Features

Table 2.5 A Comparison of Major Class Features

	Dogil (1992)	Padgett (1995)	Clements & Hume (1995)	Keyser & Stevens (1994)	RAT (2000)
[son]		*	*		*
[cons]	*	*			*
[approx]		*	*		
[vocoid]			*		

The traditional *SPE* major class features have prevailed in feature geometry structures, albeit with some variation. The features [cons] and [son] are both used in the Padgett (1995) and RAT structures. But, Dogil (1988) uses only [cons]. Clements & Hume (1995) retain the feature [son], but add the features [approximant] and [vocoid][9]. Keyser & Stevens (1994) do not assign features to the Root Node but they do include the feature [son] under the manner of articulation node. They have a distinct manner of differentiating between vowels and consonants (cf. 2.4.3.1).

Halle (1992) recognizes that the features [cons] and [son] are able to delineate the following natural classes:

Obstruents [+cons, -son]

Liquids and Nasals [+cons, +son]

Glides and Vowels [-cons, +son]

While the status of [son] as a major class feature is not controversial[10], the same does not apply to the feature [cons]. Stevens & Keyser (1989) identify [son], but not [cons], as a primary feature. According to them (op.cit.:86-87) a primary feature has more salient “acoustic manifestations” i.e. its acoustic properties are not dependent on the specific values of other features. As the feature [cons] does not satisfy the criteria for a primary feature, it is accorded status as a secondary feature, one that enhances primary features.

Kaisse (1992), however, motivates for the retention of [cons] as a major class feature. Examples from Cypriot Greek and Räto-Romansh describe the spreading ability of the feature [cons]. Further examples, from the Turkic language Uyghur where the consonantalization of vowels occurs, and Swedish where the dissimilation of [cons] occurs, are also cited in support.

Hume & Odden (1996), however, remain unconvinced. Similar occurrences are accounted for by lenition and fortition. Therefore, the feature [cons] is considered "superfluous".

Halle (1995:12) points to the fact that a fundamental distinction in every language is between phonemes that have the feature [+cons] and those that are [-cons]. McCarthy is quoted in Halle (op.cit.:13), explaining that [cons] and [son] are unlike other features. They are only subject to assimilation, dissimilation or reduction, in conjunction with the entire segment. Therefore these features should constitute the Root Node. The arguments of Stevens & Keyser (1989) and Hume & Odden (1996), wanting only [son] to constitute the Root Node, are overshadowed by the fact that languages primarily distinguish between consonants and vowels. So while the feature [cons] may not fulfill two of the Hume & Odden (1996) criteria above, it is by no means a "superfluous" feature.

2.5.4.2. Laryngeal Features

Table 2.6 A Comparison of Laryngeal Features

	Dogil (1992)	Padgett (1995)	Clements & Hume (1995)	Keyser & Stevens (1994)	RAT (2000)
[constricted]			*	*	*
[spread]	*		*	*	*
[voiced]	*	*	*		
[stiff]				*	*
[slack]				*	*
[glottal]					*

It is perhaps in the issue of the Laryngeal features that the differing goals of Phonetics and Phonology surfaces clearly. Halle & Stevens (1971) postulate that the stiffness of the vocal cords and the static glottal opening are independently controlled parameters i.e. a manipulation of these parameters would produce voiced, voiceless, ejectives etcetera.

However, while only two parameters may exist, these generate a multitude of variables. Consider that Ladefoged & Maddieson (1996), in Figure 2.18, identify nine laryngeal features. Ladefoged (1973:78), in identifying several laryngeal features[11], acknowledges that redundancy occurs. But, he qualifies this by stating that if one is to produce an accurate feature system then such apparent redundancy is a necessity. And therein appears the conflict between Phonetics and Phonology. While it may be phonetically accurate to include all variables, it is not phonologically necessary. Lombardi (1995:42-43) while acknowledging that the goals of Phonetics and Phonology differ, nevertheless recognizes that the use of each and every phonetic laryngeal features will include “properties of sounds that are never used distinctively.” This is compounded by the complexity of the laryngeal features. They are not simply a distinction between vibrating and non-vibrating vocal cords. Rice & Avery (1990:428) identify two types of [+voice] features - Laryneal Voicing and Spontaneous Voicing, which are characteristic of voiced consonants and sonorants, respectively. While their distinction is phonologically motivated, experimental evidence from Santerre & Suen (1981) corroborates the question of the complexity of the voicing feature. In their study of the spectrograms of a corpus of 720 samples of minimal pairs with stop consonants, Santerre & Suen measured the vowel duration, formant and formant transitions, silent interval and VOT and found that these factors, individually, could not distinguish between voiced and voiceless stop consonants. Given that the same set of factors jointly impact on the specification of a feature implies that true phonetic accuracy has the potential to become extensive and may lead to an illogical number of features.

Examining the distinctive features used in the six structures, the popular choices are [const] for ejectives and [spread] for aspirated sounds. Keyser & Stevens (1994) and the RAT structure used the features [stiff] and [slack] which are equivalent to [-voice] and [+voice], respectively. But these features are not included in the Ladefoged & Maddieson (1996) inventory. Furthermore, the latter (1996:48) explain that [stiff] and [slack] are “enhanced” versions of the feature [modal voice]. The following distinctions are made:

Modal voice:	regular vibrations of the vocal folds at any frequency within the speaker is normal range
Slack voice:	vocal folds vibrating but more loosely than in modal voice; slightly higher rate of airflow than in modal voice
Stiff voice:	vocal folds vibrating but more stiffly than in modal voice; slightly lower rate of airflow than in modal voice

Given the difficulty of attaining the phonetic accuracy of the laryngeal features, it seems appropriate to settle for the feature [voice].

Lombardi (1995:36) proposes the privative features [voice], [aspiration] and [glottalized], with voiceless segments having no Laryngeal node. The use of privative laryngeal features is logical, but the Lombardi selection would need to be extended to be more inclusive.

2.5.4.3. Place of Articulation Features

Table 2.7[12] A Comparison of Place of Articulation Features

	Dogil (1988)	Padgett (1995)	Clements & Hume (1995)	Keyser & Stevens (1994)	RAT (2000)
[ant]	*		*	*	*
[cor]	#	#	#		*
[dist]	*		*	*	*
[labial]	#	#	#		*
[high]	*			*	*
[back]	*			*	*
[round]	*			*	*
[dorsal]	#	#	#		*
[low]	*			*	*
[lateral]				*	

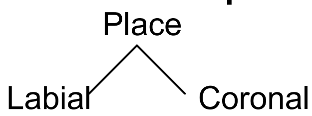
Ladefoged & Halle (1988:578) view the tree structure as one that delimits “human linguistic phonetic capabilities”. Therefore, the designated node for the various categories. Of these, the place of articulation category probably contains the most tangible features. Hence, the degree of overlap among the six structures.

The problem with this category, as with the Laryngeal category, is the extent to which one decides to specify the features. The Ladefoged & Maddieson (1996) structure in Figure 2.15 identifies seventeen individual places of articulation. Clearly such a number would be difficult to contemplate for any feature geometry structure. The following discussion, therefore, focuses on two areas. Firstly, the internal organization of the Place node[13]. And secondly, the identification of the most relevant features.

McCarthy (1988:99) identifies Place of Articulation Theory and Articulator Theory as the two trends in the internal organization of the Place node. The Clements (1985) structure is characteristic of the former, where distinctive features are used to identify places of articulation. The latter, Articulator Theory, identifies the active articulators first. The [coronal], [labial] and [dorsal][14] nodes of Dogil (1988), Padgett (1995) and Clements & Hume (1995) would such constitute active articulators. In these structures, the class nodes function as what Cho (1991:161) terms "monovalent, privative features". The Keyser & Stevens (1994) and RAT (2000) structures identify similar nodes but instead use the terms Body, Blade and Lips to identify the active articulators.

Articulator Theory is the preferred structure as it can depict complex segments, like /pt/ shown in Figure 2.20, which may have two different articulators linked to the Place node:

Figure 2.20 The Complex Segment /pt/



The second issue relating to the selection of features is more problematic. A comparison from Table 2.7 indicates that [anterior], [coronal] and [distributed] are the key place of articulation features for consonants.

Since their inception in *SPE* [cor] and [ant] have been subject to the most discussion. The status of [coronal] is particularly significant as Stevens & Keyser (1989:86) identify it as a primary feature. This was enhanced when Pulleyblank (1989:379), inter alia, motivated for the association between coronal and front vowels. In fact, Clements & Hume (1995) dispense with the traditional vowel features [high], [low] and [back] and use [cor] under the V-Place node. Keating (1991:29-30) states that coronals have special status because they are "able to include more place and manner contrasts than other consonant classes". Coronals also constitute a high proportion of consonants. And, the flexibility of the tongue blade allows coronals to be formed in several ways. Therefore, [cor], as a place feature, is inherent in any feature geometry structure.

The status of [ant] is less agreeable. This feature which occurs in all six feature geometry structures is used, together with [dist], to distinguish the various coronal places of articulation. McCarthy (1988:99-100) notes that [ant] "cannot be defined in either articulatory or acoustic terms". Also, this feature cannot "characterize a class of segments referred to consistently by phonological processes".

Gnanadesikan (1993:30) suggests that the feature [ant] be removed, and replaced with [back], under the Coronal node. Her motivation is that [-ant] coronals, such as alveopalatals and retroflexes, can use vowel features as secondary place features. Naturally the converse is also applicable – dispense with the use of [back] and retain [ant].

The feature [distributed] was introduced to differentiate among the fricative places of articulation. Ladefoged (1982:247) explains that this feature is used specifically to differentiate bilabial, dental and retroflex fricatives from their respective labiodental, alveolar and palato-alveolar counterparts. Given that such a distinction does not obtain in Zulu, the feature [distributed] would be considered redundant. The Keyser & Stevens (1994) structure locates [lateral] under the place of articulation category. Generally, this feature is located under the manner of articulation category (cf.2.5.4.4).

2.5.4.4. Manner of Articulation Features

Table 2.8 A Comparison of Manner of Articulation Features

	Dogil (1988)	Padgett (1995)	Clements & Hume (1995)	Keyser & Stevens (1994)	RAT (2000)
[nasal]	*	*	*	*	*
[cont]	*	*	*	*	*
[lateral]	*				*
[strident]	*				*
[suction]					*

Manner or Stricture features describe the articulation process, differentiating among plosives, fricatives, affricates etcetera. Table 2.8 indicates that the features [nasal], [cont], [strident] and [lat] are commonly identified as manner features. However, the location of the manner features in a feature geometry structure is a keenly contested issue.

Iverson (1989:258) proposed that the "conventional bifurcation" into Supralaryngeal (which subsumes the manner and place features) and Laryngeal nodes should be abandoned. He proposed that the manner and place features be attached directly to the Root node. In an attempt to determine whether the Supralaryngeal node was really necessary, Davis (1989) examined a range of assimilatory processes in various languages. He concluded that it was preferable to have the manner features subsumed under the Supralaryngeal node as this was an efficient and effective means of describing assimilatory processes. Dinnsen (1998:1), on the otherhand, supports the Iverson position, stating:

> Empirical evidence for a manner node has been weak. Evidence for an organizing node has usually required a set of features to act together in the same way by either triggering or blocking some physical rule.

Dogil (1988) and Keyser & Stevens (1994) support the Davis position. In addition they introduce a Soft Palate node that subsumes the feature [nasal]. Keyser & Stevens (1994), although including a Supralaryngeal node, do not have a designated node for manner features. The latter are attached onto the physical articulator (cf.2.4.3.1). The Clements & Hume (1995) structure renames the Supralaryngeal node the Oral Cavity node. But, only one manner feature [cont] is used. The feature [nasal] is attached directly to the Root node. Although Padgett (1995) places much emphasis on stricture issues, the manner features are actually subsumed under the Place node. The Padgett and Keyser & Stevens structures are similar in this respect. RAT (2000) follows the Iverson (1989) proposal, abandoning the Supralaryngeal node.

Moving onto the distinctive features used in the manner category, [nasal] is the least controversial. It is included in all structures with a preference for placing this feature under the Soft Palate node. Unlike other manner features, [nasal] is an articulator bound feature. Halle (1995:6), inter alia, identifies [cont], [lat], [strident] and [suction] as articulator-free features because they can be executed by more than one articulator. For example, /p, t, k/ are executed by the labial, coronal and dorsal articulators, respectively. Yet, they share the same manner and laryngeal features. It is the articulator-free nature of the manner features that have led Padgett (1995) and Keyser & Stevens (1994) to attach [cont] directly onto the articulators.

The features [lateral] and [strident] are essentially secondary features. They give greater clarity to sounds initially identified as [-cont] or [+cont] or [-cont, +cont]. While Keyser & Stevens (1994) locate the feature [lateral] under the place of articulation node, all other theorists locate this feature under the manner of articulation node. Given that Crystal (1997:216) defines this feature in terms of its airflow, “any sound where the air escapes one or both sides of a closure made in the mouth”, it follows that [lateral] should be classified as a manner feature.

McDonough (1993) also supports the location of [lateral] under the manner category as this feature, unlike other place features, is unlikely to be binary.
[-lateral], according to McDonough (op.cit.:19) is a "vacuous feature".
The feature [strident] which describes the sibilance of sounds i.e. the hiss characteristic found in /f, v, s, z, ts, tsh/, is vital to the description of affricates. This feature, in particular, encapsulates the acoustic phonetic quality of these sounds, namely high frequency and intensity (Crystal, 1997:365).
[suction] is a language-specific feature, used to identify click phonemes. Given the rarity of such sounds, many inventories omit this feature.
With regard to the status of [cont], Stevens & Keyser (1989:86) identify this feature as a primary feature. Lauttamus (1990:298) supports this position. But, Cser (1999:229) finds that [cont] is a replaceable feature. Given that [cont] makes a primary distinction between stops and continuants its role is deemed inherent.

2.6. The Ideal Selection

The preceding evaluation has shown that arguments around phonetic and phonological descriptions can be very complex. Even though this study advocates phonetic accuracy and is highly suspicious of impressionistic descriptions, it must be conceded that the inclusion of each and every nuance in a description is an unreasonable requirement. In fact it does little to enhance the fundamental purpose of Phonology – the study of language sound systems. Also, the idea of a universal distinctive feature inventory is overly ambitious. The Ladefoged & Maddieson (1996) study exemplifies how too many distinctive features become untenable. Moreover, despite the numerous distinctive features within a category, subtle and not so subtle variations persist, as discussed in 2.5.2. and 2.5.4.2. (cf. Santerre & Suen:1981; Schmidt:1984; Kingston & Diehl:1994).
Based on the critique in the preceding discussion, this section identifies the distinctive features and structure which the writer would opt to retain for a description of Intrusive Stop Formation in Zulu. In 2.6.1 the distinctive features are identified. In 2.6.2 the feature geometry structure is discussed. Following the experimental investigation in Chapter Three, this structure and distinctive features will be interfaced with the experimental results to create a new feature geometry structure to be presented in Chapter Four.

2.6.1. The Ideal Distinctive Features

From the discussion in 2.5.4.1 [±cons] and [±son] have been identified as significant Major Class Features. Based on the evaluation of the Laryngeal features, the following privative features[15] have been selected: [voice], [spread] [glottalized] and [constricted]. It must be noted that Laryngeal is one of the more complex categories. Therefore, Ladefoged & Maddieson (1996) identified nine laryngeal features. Naturally many of these are not applicable to Zulu. And, given the variability that may occur, this is the one category where it would be futile to strive for complete phonetic accuracy.

Moving onto Place of Articulation features, the RAT structure facilitates the identification of three groups of place of articulation features – Lips, Tongue Blade and Tongue Body. In Table 2.9 both privative and binary place of articulation features are used. The privative features [round] and [labial] are selected for the Lip node. [±coronal] and [±anterior] are selected for the Tongue Blade node and [dorsal] for the Tongue Body node. Following Clements & Hume (1995), the same features are used for the description of vowels and consonants, namely [labial] for rounded vowels; [+coronal] for front vowels and [-coronal] for central and back vowels. The privative feature [dorsal] functions to identify vowel phonemes.

[nasal], [±continuant], [strident], [lateral] and [suction] are selected as Manner of Articulation features. As per the RAT structure these features (including [nasal]) are attached directly to the Root node. Justification for this comes from the understanding that manner features are not attached to any identifiable physical articulator. Hence, in keeping with the anatomical accuracy theme, no intervening manner node is introduced. A criticism would be that this is not applicable to [nasal], but the argument for economy motivates the non-use of the Soft Palate node.

Presented in Table 2.9 are the distinctive features selected.

Table 2.9. The Ideal Distinctive Features

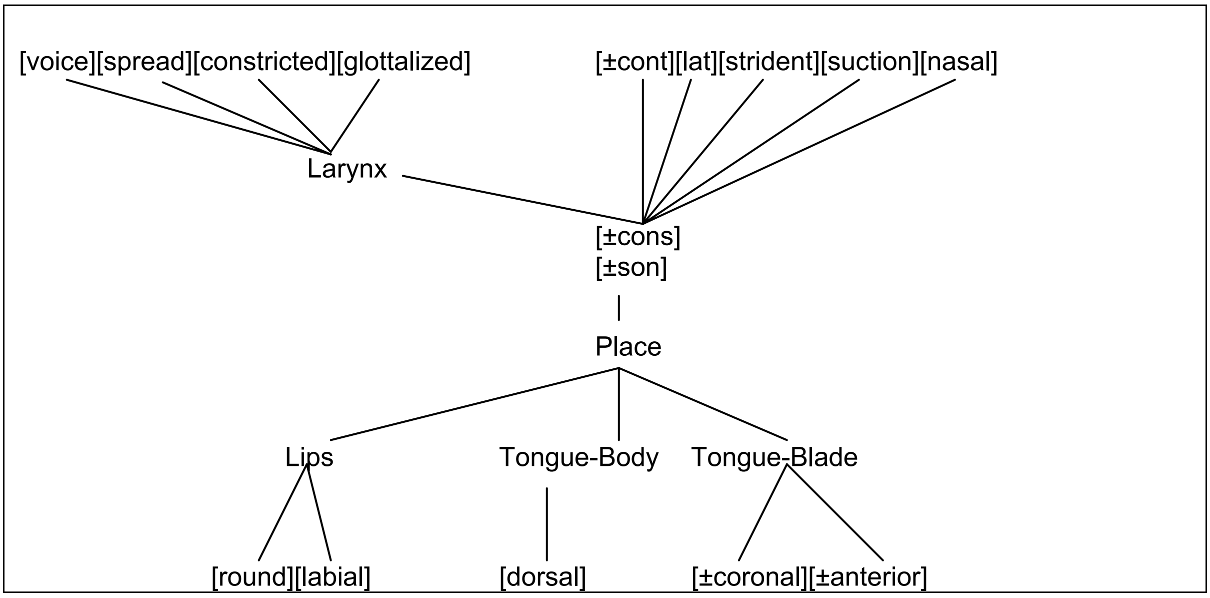
Major Class Features	Laryngeal Features	Place Features Lips	Place Features Tongue Blade	Place Features Tongue Body	Manner Features
[±cons]	[voice]	[round]	[±coronal]	[dorsal]	[nasal]
[±son]	[spread]	[labial]	[±ant]		[±cont]
	[constricted]				[strident]
	[glottalized]				[lateral]
					[suction]

2.6.2. The Ideal Feature Geometry Structure

Notwithstanding the various arguments for nonlinear description, feature geometry was developed fundamentally to depict the vocal apparatus. It therefore attempts to be anatomically relevant, irrespective of whether its proponents are diehard phonologists. To that end, the RAT structure identifies the various anatomical components. Therefore, this structure is used, with some variation, to form the basis of the feature geometry structure to depict Intrusive Stop Formation in Zulu.

Figure 2.21, which is an adaptation of the Halle, Vaux & Wolfe (2000) feature geometry structure, shows all distinctive features at the terminal position and the identification of the articulartory apparatus.

Figure 2.21 The Proposed Feature Geometry Structure



A few differences occur and these are identified below:

- Articulatory apparatus and corresponding features are located below the Major Class Features [cons] and [son]. Features that are dependent on acoustic detail are located above the Major Class Features.
- Several of the Halle, Vaux & Wolfe (2000) features have been dispensed with. These include the Place features [high][low][back][distributed], the Tongue Root features and the Laryngeal features [stiff] and [slack] (cf. 2.5.4.2 for discussion).
- Instead of specifying a Soft Palate tier, the feature [nasal] is subsumed as a manner of articulation feature.
- Several features are converted to privative values. These include the Laryngeal features, the Place features associated with the Lips and Tongue-Body, and all the Manner of Articulation, with the exception of [±continuant].

The next section examines the formalization of the Intrusive Stop Formation process.

2.7. Formalizing the Intrusive Stop Formation Process

In this section the proposals for the description of affricates, by Lombardi (1990), Rosenthall (1992), Van de Weijer (1992, 1993) and Schafer (1995), are discussed. Thereafter the formalizations of Steriade (1993) and Schafer (1995) are examined.

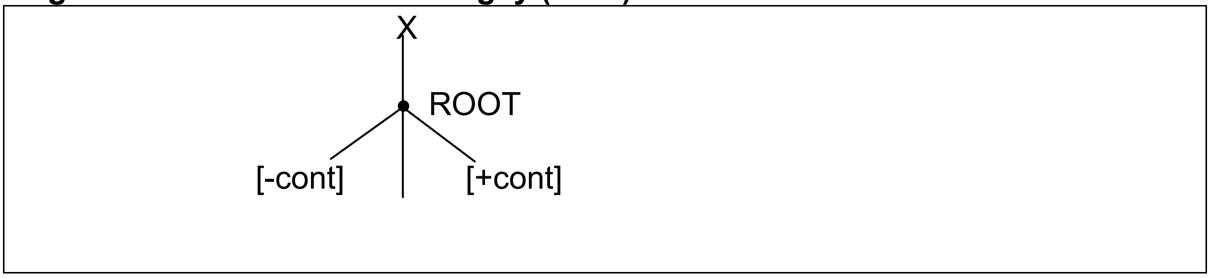
2.7.1. Problems Describing Affricates

From the several definitions of affricates given in the preceding sections, it is apparent that this class of sounds is complex. While stops and nasals are clearly single segment sounds that can be respectively identified by the features [-cont] and [+nasal], affricates are composed of a ‘sequence’ and therefore the specification is not straightforward.

In this section two aspects related to affricate description are examined – the contour nature of the affricate and the concept of dominance.

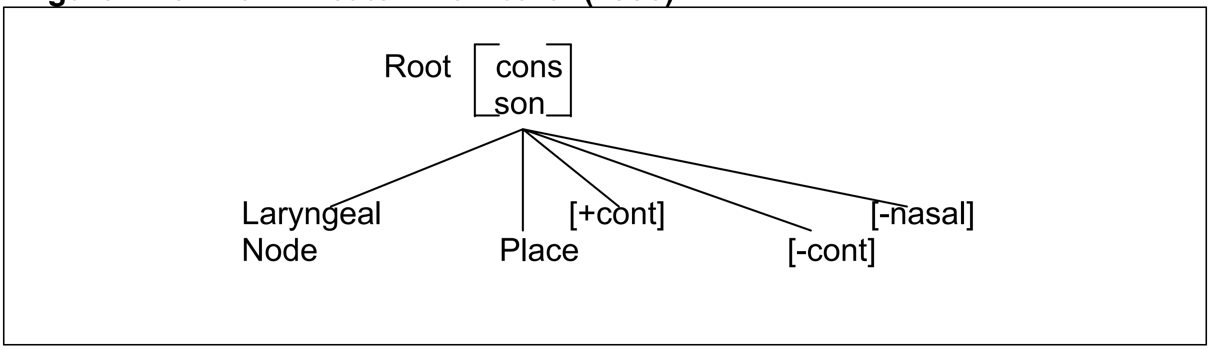
The nonlinear framework, as evinced by the six feature geometry structures, has a preference for the feature [-cont,+cont]. This is in keeping with the identification of affricates as contour segments. Piggott (1988:346) explains that such a segment contains both values for one feature. The identification of the affricate as having the features [-cont,+cont] is based on that of Sagey (1986) who described the affricate as a contour segment which should be visually represented as in Figure 2.22.

Figure 2.22 The Affricate – Sagey (1986)



However, Lombardi (1990:376) rejects the description on the basis that the ordering of [-cont][+cont] implies “that phonological processes will show edge effects[16]” and “incorrectly predicts a nonexistent type of consonant[17]”. Therefore the features for affricates should be unordered as in Figure 2.23.

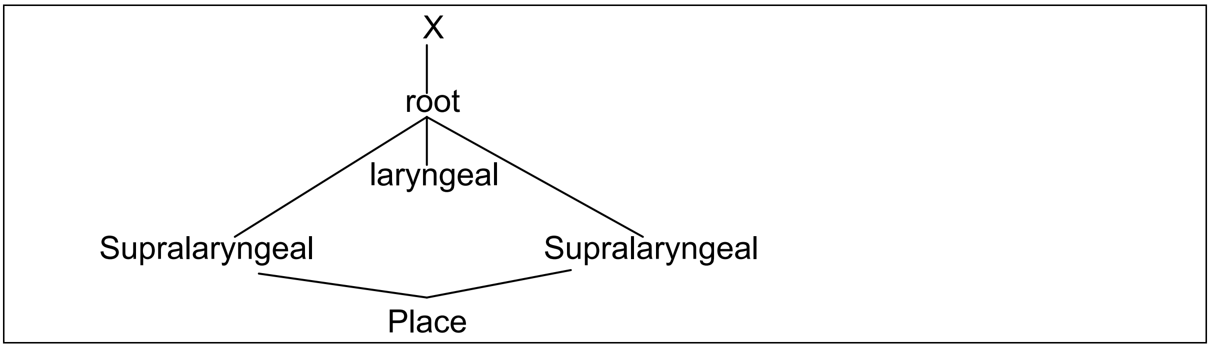
Figure 2.23 The Affricate – Lombardi (1990)



Lombardi (op.cit.) also prefers the use of the features [+stop,+cont] for the description of affricates.

Rosenthall (1992) deals with affricates in the context of a discussion on prenasalized stops. Although not specifying distinctive features, Rosenthall, like Lombardi, acknowledges that affricates constitute a single segment with differing specifications for a single feature. Hence, the two Supralaryngeal nodes in Figure 2.24. In addition, the Rosenthall structure shows that the two components of the affricate share a common place of articulation feature.

Figure 2.24 The Affricate - Rosenthall (1992)



Lombardi’s specifications [+stop,+cont] are adopted by Van de Weijer (1992, 1993). But, the latter (1992:133) rejects Figure 2.23 for theoretical and empirical reasons, the most significant being that if [-cont][+cont] can be considered as one segment, then theoretically a sequence like [ga] could also be considered as one segment. Van de Weijer (1993:87) therefore proposes that the affricate is composed of two independent unary features, shown in Figure 2.25.

Figure 2.25 The Affricate - Van de Weijer (1992, 1993)

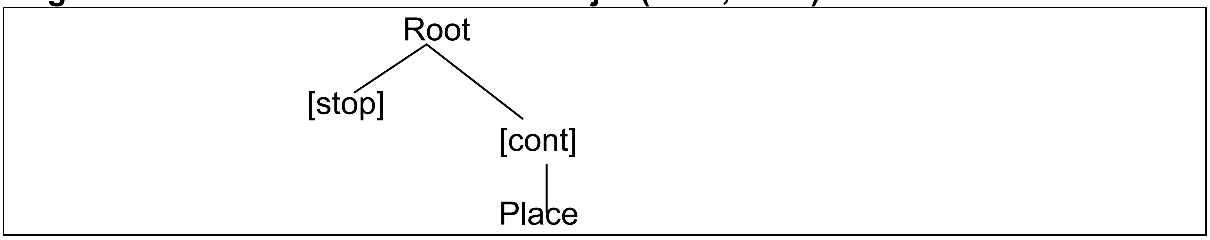


Figure 2.25, like Figure 2.24, depicts the shared Place features. It also expresses the observation that “affricates are typically found at the place of articulation where fricatives are also found, either in a particular language or cross-linguistically. The head Manner feature dominates Place” (Van de Weijer, 1993:94). Implicit in Figure 2.25 is the concept of dominance as the features [stop] and [cont] are not aligned. However, it is Schafer (1995) who explicitly expounds the concept of the head feature or dominance[18]. Schafer (1995:83) states:

> In every pair of features of the same set within the same geometry (segment), one must be singled out as the unique head.

Figure 2.26 shows the Schafer[19] (op.cit.:62) representation of affricates.

Figure 2.26 The Affricate – Schafer (1995)

[+cont]
[-son]
|
[stop]
|
[cont]

The next section examines the formalization of Intrusive Stop Formation in Zulu.

2.7.2. Towards Formalizing Intrusive Stop Formation in Zulu

In the following discussion the proposals of Steriade (1993) and Schafer (1995) for formalizing the Intrusive Stop Formation process are expounded. These formalizations are alternatives to those described in 2.4.

Steriade (1993), who subscribes to Aperture Theory, proposes the description shown in Figure 2.27. The Aperture position which specifies the airflow is comparable to the root node of Feature Geometry Theory. Thus affricates would have the specification A_oA_f. A_o indicates a “total absence of airflow” and A_f the “degree of oral aperture sufficient to produce a turbulent airstream” (op.cit.:402). The type of affrication discussed for Zulu is termed Postnasal Hardening by Steriade (op.cit.:424) and is formalized in Figure 2.27.

Figure 2.27 The Affrication Process – Steriade (1993)

Underlying	[nas]	
	A_oA_f	= *n + z*
	coronal	
	strident	
PNH	[nas]	
	A_oA_f	
	coronal	
	strident	
Release Adjustment	[nas]	= ^{n}(d)z
	A_oA_f	
	Coronal	
	strident	

In Figure 2.27 the Underlying level depicts the environment in which the affricate is created, namely a nasal preceding a fricative. Note that the association line links the [nas] to A_o indicating that this is a stop. Association lines link A_f to the place feature Coronal and the manner feature Strident. This is consistent with the Affrication process where the place of articulation of the fricative is inherent. In the next step, Post Nasal Hardening (PNH), the depiction is of shared features. According to Steriade (op.cit.:427)

> The output of PNH combine the features of the two input segments and maintains the basic aspects of the initial sequence of the A positions: a closure and a release.

The Release Adjustment shows the ordering of nasal, stop and fricative. The contour nature of the affricate is depicted. But complete clarity in representation is lacking. The presence of the intrusive stop is inferred rather than explicit.

The Zulu affrication process would constitute strengthening in Schafer's terminology. Schafer (1995:74) depicts the process in Figure 2.28.

Figure 2.28 The Affrication Process – Schafer (1995)

Root [+cons] [-son] [+cons] [-son] [+cons] [-son]

Stricture 1 [stop][cont] ⇒ [stop][cont] ⇒ [stop][cont]

The delinked [cont] must be reassociated.

Root [+cons] [-son]

Stricture 1 [stop]

Stricture 2 [cont]

Figure 2.28 depicts a stop sound being juxtaposed with a [cont] or fricative sound. This is indicated by the broken line linking [stop] to the Major Class Features. This juxtapositioning creates an affricate with the privative features [stop][cont]. In terms of Schafer's concept of hierarchy (cf.2.7.1) [stop] and [cont] cannot occur at the same level. One is singled out as the dominant feature. Stricture 1 illustrates that the [stop] feature is dominant – it is afterall the first feature of the segment. Therefore, the feature [cont] has to be relegated to another level, namely Stricture 2. Schafer's focus was on dominance and it is assumed that all other phonetic detail would follow somewhere on the structure. But, the expositions of Steriade and Schafer bring another perspective to the use of notational conventions in Phonology.

In 2.2.2 weaknesses with the *SPE* notational system were highlighted. It was for such reasons that the nonlinear framework developed. However, Van der Hulst & Smith (1985:3) note that *SPE* conventions have persisted in most post-*SPE* developments. This is confirmed by the formalizations used in Chapter Two which retain the Generative conventions of linking and delinking. Bernhardt & Gilbert (1992:124) identify the latter as the two basic operations of phonological rules and processes. In terms of the formalization of the Affrication process, with the exception of Padgett (1995), cf. Figure 2.7, all the other theorists discussed in 2.4, use the linking/spreading technique (cf. Figures 2.3, 2.5, 2.9, 2.11 and 2.13). Padgett, on the otherhand, allows for an insertion rule. This resembles the Steriade and Schafer formalizations in Figures 2.27 and 2.28 where reassociation and release adjustment, respectively, are depicted. While it is only in Chapter Four that the formalization of the Intrusive Stop Formation process is finalized, the depictions of Schafer and Steriade will impact on the chosen notational conventions.

The next section summarizes the areas for further investigation.

2.7.3. Further Investigation/Unresolved Issues

The discussion in 2.7 has brought a new perspective to describing affricates and formalizing the Intrusive Stop Formation process. While the use of the distinctive features [-cont,+cont] is controversial, the introduction of a distinctive feature [stop], whose use is limited to affricates is equally contentious. The dilemma of linguist becomes choosing the "lesser incorrect" distinctive feature.

The next point of contention is the use of notational conventions. Notational conventions are crucial to phonological description. Most linguists concur that a representational system is the corollary to phonological description. Coleman (1998:12-13) states that disciplines such as mathematics and chemistry employ "specially constructed notations" and therefore such a system in Linguistics will "offer phonologists of different schools a lingua franca for constructive debate".

Beckman (1999:200) explains that phonological representations are 'algebraic objects' as opposed to phonetic representations that are "quantitative, non-cognitive models of physical, temporal events". She adds that the "discrete symbolizable phonetic categories function as an intermediate device in the phonetic implementation of phonological contrasts". The theorists discussed in this chapter all reiterate the contour nature of the affricate. However, Steriade (1993) and Schafer (1995) use new formalization techniques. The latter issue is addressed in Chapter Four.

What remains unresolved is the distinction between the phonetic qualities of pure and derived affricates. Clarification on that can only be ascertained through experimental investigation. This will be done in the next chapter.

2.8. Summary

The discussion in Chapter Two has dealt with four issues. Firstly, the historical development of Distinctive Feature Theory was presented. The linear representation of the Intrusive Stop Formation process was discussed and found inadequate.

Secondly, the development of the nonlinear feature geometry framework was chronologized. Issues relating to the phonological and phonetic/anatomical motivations for such structures were critiqued.

Thirdly, using the Ladefoged & Maddieson[20] (1996) proposal for distinctive features as a point of departure, a proposal that is heavily influenced by anatomical and phonetic considerations, the distinctive features were compared and critiqued. While the Ladefoged & Maddieson (1996) proposal attempts to produce universal and comprehensive distinctive features, the sheer number of features makes this a cumbersome inventory. This leads to the postulation that perhaps the purist position would not endure when determining a distinctive feature inventory. And, it may be more prudent to préci the phonetic details. What emanates is the realization that as vital as scientific facts are, they must be properly harmonized with the phonology of the language, i.e phonetics facts and phonological description must be sensibly integrated.

Fourthly, the description of affricates and the formalization of the Intrusive Stop Formation process was examined. New perspectives which saw affricates being described in terms of Headedness and Dominance were introduced. Furthermore, using such descriptions resulted in the Intrusive Stop Formation process being formalized in a more explanatory manner as opposed to the simple assimilation techniques of the five feature geometry structures discussed.

In Chapter Two the theoretical complexities of Feature Geometry Theory[21] and Intrusive Stop Formation were established. Chapter Three undertakes an experimental investigation into Intrusive Stop Formation in Zulu and focuses on the acoustic parameter Duration as opposed to the mainly articulatory concerns of this chapter. The experimental results will be used to enhance the distinctive feature inventory determined in Table 2.9. The results will also be used to inform the introduction of new tier in the already established feature geometry structure in Figure 2.21.

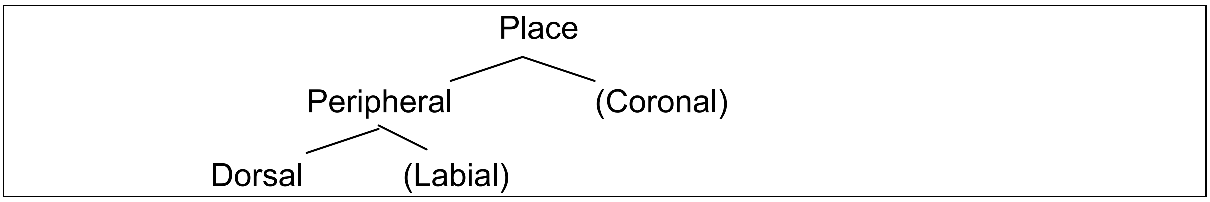
NOTES

1. Chomsky & Halle (1968:299) mention the importance of acoustic and perceptual parameters, but due to constraints on length, do not pursue discussion of these.
2. The critique of these distinctive features is incorporated into 2.5.
3. Generative Phonology was succeeded by several trends, each, to some extent, resembling or developing on the Chomsky & Halle brand. Vennemann & Hooper developed Natural Generative Phonology. Stampe was the founder of Natural Phonology. Then the trend toward suprasegmental phonology began. Goldsmith, founder of Autosegmental Phonology, concentrated on the study of tone. Liberman, with Metrical Phonology, concentrated on the study of stress. Thereafter two major trends were Lexical Phonology and Dependency Phonology. The proponents of the former were Strauss, Kiparsky & Mohanan; and the latter Anderson & Ewen (Clark & Yallop, 1990:341-351). Despite the recognition of suprasegmental factors, the role of distinctive features was not diminished. Instead there was a move toward bringing Distinctive Feature Theory into the nonlinear framework that was typical of post-Generative Phonology. The problems of Generative Phonology relating to phonetic description and representational patterns, in particular, were dealt with using the nonlinear feature geometry framework.
4. [son] is identified as a manner of articulation feature in Clements (1985).
5. Crystal (1997:24) explains that the feature [+approximant] would be used to classify all vowels and frictionless continuants i.e. liquids and glides.
6. Given that the focus of this chapter is on the feature geometry structure per se, the validity of Clements's motivation is not evaluated.
7. Maddieson (1997:663), however, argues that universals should be viewed as "reflections of the overall context within which language is produced and heard" i.e. "'universals' are not fixed attributes of languages".
8. The Clements (1987) distinctive features are not discussed as the Clements & Hume (1995) inventory takes precedence.
9. [vocoid] is the converse of [cons].
10. The writer has not encountered any linguistic arguments that have strongly motivated for the exclusion of the feature [son] as a major class feature. Rice (1993) has sought to replace this term with [sonorant voice] or [SV]. Her

argument is that this feature [SV] would define the particular type of voicing characterized by sonorants. Furthermore, she identifies phonological processes involving nasals that support the use of the feature [SV]. While there is considerable merit in the Rice motivation, its limited application does not justify the change.

11. Nine of these are reproduced in Ladefoged & Maddieson (1996:372).
12. The hash # symbol indicates that these features exist as nodes only. The Keyser & Stevens (1994) inclusion of [lateral] as a place of articulation feature is discussed in the next section. Although the places of articulation for vowel phonemes are included, discussion is confined to the features for consonant phonemes.
13. There have been several proposals for a Place Node, each motivated by different arguments. For example, Rice (1994) brings the concept of hierarchy to the Place Node. This is seen in Figure 2.29.

Figure 2.29 The Place Node – Rice (1994)



According to Rice (op.cit.:193) the features Coronal and Labial are default features at the Place and Peripheral nodes, respectively. Rice goes on to justify this organization as being able to illustrate how coronals assimilate to labials and dorsals, and how labials assimilate to dorsals. It is the contention of this study that the hierarchical organization of the Place Node does not enhance phonetic or phonological description. Therefore discussion on such a structure is not pursued in this study.

14. As [dorsal] is applicable to vowel phonemes, discussion on this feature is not pursued. The same applies to the features [hi], [back], [round] and [low]. However, as shown in Figure 2.21, of the latter features, only [round] is retained. This is because the distinctive feature [round] is able to enhance the description of vowel phonemes.
15. The use of binary and/or privative features is in itself a complex issue. Both privative and binary feature systems have advantages. While Rice (1992:362-

364) argues for the use of privative features because it facilitates a more restrictive phonology, she nevertheless identifies the following advantages of binary systems: cross-linguistic factors; both values of a feature may be operational in a language; contour structure of segments and blocking. Clements (2003:300) proposes a combined privative-binary system. Table 2.9 subscribes to the Clements position. However, based on the Zulu phonological system the same one and two valued features do not obtain in the Zulu inventory.

16. Lombardi (1990:376) cites evidence from Archangeli & Pulleyblank (1987) who identify phonological processes which do not adhere to edge effects i.e. the processes apply after stops and affricates.
17. Lombardi (ibid.) expresses concern that by using the features [-cont,+cont], the implication is that a contrastive [+cont,-cont] segment occurs. And, according to her research such a segment does not exist.
18. This concept has its origins in the work of Anderson (1976) who suggested that in a complex segment, one articulation is “primary”. Of greater significance is Anderson’s proposal that dominance is a phonological, not a phonetic phenomenon. He is quoted in Sagey (1988:183):

    > The primary versus secondary status of the articulations in a complex segment is not phonetically determined. Primaryness, then, is a phonological, abstract property, not a phonetic one.

19. Schafer (1995) does not specify the location of the Place node.
20. Ladefoged (1988a & 1988b) proposed a feature geometry structure which took into account the auditory dimension. In a personal communication he suggested that the use of the Ladefoged & Maddieson (1996) feature geometry structure would be preferable.
21. Feature Geometry Theory has itself had a recent development with Padgett’s (2002) proposal of Feature Class Theory. The underlying principle of Feature Class Theory, according to Padgett (2002:82), is that “features are always affected directly and individually” i.e. class nodes are not involved in rule or constraint formalizations, only distinctive features. The RAT structure is similar in that all features are allotted at the terminal position. However, class nodes are not precluded from engaging in operations. The most significant point about

Feature Class Theory is that it operates within the Optimality Theory framework and is therefore incongruent with the line of argument in this thesis. But, it would be remiss not to mention this development from Feature Geometry Theory. However, based on Padgett's (1995; 1996) proposals, Cahill & Parkinson (1997:89) reject Feature Class Theory stating:

> To be accepted, a new theory should have significant advantages over the one it seeks to replace…It goes without saying that the new theory should, in fact be, different from what it replaces. We have shown that Feature Class Theory does encode the same hierarchy of information that Feature Geometry does, that the cases proposed as problematic for Feature Geometry are not, and that the apparent additional power and novelty of Feature Class Theory is not a function of it being significantly different from Feature Geometry, but of being presented within Optimality Theory. We maintain that the burden of proof required of new theory has not been sustained, and that Feature Class Theory has not been established as superior to Feature Geometry in any way.

Therefore Feature Geometry Theory continues to be the dominant model.

Chapter Three

An Experimental Investigation into Intrusive Stop Formation in Zulu

There is no more convincing way to show that experiments can help to answer questions in phonology than by answering phonological questions through experimentation
Ohala & Jaeger (1986:6)

3.0. Introduction

Chapter Three is an account of the experimental investigation into Intrusive Stop Formation in Zulu. It commences with an outline of the move towards Laboratory Phonology. Phonetic descriptions for Intrusive Stop Formation are then presented. The factor Duration is the focus of this experimental investigation, and justification for this is discussed. Chapter Three then proceeds with the presentation of the experimental investigation.

The aim of this chapter is to determine if durational differences exist between pure and derived affricates in Zulu. If such differences obtain, then the factor Duration becomes a crucial parameter in the phonological description of the Intrusive Stop Formation process.

3.1. Towards an Experimental Framework

Traditionally Phonetics and experimentation were synonymous, with a history that dates back to the nineteenth century. Van Helmholtz, Sweet, Bell, Dudley, Cooper, Liberman, Delattre and Rousselot were among the theorists who made a scientific contribution to the study of Phonetics (cf. Lyons:1969; Prideaux et al.:1980; Borden & Harris:1980; Blumstein: 1991).

The concept of experimentation in Phonology had been touted for some time and the following discussion captures some of the salient points.

Yngve (1986:258), a strong proponent of the need for a scientific tradition in Linguistics, noted:

> Crucial for the question of the status of linguistics as a science and its place among the other sciences is that …in the scientific tradition theories are tested against

> observations of real objects, but in the grammatical tradition not.

Kohler (1987:242) also argued that Linguistics needed to move towards a systems theory that was mathematically informed in terms of model and method. Linguistic research should follow the scientific form of observation, description of observed phenomena and an explanation of results. While the Generative paradigm, as with most other paradigms in Phonology, used phonetic information and scientific logic, the nature of explanation was not based on experimental evidence (cf. 4.1 for further discussion on functionalism versus formalism). Taxonomic and descriptive trends came to be equated with 'scientific study.' And as discussed in the preceding chapter, impressionistic observations informed descriptions upon which 'theory' came to be based. Thus, Phonology was slow to embrace the concept of 'scientific study' in the sense that it was intended. Ohala (1991:9) was particularly critical of autonomous Phonology, its lack of scientific accountability and prolific generation of theories. He states:

> …it has not enlarged its repertory of ways to ensure the quality of evidence in support of its claims. It has depleted its methodological arsenal. Freed from what it regards as the confinement of an "empiricist and mechanistic" approach to speech sounds, it cannot only propose a completely new range of theories but even those which contradict phonetic findings[1].

Increasingly the realization was that Phonetics and Phonology needed to be integrated. Hyman (2001:143-145) identifies four arguments supporting the integration of Phonetics and Phonology. Firstly, there is the "economy argument". The descriptive terms of Phonetics and Phonology, for example, aspirated stop, are the same. It follows that the two areas are not as discrete as one was led to believe. Secondly, the boundaries between Phonetics and Phonology are blurred i.e. when is a process phonological and when is it on account of the "language-specific phonetics". Thirdly, Phonetics is often viewed as the explanation for phonological occurrences. Thus, integrating the two areas seems logical. Fourthly, a fundamental aim of Linguistics has been to constrain and restrict Phonology. And by integrating Phonetics that aim is served well.

One of the most successful methods to achieving integration is the post-Generative Phonology approach of Laboratory Phonology. Laboratory Phonology is premised on integrating "experimental phonetics, experimental psychology[2] and phonological theory" (Clark & Yallop, 1990: 352).

Kingston & Beckman (1990:3) succinctly identify the challenges of Laboratory Phonology:

> How can we use the physical models and experimental paradigms of phonetics to contrast more viable surface phonological representations? Conversely, what can we learn about underlying phonetic representations from the formal cognitive models and computational paradigms of phonology?

They go on to describe this interfacing of Phonetics and Phonology as a "hybrid methodology", one that includes experimentation to inform phonological description.

As far as the integration of Phonetics and Phonology is concerned within the African languages, Roux has reiterated this need on several occasions (cf. Roux: 1991; Roux:1995; Roux & Ntlabezo:1996).

In 2.7.3 one of the unresolved issues identified was the phonetic nature of pure and derived affricates. It was postulated that there could be phonetic differences between these two groups, which could have implications for the phonological representation of Intrusive Stop Formation. The only way to verify this assumption is through the implementation of the experimental framework. Phonological description of the process, in Zulu, cannot be achieved in the absence of certain basic phonetic information. As Selkirk, in Roux (1995:20), notes:

> Phonological analysis cannot be made independently of the analysis of its phonetic interpretation…different assumptions about phonetic interpretation have different consequences for the range of hypotheses that can be entertained concerning phonological representation.

Thus, the focus of this chapter is implementation of the Laboratory Phonology approach, in particular investigating the phonetic factor Duration as it obtains in Zulu affricates. So while Chapter Two concentrated on phonological descriptions of the Intrusive Stop Formation process, this chapter examines the phonetics of the process.

In the next section phonetically informed descriptions[3] on Intrusive Stop Formation are discussed.

3.2. Phonetic Descriptions of Intrusive Stop Formation

In Chapters One and Two various descriptions on affrication were given. Many were, in essence, phonetic accounts of the process. The following explanations are based on more technical details, and are more accurate in terms of the phonetics of Intrusive Stop Formation.

Ali et al. (1979) conducted an investigation using aerodynamic and acoustic criteria. Their contention is that intrusive stop formation occurs for the following reasons (op.cit.:85-86):

- A silent gap occurs between the nasal and fricative on account of the nasal devoicing lagging into the fricative closure phase. The oral air pressure buildup is slowed down and therefore fricative noise production is delayed
- A delay in releasing the oral closure of the nasal stop causes the vocal folds to stall. Friction noise can only be produced after the stop is released, therefore a gap is created
- As nasal-fricative clusters are characterized by right-left coarticulation of the velopharyngeal opening, the latter might inhibit the buildup of oral air pressure required for the creation of a noisy fricative, and this could create a silent gap
- If the oral air pressure rises before nasal release, and is combined with a rapid release, the result is burst-transient, which could create the perception of a stop consonant

Timing, mistiming and retiming explanations have also been offered. Harms, quoted in Dinnsen (1980:180), explains the process as follows:

> A nasal plus fricative sequence as the output of the phonological rules will automatically lead to an inserted stop at the level of sound production owing to the disparity in timing between the neural commands and motor events.

Ohala, quoted in Fourakis & Port (1986:201), similarly attributes the process to mistiming, stating that

> …the closing of the velum before the release of the occlusion for the nasal will produce a configuration of the articulators similar to that of a homorganic stop

And, Clements (1987:35) proposes that Intrusive Stop Formation results from

> …a systematic retiming of the articulatory gestures required in the transition from the nasal to the fricative. This transition is a complex one, requiring simultaneous changes in the values of the features [nasal], [voiced], [sonorant], [cont], as well as place of articulation.

Wetzels (1985:285), on the otherhand, defines intrusive stops as

> …sounds emerging at the phonetic surface as the result of specific co-articulation effects, generally involving the manner of articulation features “nasal”, “continuant” and “lateral”

From the preceding discussion on it is evident that timing is a significant factor. But timing, which according to Crystal (1997:389) is “temporal constraints on the articulation and sequencing of sounds in speech production” and is attributable to muscle co-ordination, is difficult to quantify experimentally.

MacKay (1987:100) brings another perspective to the description of Affrication/Intrusive Stop Formation process. According to him, in English, there is a difference between an affricate and a sequence of plosive and fricative – what this thesis terms pure affricates and derived affricates, respectively. He identifies the following phonetic criteria for affricates:

- The plosive and fricative must be homorganic
- They must be closely fused by the most direct transitional movement possible
- The total duration must not be much greater than the usual duration of either component

The last criterion, “Duration”, has been singled out in several studies on Intrusive Stop Formation as the most significant parameter in distinguishing intrusive stops from underlying stops[4]. This experimental investigation continues that trend. The next section expands on Duration.

3.3. Duration

Crystal (1997:127-128) defines duration as "the length of time involved in the articulation of a sound or syllable". Duration is a vital parameter because according to Lehiste (1976:225), in order for a segment to be recognizable it must have duration.

Duration was researched in the pre-Generative Phonology period. O'Shaughnessy (1981:385) notes the contribution made by the following linguists – Peterson & Barney (1952), Peterson & Lehiste (1960) and House (1960) who examined vowel duration; Fry (1955) who investigated the link between duration and stress; Denes (1955) and Lisker & Abramson (1964) who studied the role of duration in distinguishing phonetic segments; and Lehiste (1959) who identified duration as a parameter in distinguishing syntactic segments. Several experimental studies investigating aspects like the role of duration in perception, the link between stress and duration, determining the durational values of consonants and vowels etcetera were undertaken. O'Shaughnessy (op.cit.) reports on the findings of Barnwell (1971), Klatt (1974, 1975), O'Shaughnessy (1974) and Umeda (1977). Further studies were also conducted, inter alia, Huggins (1972), Klatt (1976, 1979), Lehiste (1977), Zue & Laferriere (1979), Carlson, Granström & Klatt (1987) and Crystal & House (1988a and 1988b) and Fowler (1992).

With regard to the African languages duration has been investigated, albeit not with respect to Intrusive Stop Formation. Jones (2001:27-29) identifies the following studies that examined the role of duration in statement and question type sentences: Doke & Mofokeng (1957), Lanham (1963), Riordan (1969), Ziervogel (1976), Lombard (1980), Khumalo (1981), Steyn (1991), Nkabinde (1999). Experimental investigations were undertaken by Louw (1968) and Theron (1991).

The following reasons have motivated the identification of Duration as the focus factor in this experimental investigation:

- According to Klatt (1974:51) durational information provides insight into "the nature and organization of speech production, speech perception and phonological theory."
- Duration measurements can be reliably measured using available software.

- Experimental research into intrusive stops has identified Duration as a significant and easily quantifiable parameter. For example, Clements (1987:34) examined the differences between the [t] occurring in the words *dense* and *dents* and was able to determine experimentally that the average duration of [t] in *dense* was 31 msec as opposed to 42 msec in *dents*. Further research has been reported in Blankenship (1992); Warner & Weber (2001); Warner (2002) and Yoo & Blankenship (2003). Interestingly, the results of Blankenship (1992) found that there were no significant durational differences between underlying and epenthetic stops. However, that position was changed when the experimental investigation of Yoo & Blankenship (2003) found that the closure duration of the underlying stop /t/ was longer than that of the epenthetic /t/. It follows that an experimental investigation for Zulu will be invaluable, not only in terms of bringing the language into the experimental paradigm, but also as a contribution to the resolution of the debate on whether durational differences exist between pure and derived affricates
- The parameter is essential to applied research – speech generation and recognition (cf.4.2.2 and 5.2).

A notable complexity regarding duration is that adjacent segments influence it. Umeda (1977:854) notes that the nasal tends to shorten the following consonant. Quoting the work of Schwartz (1970); Lindblom & Rapp (1973); Haggard (1973) and Klatt (1974), Umeda (op.cit.) also notes that consonant clusters cause the shortening of duration of their constituents. This observation is reiterated by O'Shaughnessy (1981) and Crystal & House (1988b). The implication of these findings is that the derived affricates in Zulu, which are essentially prenasalized fricatives, will have their duration shortened on account of the adjacent nasal. Comparing the duration values of the derived and pure affricates may then appear to be dubious. However, Klatt (1979:287), while identifying psychological and semantic variables; syntactic structures and the lexical component as factors which influence the duration of a segment, states:

> The phonological component specifies inherent duration for each phonetic segment type…and executes a set of rules that modify the inherent durations according to the phonetic context and other factors.

Klatt (ibid.) uses that logic to justify the exclusion of adjacent segments when measuring the duration of specific segments. So while innate length, manner of articulation, place of articulation, and the preceding and following sounds may influence the duration of a phoneme the experimental investigation in this study subscribes to Klatt's position and ignores these influences.

The next section presents the experiment where the duration of affricates sounds is measured.

3.4. The Experiment – An Analysis of the Duration of Affricates in Zulu

The focus of this experiment is on determining the duration of the pure and derived affricates. By it's very nature the experiment marks a move away from 'impressionism' towards an approach in which claims and interpretations are based on empirical support. In the following section the experimental methodology is expounded, followed by a presentation and analysis of the results.

3.4.1. Aims

The aim of this experiment is to measure the duration of the pure affricates /kl', dZ, tS', ts'/ and the derived affricates /{v, φf', ts', dz, tñ', dL, tS'/. This aim is realized by:

- Measuring and comparing the duration of the pure and derived forms of /ts'/ and /tS'/[5] to determine the extent of their similarities and/or differences
- Measuring the duration of the pure affricates, /kl', dZ/, and the derived affricates, /{v, φf', dz, dL, tñ'/. This is to establish the degree of durational similarity or difference between these two forms.

As a consequence of the experimental investigation further aims are realized, namely:

- Establishing experimentally whether the classification of /kl', dZ, tS', ts'/ and /{v, φf', ts', dz, tñ', dL, tS'/ as affricates is correct
- Establishing experimentally whether the traditional classification of voiceless Zulu affricates as ejectives is correct.

3.4.2. Participants

Five mother-tongue speakers of Zulu are used to record the corpus. The participants are all female[6], between the ages of 18-25.

3.4.3. Method

The methodology used in this thesis is experimental in nature. It involves recording words containing the relevant sounds directly onto a speech-processing platform, PRAAT[1] (version 4.1.7). This is followed by an analysis of waveforms and spectrograms.

The preparation of the data for the acoustic analysis was done in the following phases:

- A corpus was selected
- Speech was digitally recorded
- Tags were inserted to identify the relevant segments

3.4.3.1. Corpus

While investigation into intrusive stops has often been in the context of homonyms, such data is unavailable for Zulu. The words, shown in Table 3.1, containing pure and derived affricates are used as tokens. All the affricates are embedded in the frame sentences[7]:

Ngithi uku_____ manje	Pure
Ngithi _____ manje	Derived

[1] www.praat.org

Table 3.1 Corpus

Pure Affricates	Gloss	Derived Affricates	Gloss
/ts'/		**/ts'/ derived from /N + s/**	
ukutsaka	to squirt through closed teeth	insalelo	remnant
ukutsavuza	to lance, pierce	insangano	confused state of mind
/tS'/		**/tS'/ derived from /N + S/**	
ukutshuma	to glide along	intshawula	species of weed, dry grass
ukutshaza	to squirt	intshumayelo	sermon
/kl'/ & /dZ /		**/þf', {v, dz, tñ', dL/**	
ukuklaza	to discharge from salivary glands		
ukujabula	to rejoice		
		imfanelo	a right, duty
		imvakazi	hair fringe, veil
		inzala	grass seed
		inhlaba	small species of aloe
		indlozi	serval or tiger-cat

3.4.3.2. Recording

The speech was recorded directly onto PRAAT (version 4.1.7) at the Research Unit for Experimental Phonetics, University of Stellenbosch (RUEPUS)[8]. The data was recorded at a sampling frequency of 11kHz[9]. The words were recorded in a carrier phrase and were read in a systematic order, commencing with the pure affricates, followed by the derived affricates. Appendix A contains detailed waveforms and spectrograms for the affricates.

Each sentence was saved in a separate file with a unique file name (refer to the accompanying CD). Each character of the filename serves as an information carrier. For example, **n_fricative_01.5**, translates to n indicating that this sound is a derived form (with a preceding nasal), the second word indicates that the sound is a fricative, the third character identifies the example number and the last character identifies the speaker (fifth speaker).

3.4.3.3. Tagging

3.4.3.3.1. Identifying the Affricate

In order to determine the duration of the affricate, the sound is identified and segmented. Also, given that the affricate is a complex segment (cf. 2.7.1), the components are also identified. In this experiment the criteria for the segmentation of the affricate are based on theoretical and experimental observations from various studies. The following discussion expands on this.

Olive et al. (1993:242) explain an affricate as being constituted of a stop and a fricative. From waveform evidence, they further identify the stop portion as being composed of a closure and a burst. Stevens (1993:33) concurs with that explanation but uses different terms. He identifies an anterior (closure and burst/stop) and posterior (frication noise) section. The "stop-fricative" or "anterior-posterior" components of Olive et al. (1993) and Stevens (1993), respectively, are realized by different terms in this study. The term Closure Duration is equivalent to stop or anterior, and Release Duration is equivalent to fricative or posterior. Closure Duration and Release Duration[10] are identified as the acoustic features to measure in order to obtain the actual duration of phonemes. This is consistent with the experimental methodology of Pitrelli & Zue (1989:325) who explain:

> Usually, a phoneme is associated with a single phone, but in the case of stops and affricates, the closure and release portions are labeled with separate phone tokens…the duration of the phoneme is taken to be the sum of the closure and release durations.

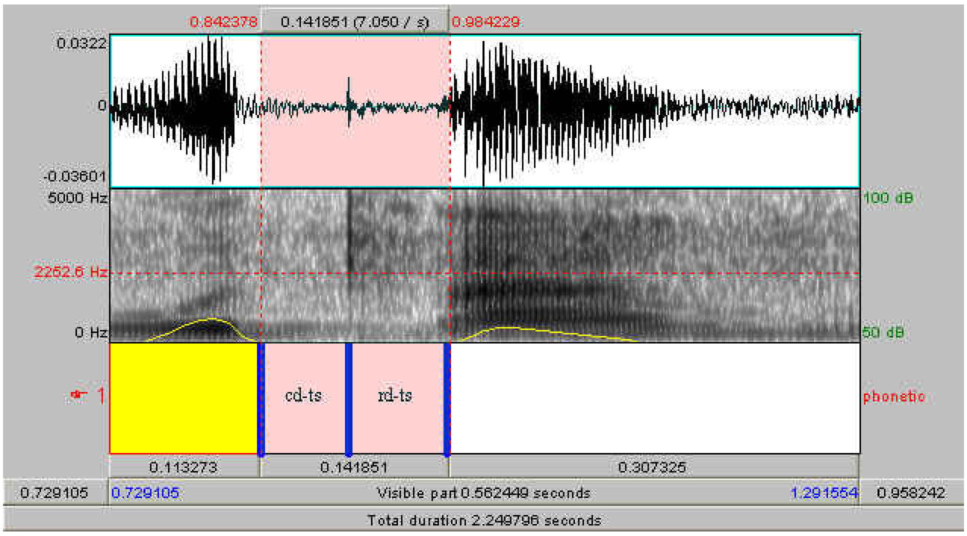
The next section explains how the procedure for distinguishing the closure and release duration is implemented.

3.4.3.3.2. Tagging the Affricate

In order to calculate the duration of affricates, the boundaries between phonemes must be marked. PRAAT was used to annotate the speech signal with tags. The tags store the time instant of the tag and the phonetic context. PRAAT displays three windows. The speech signal or waveform is displayed in the top most window, and the spectrogram directly below. The tags, which isolate the sound segments, are displayed below the spectrogram in the form of vertical lines. The tags were inserted manually. Tagging was done both auditorally by playback method (i.e. listening to the segments), and visually, with the help of the spectrogram and waveform. LPC formant tracks were sometimes superimposed on the spectrogram to assist in the identification of segment boundaries.

Figures 3.1 and 3.2 illustrate the waveform, spectrogram and tags as it is displayed in the PRAAT Objects Window

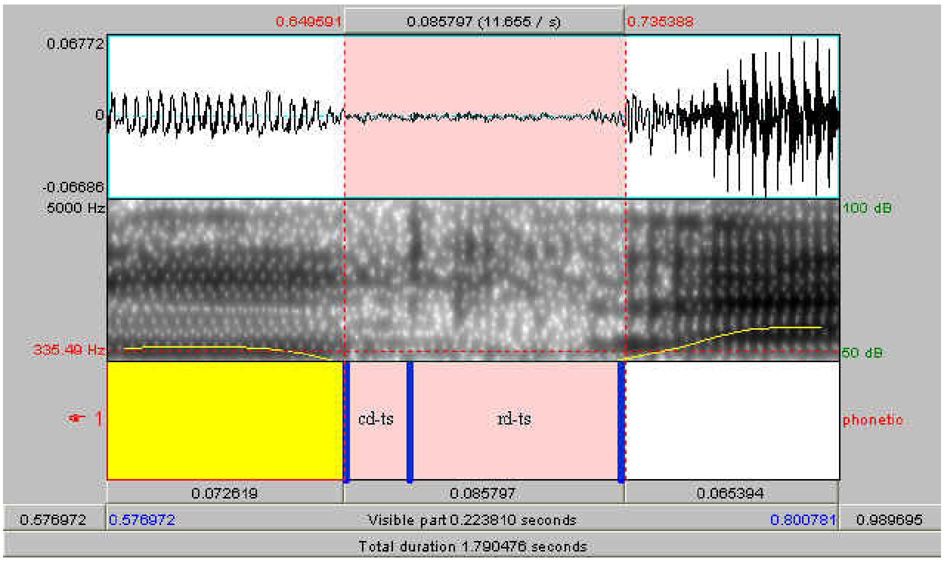
Figure 3.1 /utsa/ in *ukutsavuza* – Speaker Two



For pure affricates tags were inserted in the following contexts:

- Between the vowel and the burst i.e. V_2C_2, to calculate Closure Duration – the area labeled cd-ts on Figure 3.1. This constitutes the stop portion of the affricate.
- Between the burst and the end of the consonant C_2 to calculate Release Duration - the area labeled rd-ts on Figure 3.1. This constitutes the fricative portion of the affricate.
- The total duration of the pure affricate is the sum of the Closure Duration and Release Duration.

Figure 3.2 /ntsa/ in *insalelo* - Speaker Two



For derived affricates tags were inserted in the following contexts:

- Between the nasal and the burst i.e. N_1C_1, to calculate Closure Duration[11] – the area labeled cd-ts on Figure 3.2. This constitutes the stop portion of the affricate.
- Between the burst and the end of the consonant C_1 to calculate Release Duration - the area labeled rd-ts on Figure 3.2. This constitutes the fricative portion of the affricate.
- The total duration of the derived affricate is the sum of the Closure Duration and Release Duration

The experimental studies of Warner & Weber (2001) and Yoo & Blankenship (2003) identify selected areas of difficulty in determining boundaries. Firstly, the identification of voiced affricates poses difficulty as the voicing of consonants is influenced by the following vowel i.e. a voiced consonant is usually auditorally more clear when part of the following vowel is included in its display. In order to standardize the interpretation of affricates the spectrogram is used as the primary indicator of boundaries. Therefore, in this experiment the commencement of the first pulses of the vowel in the spectrogram is identified as the end of the affricate tag, irrespective of whether that affricate was auditorally voiced.

Secondly, the identification of the burst can be problematic. The burst is an important marker as it signifies the commencement of the Release Duration phase i.e. the fricative portion of the affricate. Warner & Weber (2001:61) identify an epenthetic burst, in the equivalent of Zulu derived affricate examples,

> …if there was a broadband burst-like noise visible in the spectrogram either late in the nasal or during the silence between the nasal and the burst of the intended stop.

For the Zulu tokens where the burst was not clearly visible on the spectrogram, the waveform is zoomed into to identify changes, which in turn marks the onset of the burst. Thirdly, although not applicable to the Zulu examples as the nasal is clearly discernable from the spectrogram, Yoo & Blankenship (2003:156) find difficulty in identifying the end of the nasal in many tokens. Therefore they opted to identify "any visible remnant of voicing before the silence" as part of the preceding nasal.

3.4.3.3.3. Calculation of Duration

PRAAT generates a Textgrid, shown in Table 3.2. For each tag that is selected, PRAAT shows the time, in sec, at which that particular sound commences and ends. Xmin and xmax refer to those points respectively.

Table 3.2 PRAAT Textgrid – *ukutsavuza* - Speaker Two

```
File type = "ooTextFile"
Object class = "TextGrid"

xmin = 0
xmax = 2.2497959183673468
tiers? <exists>
size = 1
item []:
    item [1]:
        class = "IntervalTier"
        name = "phonetic"
        xmin = 0
        xmax = 2.2497959183673468
        intervals: size = 4
        intervals [1]:
            xmin = 0
            xmax = 0.8424686370337765
            text = ""
        intervals [2]:
            xmin = 0.8424686370337765
            xmax = 0.90859555046032781
            text = "cd-ts"
        intervals [3]:
            xmin = 0.90859555046032781
            xmax = 0.98174885069673934
            text = "rd-ts"
        intervals [4]:
            xmin = 0.98174885069673934
            xmax = 2.2497959183673468
            text = ""
```

Deducting xmin from xmax gives the actual duration of the sound, or the Closure or Release Duration. The time points are pasted in Excel that automatically performs the calculations.

All raw durations are given in Appendix B.

3.4.4. Results

In this section qualitative and quantitative results are presented. Qualitative results examine the visual display of spectrograms. Quantitative results have been established by statistical application[12]. The latter compare the mean total, closure and release durations of affricates.

3.4.4.1. Qualitative Results

Johnson (1997:126-127) depicts the stages of affricate production in Figure 3.3[13]. Point A simply illustrates the closing of the articulators in anticipation of the stop. Points B and C are the significant stages. B corresponds to the closure phase i.e. the stop portion of the affricate. C corresponds to the release phase i.e. the fricative portion of the affricate.

Figure 3.3 Stages of Affricate Production

A B C

When examining the spectrograms in the following discussion, it would be useful to visualize B and C, particularly the period of silence between points B and C, then the burst that occurs at point C and the frication noise, which follows point C.

3.4.4.1.1. Closure Patterns

Table 3.3 shows the closure patterns for the corpus.

Table 3.3 Closure Patterns

	Speaker One	**Speaker Two**	**Speaker Three**	**Speaker Four**	**Speaker Five**	**Appendix**
tsavuza	✓	✓	✓	✓	✓	**A1**
tsaka	✓	✓	✓	✓	✓	**A2**
insalelo		✓	✓	✓	✓	**A3**
insangano		✓	✓	✓	✓	**A4**
tshuma	✓	✓	✓	✓	✓	**A5**
tshaza	✓	✓	✓	✓	✓	**A6**
intshawula	✓	✓	✓	✓	✓	**A7**
intshumayelo	✓	✓	✓	✓	✓	**A8**
klaza	✓	✓	✓	✓	✓	**A9**
jabula	✓	✓	✓	✓	✓	**A10**
imfanelo		✓	✓	✓	✓	**A11**
imvakazi		✓	✓	✓	✓	**A12**
inzala		✓	✓		✓	**A13**
inhlaba		✓	✓	✓	✓	**A14**
indlozi		✓	✓		✓	**A15**

The symbol ✓ indicates that a complete closure occurs during the Closure Duration phase. On Figure 3.4 the yellow intensity line[14] seems to disappear at the commencement of the cd-ts phase and then rises at the end of the rd-ts phase. This illustrates a complete closure.

Figure 3.4 [ts'] in *ukutsaka* – Speaker One

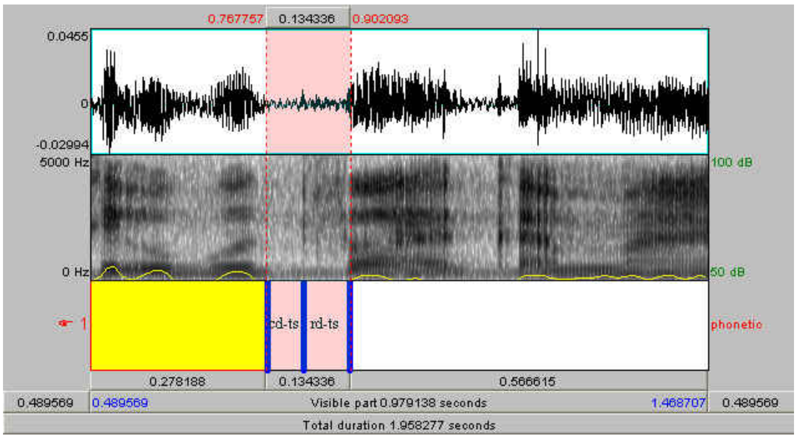


Table 3.4 provides cross-reference for complete closure illustrations on spectrograms in Appendix A.

Table 3.4 Complete Closure References in Appendix A

Appendix	Figure Number
A1	Figures 1-5
A2	Figures 6-10
A3	Figures 12-15
A4	Figures 17-20
A5	Figures 21 & 24
A6	Figures 29 & 30
A7	Figures 31, 32 & 35
A8	Figures 36, 38 & 39
A9	Figure 43
A10	Figures 49 & 50
A11	Figures 52-55
A12	Figures 57, 58 & 60
A13	Figures 62, 63, 65
A14	Figures 67 & 69
A15	Figures 72, 73 & 75

The symbol ✓ indicates that a complete closure occurs during the Closure Duration phase, but there is an opening during the Release Duration phase.
On Figure 3.5 the yellow intensity marking is not visible during the cd-tsh phase, but becomes visible during the rd-tsh phase.

Figure 3.5 [tS] in *ukutshuma* - Speaker Three

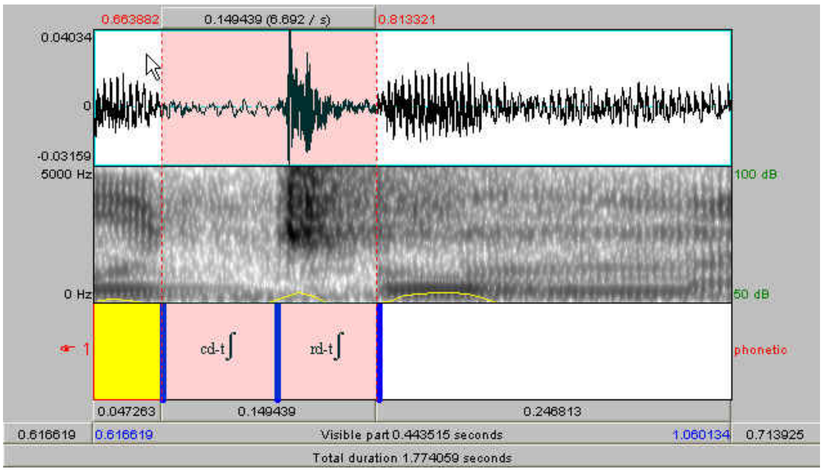


Table 3.5 provides cross-reference for incomplete closure illustrations[15] on spectrograms in Appendix A.

Table 3.5 Incomplete Closure References in Appendix A

Appendix	**Figure Number**
A5	Figures 22, 23 & 25
A6	Figures 26 - 28
A7	Figures 33 & 34
A8	Figures 37 & 40
A9	Figure 41, 42, 44 & 45
A10	Figures 46 - 48
A12	Figure 59
A14	Figure 68 & 70

A blank space on Table 3.3 indicates that closure does not commence at the beginning of the Closure Duration phase i.e. the closure is delayed. The yellow intensity marking on Figure 3.6 illustrates the closure occurring nearly halfway into the Closure Duration-ts phase.

Figure 3.6 [ts’] in *insalelo* - Speaker One

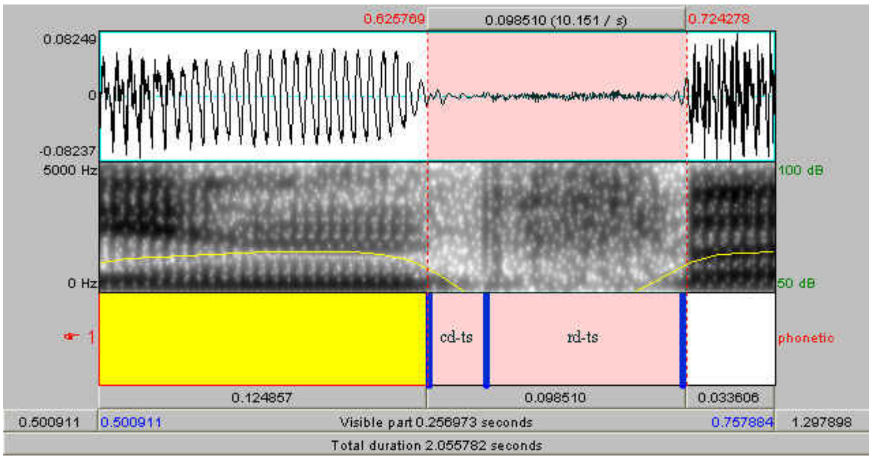


Table 3.6 provides cross-reference for delayed closure illustrations on spectrograms in Appendix A.

Table 3.6 Delayed Closure References in Appendix A

Appendix	**Figure Number**
A3	Figure 11
A4	Figure 16
A11	Figure 51
A12	Figure 56
A13	Figures 61 & 64
A14	Figures 66
A15	Figures 70 & 74

3.4.4.1.2. Burst Patterns

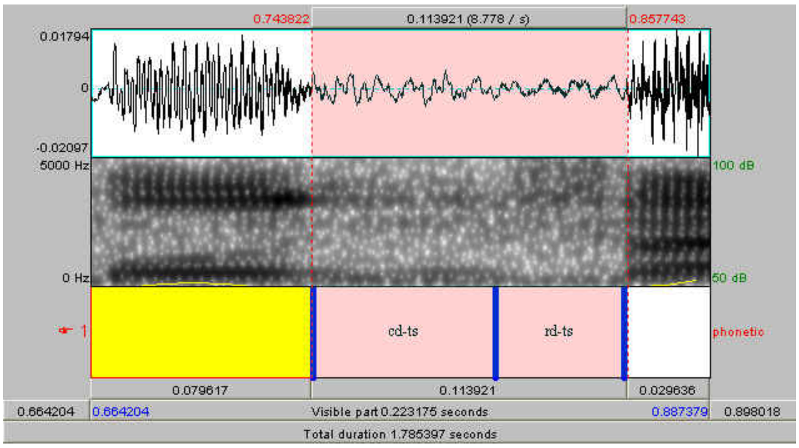
Table 3.7 shows the distribution of the bursts. Where a blank occurs, the burst is either indistinct or non-occurring. The symbol ✓ indicates that a burst is clearly distinguished. The E symbol indicates the occurrence of a double burst that symbolizes an ejective (cf. Figure 3.6 above). According to Johnson (1997:133) ejectives are characterized “by two release bursts: the oral release and the glottal release…”.

Table 3.7 Burst Patterns

	Speaker One	Speaker Two	Speaker Three	Speaker Four	Speaker Five	Appendix
tsavuza		✓	✓ E		✓ E	**A1**
tsaka	✓	✓ E			✓ E	**A2**
insalelo	✓ E	✓ E		✓	✓ E	**A3**
insangano	✓ E	✓ E	✓		✓ E	**A4**
tshuma	✓ E	✓	✓ E	✓	✓	**A5**
tshaza		✓ E	✓	✓	✓	**A6**
intshawula		✓ E	✓	✓	✓	**A7**
intshumayelo	✓		✓	✓	✓	**A8**
klaza	✓ E	✓ E	✓ E	✓	✓	**A9**
jabula		✓	✓	✓		**A10**
imfanelo	✓	✓ E	✓ E			**A11**
imvakazi			✓	✓		**A12**
inzala		✓				**A13**
inhlaba	✓ E	✓	✓ E	✓ E	✓	**A14**
indlozi	✓	✓	✓	✓	✓	**A15**

Figures 3.7 and 3.8 illustrate an indistinct and non-occurring burst, respectively.

Figure 3.7 [ts'] in *ukutsaka* - Speaker Three



In Figure 3.7 above, a burst is not visible. In Figure 3.8 below, it may be inferred that a burst occurred – fricative noise is distinguishable from the spectrogram but the burst is not as clear as in Figure 3.9.

Figure 3.8 [dZ][16] in *ukujabula* - Speaker Five

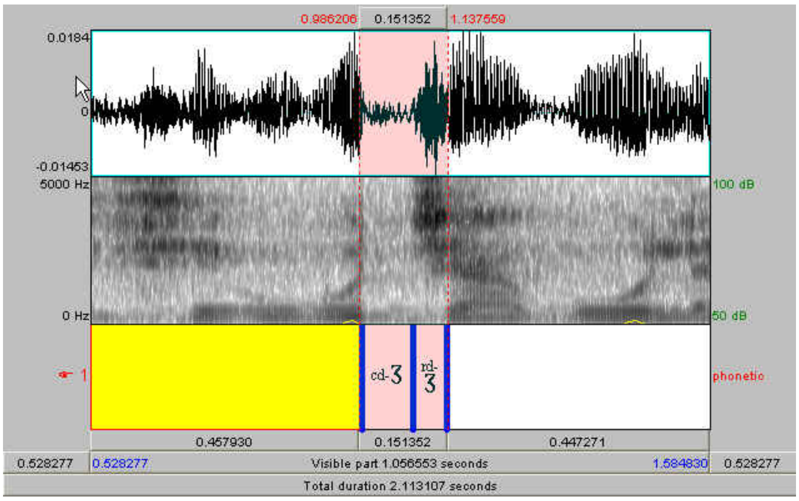


Figure 3.9, below, illustrates a single burst.

Figure 3.9 [dZ] in *ukujabula* - Speaker Two

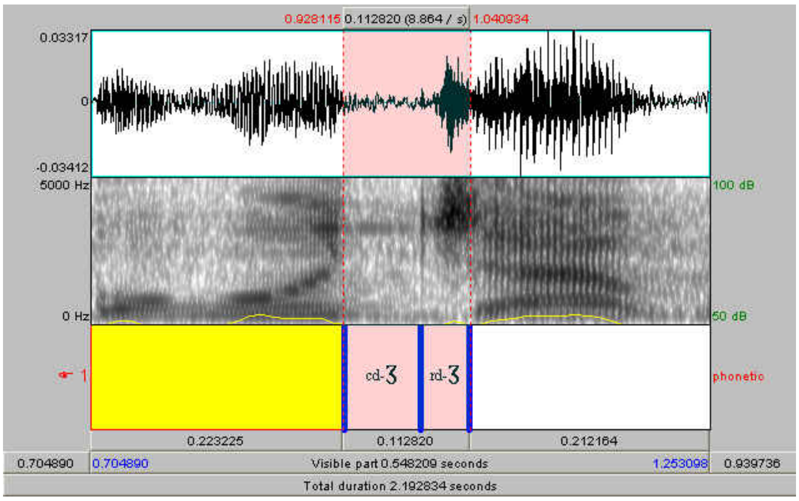


Table 3.8 provides cross-reference for indistinct, single and double burst illustrations on spectrograms in Appendix A.

Table 3.8 Indistinct, Single and Double Burst References in Appendix A

Appendix	Indistinct Bursts	Single Bursts	Double Bursts
A1	Figures 1 & 4	Figure 2	Figures 3 & 5
A2	Figures 8-9	Figure 6	Figures 7 & 10
A3	Figure 13	Figure 14	Figures 11, 12 & 15
A4	Figure 19	Figure 18	Figures 16-17 & 20
A5		Figures 22, 24 & 25	Figures 21 & 23
A6	Figure 26	Figures 28, 29 & 30	Figures 27
A7	Figure 31	Figures 33 - 35	Figure 32
A8	Figure 37	Figure 36 & 38-40	
A9		Figures 44-45	Figures 41-43
A10	Figures 46 & 50	Figures 47-49	
A11	Figures 54-55	Figure 51	Figures 52 & 53
A12	Figures 56, 57 & 60	Figures 58-59	
A13	Figures 61, 63-65	Figure 62	
A14		Figures 67 & 70	Figures 66, 68 & 69
A15		Figures 71-75	

3.4.4.1.3. Frication Noise Patterns

The fricative portion of the affricate is characterized by fricative noise on the spectrogram i.e. a dark grey or black patch. Table 3.9 shows the pattern of frication noise on the spectrograms.

Table 3.9 Frication Noise Patterns

	Speaker One	Speaker Two	Speaker Three	Speaker Four	Speaker Five	Appendix
tsavuza		✓	✓	✓	✓	**A1**
tsaka	✓	✓	✓	✓	✓	**A2**
insalelo	✓	✓		✓	✓	**A3**
insangano	✓	✓	✓	✓	✓	**A4**
tshuma	✓	✓	✓	✓	✓	**A5**
tshaza	✓	✓	✓	✓	✓	**A6**
intshawula	✓	✓	✓	✓	✓	**A7**
intshumayelo	✓	✓	✓	✓	✓	**A8**
klaza	✓	✓	✓	✓	✓	**A9**
jabula	✓	✓	✓	✓	✓	**A10**
imfanelo	✓	✓	✓	✓	✓	**A11**
imvakazi			✓	✓	✓	**A12**
inzala	✓	✓		✓	✓	**A13**
inhlaba	✓	✓	✓	✓	✓	**A14**
indlozi	✓	✓	✓	✓	✓	**A15**

Figures 3.5 and 3.8 clearly illustrate frication noise during the Release Duration phase. This is less clear in Figure 3.7. However, if one zooms in on the speech signal, high frequency activity is evident.
Table 3.10 provides cross-reference for frication noise illustrations on spectrograms in Appendix A.

Table 3.10 Frication Noise References in Appendix A

Appendix	Frication Noise
A1	Figures 2-5
A2	Figures 6-10
A3	Figures 11-12, 14-15
A4	Figures 16-20
A5	Figures 21-25
A6	Figures 26-30
A7	Figures 30-35
A8	Figures 36-40
A9	Figures 41-45
A10	Figures 46 - 50
A11	Figures 51-55
A12	Figures 58-60
A13	Figures 60-61 & 63-65
A14	Figures 66-70
A15	Figures 71-75

The next section examines the quantitative results.

3.4.4.2. Quantitative Results

Using the textgrids, duration values were calculated for all affricates i.e. Total Duration, Closure Duration and Release Duration. A statistical analysis was conducted on these values. It was not possible to use the full factorial model as all factors were not considered i.e. since there are two types of affricates (pure and derived), fifteen words and nine sounds in the experiment, there are 2X15X9 = 270 ways in which these levels of factors can combine. But as only fifteen possibilities of these factors were observed, all the levels of the factors were not combined[17]. In preparing the data for analysis the following groupings were delineated:

- Pure and derived affricates /ts'/ and /tS'/
- Pure affricates /kl', dZ/ and the derived affricates /þf', {v, dz, tñ', dL/

The reason for the delineation is as follows. The /ts'/ and /tS'/ sounds appear under both pure and derived affricates. Therefore these sounds are crossed. /kl'/ and
/dZ/ appear under pure affricates only. /þf', {v, dz, tñ', dL/ appear under derived affricates only. The latter two sets of sounds are therefore described as nested. Furthermore, the effects of these sounds /kl', dZ, þf', {v, dz, tñ', dL/ are confounded i.e. only one word under each sound (as opposed to the two words per sound for each of the pure and derived affricates /ts'/ and /tS'/).

The effects of the Total Duration, Closure Duration and Release Duration of the affricates are quantified in the following presentation. The F-statistics and p-values are shown. The F-statistic is used to perform tests for equality of means under the assumption of sampling from a normal population. Such a statistic (a value that is calculated from the data according to a formula) can be applied when testing in various situations e.g. mean duration of pure versus derived affricates, mean duration of /ts'/ versus /tS'/ sounds, mean duration of /ts'/ versus /tS'/ sounds within affricates etcetera. A value of the F-statistic of around 1 or less than 1 implies that the means that are being tested do not differ significantly. A value of the F-statistic that is substantially larger than 1 (special tables are used to determine what value of the statistic will constitute "substantially larger than 1") indicates that the means differ significantly. The p-value is the chance of getting a value more extreme (greater than) than the F-statistic. The greater the F-statistic, the smaller the p-value. A sufficiently large F-statistic (small p-value) indicates a significant result (means not the same, one mean greater than the other one). A p-value less than 0.05 (in some cases less than 0.01) usually indicates a significant result. The further it is above 0.05, the less significant the result. The further it is below 0.05, the more significant the result i.e. the result is less likely to be attributable to chance factors.

The following presentation tabulates the statistical results of the crossed affricates, /ts'/ and /tS'/, under the grouping Total duration, Closure Duration and Release Duration.

* Indicates significance at the 5% level of significance.

** Indicates significance at the 1% level of significance.

3.4.4.2.1. Crossed Affricates

Table 3.11 shows the mean duration of the pure and derived affricates. Also, the mean duration of the sounds /ts'/ and /tS'/ is shown.

Table 3.11 Comparison of Total Duration Mean: Main Effects

Factor	Level	Total Duration Mean
Affricates	pure	0.13832640
	derived	0.08482918
Sounds	/ts'/	0.11049113
	/tS'/	0.11266445

Table 3.11 indicates that the pure affricates have a higher Total Duration Mean than the derived affricates. With Total Duration Mean values of 0.110sec and 0.112sec, the sounds /ts'/ and /tS'/ exhibit similarity.

Table 3.12 provides the F-statistics and p-values for the total duration parameter.

Table 3.12 F–statistics and p-values

Factor	
affricates	F = 84.10** with p-value < 0.0001
sounds	F = 0.14 with p-value = 0.7119

Table 3.12 indicates that with a p-value < 0.05, there is a significant result in the Total Duration Mean of pure and derived affricates. However, with a p-value = 0.7119, the sounds /ts'/ and /tS'/ do not display a significant result.

Table 3.13 examines the duration of the sounds /ts'/ and /tS'/ as they obtain separately in pure and derived affricates. In Table 3.11 the duration of these sounds were jointly assessed.

Table 3.13 Comparison of Total Duration Mean: Sounds Interaction

Factor	Level	/ts'/	/tS'/
affricates	pure	0.13610190	0.1405509
	derived	0.08488037	0.0847780

F = 0.15 with a p-value = 0.6991.

Table 3.13 confirms that the pure affricates have a longer Total Duration Mean than the derived affricates. Also while the derived affricates /ts'/ and /tS'/ have a similar Total Duration Mean of 0.084sec, the pure affricates differ slightly. The pure affricate /tS'/ is longer with a duration of 0.140sec as opposed to 0.136sec for /ts'/. With a p-value = 0.6991, there is no significant result in the Total Duration Mean of the pure and derived affricates /ts'/ and /tS'/.

Table 3.14 provides the mean durations for each sound. These durations are obtained from the five speakers' pronunciations of each word.

Table 3.14 Comparison of Total Duration Mean: Words Within

Factor	Level	Sound	Word	Total Duration Mean
affricates	Pure	/ts'/	*ukutsavuza*	0.13491060
			ukutsaka	0.13729320
		/tS'/	*ukutshaza*	0.12431560
			ukutshuma	0.15678620
	derived	/ts'/	*insalelo*	0.08329353
			insangano	0.08646720
		/tS'/	*intshumayelo*	0.08696700
			intshawula	0.08258900

F = 2.00 with a p-value = 0.1182

Table 3.14 indicates that the words containing the pure affricate /ts'/ differs with respect to Total Duration Mean by 0.004sec. However, a longer difference in Total Duration Mean obtains for the pure affricate /tS'/. The word *ukutshuma* has a Total Duration Mean of 0.156sec as opposed to *ukutshaza* with 0.124sec. Thus a difference of 0.032sec obtains between the /tS'/ sound in these words.
Words containing the derived affricate /ts'/ differ in their Total Duration Mean by 0.003sec. A difference of 0.004sec obtains for words containing the derived affricate /tS'/. All the derived affricates therefore appear to share a close Total Duration Mean.
With a p-value = 0.1182, there is no significant result in the Total Duration Mean of the affricates within words.

The following tables present results of the Closure Duration and Release Duration values.

Table 3.15 Comparison of Closure Duration & Release Duration Mean: Main Effects

Factor	Level	Closure Duration Mean	Release Duration Mean
affricates	Pure	0.06014680	0.07817960
	derived	0.02331998	0.06150920
sounds	1	0.03973198	0.07075915
	2	0.04373480	0.06892965

Table 3.15 indicates that the pure affricates have a longer Closure Duration Mean (0.060sec) compared to the derived affricates (0.023sec). Similarly, the Release Duration Mean of the two groups differs.

The affricate /tS'/ has a Closure Duration Mean of 0.043sec, while that of affricate /ts'/ is 0.039sec. The Release Duration Mean of the latter is 0.070sec, while that of /tS'/ is 0.068sec.

Table 3.16 shows the F-statistics and p-values.

Table 3.16 F–statistics and p-values

Factor	Closure	Release
Affricates	F = 99.31** with p-value < 0.0001	F = 6.00* with p-value = 0.0199
Sounds	F = 1.17 with p-value = 0.2868	F = 0.07 with p-value = 0.7897

With a p-value < 0.05, the Closure Duration Mean has a significant result.

In Table 3.15 the duration of the sounds were jointly assessed. Tables 3.17 and 3.18 depict the values for the Closure Duration and Release Duration of the sounds /ts'/ and /tS'/ as they obtain separately in pure and derived affricates. F-statistics and p-values are given below each table.

Table 3.17 Comparison of Closure Duration Mean: Sounds Interaction

		/ts'/	/tS'/
affricates	pure	0.05705320	0.0632404
	derived	0.02241077	0.0242292

F = 0.35 with a p-value = 0.5586.

Table 3.17 indicates that when comparing the Closure Duration Mean, the pure affricate /ts'/ has a longer duration than its derived counterpart i.e. 0.057 sec and 0.022 sec respectively. Similarly, the pure affricate /tS'/ has a duration of 0.063sec as opposed to that of the derived affricate, 0.024sec. While the Closure Duration

Mean of the derived affricates is similar – 0.022sec and 0.024sec, that of the pure affricates differs somewhat with values of 0.057sec and 0.063sec.
With a p-value > 0.05 the result of the Closure Duration Mean is not significant.

Table 3.18 indicates that the pure affricates have a slightly longer Release Duration Mean compared to the derived affricates. However, within each group the Release Duration Mean is similar. With a p-value = 0.9894 the Release Duration Mean result is not significant.

Table 3.18 Comparison of Release Duration Mean: Sounds Interaction

		/ts'/	**/tS'/**
affricates	pure	0.0790487	0.0773105
	derived	0.0624696	0.0605488

F = 0.00 with a p-value = 0.9894.

Table 3.19 provides the Closure Duration and Release Duration Means for each sound. These durations are obtained from the five speakers' pronunciations of each word.

Table 3.19 Comparison of Closure Duration and Release Duration Mean: Words Within

Factor	**Level**	**Sound**	**Word**	**Closure**	**Release**
affricates	pure	/ts'/	*ukutsavuza*	0.0577836	0.0771270
			ukutsaka	0.0563228	0.0809704
		/tS'/	*ukutshaza*	0.0571950	0.0671206
			ukutshuma	0.0692858	0.0875004
	derived	/ts'/	*insalelo*	0.02210973	0.0611838
			insangano	0.0227118	0.0637554
		/tS'/	*intshumayelo*	0.0222434	0.0647236
			intshawula	0.0262150	0.0563740

Table 3.19 indicates that the pure affricate /ts'/ has a longer Closure Duration Mean than the derived affricate /ts'/. Whereas the former has durations of 0.057sec and 0.056 sec in the words *ukutsavuza* and *ukutsaka* respectively, the derived affricate /ts'/ has durations of 0.022sec in the words *insalelo* and *insangano.* Differences also obtain for the Release Duration Mean of these words. /ts'/ in *ukutsavuza* and *ukutsaka* has values of 0.077sec and 0.080 sec respectively. /ts'/ in *insalelo* and *insangano* has values of 0.061sec and 0.063 sec respectively.

The pure affricate /tS'/ has a longer Closure Duration Mean than the derived affricate /tS'/. Whereas the former has durations of 0.057sec and 0.069 sec in the words *ukutshaza* and *ukutshuma* respectively, the derived affricate /tS'/ has durations of 0.022sec and 0.026sec in the words *intshumayelo* and *intshawula* respectively. Differences also obtain for the Release Duration Mean of these words. /tS'/ in *ukutshaza* and *ukutshuma* has values of 0.067sec and 0.087 sec respectively. /tS'/ in *intshumayelo* and *intshawula* has values of 0.064sec and 0.056 sec respectively.

A noticeable difference occurs in the Closure Duration Mean and Release Duration Mean within the pure affricates. In the word *ukutshaza* the Closure Duration Mean is 0.057sec, whereas in the word *ukutshuma* it is 0.069sec. Similarly the Release Duration Mean in these words is 0.067sec and 0.087sec respectively.

With the exception of the word *intshawula,* all the derived affricates have a Closure Duration Mean of 0.022sec. The Release Duration Mean in *intshawula* is also shorter (0.056sec) than the other derived affricates.

Table 3.20 shows the significance of these durations.

Table 3.20 F–statistics and p-values for Closure Duration and Release Duration: Words Within

Closure	**Release**
F = 0.75 with p-value = 0.5636	F = 0.68 with p-value = 0.6083

With a p-value >0.05, both the Closure Duration Mean and Release Duration Mean results are not significant.

The next section presents the statistical results of the nested affricates.

3.4.4.2.2. Nested Affricates

Table 3.21 shows the Total Duration Mean of the pure and derived affricates.

Table 3.21 Comparison of Total Duration Mean: Main Effects – Nested Affricates

Factor	Level	Total Duration Mean
affricates	pure	0.12285320
	derived	0.07959244

Table 3.21 indicates that the pure affricates /kl', dZ/ have a noticeably longer Total Duration Mean as opposed to the derived affricates /þf', {v, dz, tñ', dL/.
Table 3.22 provides the F-statistics and p-values.

Table 3.22 F–statistics and p-values

Factor	
affricates	F = 44.01** with p-value<0.0001

With a p-value < 0.05, the result for the Total Duration Mean is significant.

Table 3.23 provides the Total Duration Mean for each nested sound. These durations are obtained from the five speakers' pronunciations of each word. The figures below indicate the significance of these values.

Table 3.23 Comparison of Total Duration Mean: Sounds within Nested Affricates

Factor	**Level**	**Sounds**	**Total Duration Mean**
affricates	pure	/kl'/	0.1319960
		/dZ/	0.1137104
	derived	/þf'/	0.0832794
		/{v/	0.0537112
		/dz/	0.0704718
		/tñ'/	0.1053956
		/dL/	0.0851042

F = 5.37** with a p-value = 0.0014

Table 3.23 indicates that there is variation in the Total Duration Mean of the pure and derived affricates. The Total Duration Mean of /kl'/ is longer than that of /dZ/ - 0.131sec as opposed to 0.113sec., respectively.
Among the derived affricates /{v/ has the smallest Total Duration Mean of 0.053sec. /dz/ has a value of 0.070sec. /þf'/ and /dL/ share similar Total Duration

Mean values of 0.083sec and 0.085sec, respectively. /tñ'/, with a duration of 0.105sec, has the longest Total Duration Mean.
With a p-value < 0.05 a significant result obtains with regard to the Total Duration Mean of the nested affricates.

Table 3.24 depicts the values for the Closure Duration and Release Duration Means for the nested sounds as they obtain in pure and derived affricates.

Table 3.24 Comparison of Closure Duration & Release Duration Mean – Nested Affricates: Main Effects

Factor	Level	Closure Duration Mean	Release Duration Mean
affricates	pure	0.06241650	0.06436700
	derived	0.02715352	0.05243892

Table 3.24 indicates that the derived affricates have a shorter Closure Duration Mean (0.027sec) compared to the pure affricates (0.062sec). A less substantial difference obtains with the Release Duration Mean. The derived affricates have a value of 0.052sec and the pure affricates 0.064sec.
The Closure Duration Mean and Release Duration Mean of pure affricates are similar with respective values of 0.062sec and 0.064sec. However, the derived affricates have a longer Release Duration Mean of 0.052sec as opposed to the Closure Duration Mean of 0.027sec.
Table 3.25 shows the F-statistics and p-values.

Table 3.25 F–statistics and p-values

Closure	Release
F = 25.64** with p-value < 0.0001	F = 1.06 with p-value = 0.3115

With a p-value <0.05, the Closure Duration Mean has a significant result.

Table 3.26 provides the mean Closure and Release durations for each nested sound. These durations are obtained from the five speakers' pronunciations of each word.

Table 3.26 Comparison of Closure Duration & Release Duration Mean: Sounds within Nested Affricates

Factor	Level	Sounds	Closure	Release
affricates	pure	/kl'/	0.071995	0.0600010
		/dZ/	0.052838	0.0608724

	derived	/þf'/	0.0382384	0.0450410
		/{v/	0.0228124	0.0308988
		/dz/	0.0240486	0.0464232
		/tñ'/	0.0338110	0.0715846
		/dL/	0.0168572	0.0682470

The Closure Duration Mean of /kl'/ is longer than that of /dZ/. Among the derived affricates, /dL/ has the shortest Closure Duration Mean of 0.016sec. /{v/ has a value of 0.022sec, /dz/ 0.024sec. /tñ'/ and /þf'/ have the higher Closure Duration Mean of 0.033sec and 0.038sec, respectively.

The pure affricates, /kl'/ and /dZ/, have a similar Release Duration Mean. Among the derived affricates /{v/ has the shortest Release Duration Mean of 0.030sec, followed by /þf'/ and /dz/ with respective values of 0.045sec and 0.046sec. /dL/ has a value of 0.068sec and /tñ'/ has the highest Release Duration Mean of 0.071sec. Table 3.27 shows the significance of these durations.

Table 3.27 F–statistics and p-values

Closure	**Release**
F = 1.40 with p-value = 0.2544	F = 2.72* with p-value = 0.0.0397

With p-values >0.05, the Closure Duration Mean and Release Duration Mean of the nested affricates do not produce a significant result.

In the next section the qualitative and quantitative results are discussed.

3.4.5. Discussion

The results of this experimental investigation require comment on the visual depiction from the spectrograms and statistical output. This is done in 3.4.5.1 and 3.4.5.2, respectively.

3.4.5.1. Qualitative Output

The speech signal and more especially the spectrogram have been the key to establishing the affricate status of the sounds [kl', dZ, tS', ts'] and [þf', {v, ts', dz, tS', tñ', dL]. The visual displays of the burst and frication noise on the spectrogram have been vital markers. The following discussion concentrates on these two markers.

The burst is the first vital marker on the spectrogram. It signals the end of the stop portion of the affricate. Johnson (1997:131) describes the burst as compulsory and states that the "…stop release burst is not optional, and is unique to stop releases…" Fifty-five of the seventy-five spectrograms depict a clear burst (cf. Tables 3.7 & 3.8). There are times when the burst is not as apparent, although small perturbations may be visible. Warner & Weber (2001) in a discussion on perception identify these as the "burstless epenthetic stop". Table 3.7 identifies 20 spectrograms that exhibit indistinct bursts. However, the audio of these pronunciations confirms that these sounds are perceived as epenthetic stops. Further investigation and a wider sample is required to determine the extent to which the "burstless epenthetic stop" obtains in Zulu.

The burst is also significant in establishing whether voiceless affricates are ejected. This was one of the aims of this investigation (cf. 1.3 & 3.4.1). Of the fifty-five possible ejective sounds (11 voiceless sounds X 5 speakers), the double burst occurs in twenty-two spectrograms (cf. Tables 3.7 & 3.8).

Two significant observations are noted. Firstly, the affricate /kl'/ (cf. Appendix A9) does not display the ejective burst as clearly as other voiceless affricates. In fact, there is appears to be more of a single burst, which is characteristic of voiced affricates. But, this may be attributed to the fact that /kl'/, having a velar place of articulation, experiences the glottal and velar release in very rapid succession, resulting in the appearance of a single burst pattern on the spectrogram. Secondly, the pure and derived affricate /tS'/ does not exhibit the double burst clearly. Only four of a possible twenty examples show the ejective burst. However, no evidence could be found to dispute the ejective status of /tS'/ - cf. inter alia Maddieson (1984:226), Laver (1994:369). A wider sample is needed to further examine the status of /tS'/.

The second vital marker of affricates is the presence of increased energy levels depicting the fricative portion of the affricate (cf. Figures 3.5, 3.6, 3.8 & 3.9). All but four of the spectrograms depict this clearly (cf. Tables 3.9 & 3.10).

While considerable uniformity prevails among the spectrograms, there are a few interesting instances of non-conformity. Speaker One appears to have a particular idiosyncratic spectrogram. Table 3.28 identifies the examples where either the closure is delayed or the release is premature:

Table 3.28 Speaker One – Highlights of Irregularities in Spectrograms

Word	**Appendix**	**Closure**	**Release**
insalelo	A3	Figure 11	
insangano	A4	Figure 16	
imfanelo	A11	Figure 51	
imvakazi	A12		Figure 56
inzala	A13	Figure 61	
inhlaba	A14	Figure 66	Figure 66
indlozi	A15	Figure 71	Figure 71

Speaker Four appears to have a particular idiosyncratic pattern, exhibiting only one of a possible eleven ejectives (cf. Figures Twenty Nine (A6) & Sixty Nine (A14)).

The qualitative output has determined the following:

- Pure and derived affricates in Zulu exhibit the characteristics of affricates
- Voiceless affricates are ejected, however
- The ejective status of /tS'/ is inconclusive.

3.4.5.2. Quantitative Output

The fundamental aim of the quantitative analysis was to determine the duration of the two types of affricates. This entailed focusing on the total duration, closure duration and release duration.

From the statistical results obtained the following observations[18] can be made on this corpus of data:

1. The total duration mean for pure affricates is significantly greater than that for derived affricates for all the sounds used in the experiment – cf. Tables 3.11, 3.12, 3.21 & 3.22
2. The mean closure duration for pure affricates is significantly greater than that for derived affricates for all the sounds used in the experiment – cf. Tables 3.15, 3.16, 3.24 & 3.25
3. The mean release durations for sounds /tñ'/ and /dL/ are significantly greater than that for sound /{v/ within the derived affricate – cf. Table 3.26
4. The total duration means for sounds /þf', tñ' and dL/ are significantly greater than that for sound /{v/ within the derived affricate – cf. Table 3.23
5. There is some evidence (p-value = 0.1182) that the total duration mean for /tS'/ in the word *ukutshuma* is greater than that of *ukutshaza* – cf. Table 3.14.

In 3.3 and endnote 4 it is explained that the investigation into Zulu affricates differs from that done for English intrusive stops as homonyms do not obtain in Zulu. Nevertheless the results and observations in this experiment correspond to that reported in Clements (1987); Warner & Weber (2001); Warner (2002) and Yoo & Blankenship (2003). The most recent study by Yoo & Blankenship (2003) found that the underlying /t/ is longer than the epenthetic /t/. Observation 1 confirms that the underlying or pure affricate is longer in duration than the derived affricate.

Yoo & Blankenship (ibid.) also found that the Closure Duration of the underlying /t/ is longer than the epenthetic /t/. Observation 2 confirms this and by implication the underlying stop in Zulu is of longer duration than the intrusive stop.

Release Duration has not been reported on in the experiments cited in this study. But, observation 3 indicates a lack of consistency in the Release Duration of affricates.

Observation 4 indicates that within derived affricates there may be variation in total duration. The expectation would be that both /þf'/ and /{v/ would have a similar duration as the IPA uses the symbols þ and { – which are not actual sounds – to identify these derived affricate forms. However, the analysis indicates that /{v/ is of shorter duration. In the data, the words *imfanelo* and *imvakazi* are used to record the sounds /þf'/ and /{v/. The words have the same number of syllables and the sounds are followed by the low vowel /a/. Therefore there are no obvious discrepancies in the words. But the results are quite different. To reach a conclusive decision one would need to test a wider sample.

Observation 5 is a surprise. One would expect differences in the duration of the pure and derived forms of /tS'/, rather than within the pure affricates (cf. Table 3.14). The words *ukutshuma* and *ukutshaza*, in which these sounds were recorded, have differing vowels following the sounds and this may be impacting on the durational differences. However, research indicates that it is not so much the vowel as opposed to specific factors that influence the duration of sounds. Umeda (1977:847) identifies the following factors:

- The position of the consonant in the word
- Its relation to lexical stress and morpheme boundary (if any) within the word
- Whether it is in the postpausal position
- Whether it is in the prepausal position
- Content-function difference of the word
- Effect of adjacent consonants both inside the word and across the word boundary

Klatt (1976) and Zue & Laferriere (1979) present similar findings. Again, a wider sample is necessary to arrive at a conclusive decision.

Another point relating to the sound /tS/ is that unlike the other derived forms, the derived /tS/ has the intrusive sound included in the lexicon. For example:

iN + shumayel + o → intshumayelo [i´tS'umajElO] "sermon"

In English, when an intrusive stop is incorporated into the lexicon, diachronic epenthesis is said to obtain. Barnitz (1974:3) cites the following examples of diachronic epenthesis:

Old English	spinel	→ Modern English	spindle
Latin	humilem	→ English	humble

Ohala (1981:205), describing the same phenomenon, refers to such stops as “fossils” as they are “independent” and “lexically specified”. He cites the example following example:

Thom + son → Thompson

In Zulu, it is only the stop /t/ in combination with the fricative /S/ that is fossilized. From the examples cited for English, it is evident that more stops /p, b, d/, may be classified as fossils. Research into diachronic epenthesis in English has been more descriptive than experimental. Ohala’s (1981) investigation in which the duration of the vowel nasal sequence preceding the epenthetic stop was measured did not yield any conclusive results. So, opportunity for further investigation exists.

In this study, the raw durations of the derived /tS/ is undoubtedly of shorter duration (cf. Appendix B – Group 2). But, given the limited corpus, it would be premature to make any final conclusions based on these observations.

3.5. Summary

Chapter Three has dealt with the experimental component of this study. Using a speech analysis program, PRAAT, the duration of pure and derived affricates in Zulu was calculated. A statistical analysis was conducted to determine the significance of the durational differences. While further investigation and a wider corpus is necessary to make conclusive judgments on some observations – durational differences among words containing the pure affricate /tS’/; the derived affricate /{v/ being of shorter duration than its counterparts – the statistical analysis has determined that **significant durational differences obtain between pure affricates and derived affricates in Zulu.** This corroborates the conclusions made for English affricates by Clements (1987); Warner & Weber (2001); Warner (2002) and Yoo & Blankenship (2003).

The result of the experiment in this chapter adds to arsenal of those linguists who identify Duration as a significant parameter in the study of sounds (cf. 3.3). The challenge is now implementing the raw data into phonological description. Cohn (1998:32), inter alia, observes:

> There is a range of information necessary for phonetic implementation which phonology doesn't make use of. This includes raw duration, details of temporal organization, specific phonetic mechanisms to realize a goal or outcome.

Cohn goes on to argue that despite evidence – timing, duration and bite block experiments – such detail is not incorporated into phonological description.

Flemming (2001:8-9) reiterates Cohn's observation, stating that phonological representations say nothing of the "precise duration" of segments or the "nature of the movement from one segment to the next". He suggests that phonological representation must be enriched by including language-specific phonetic detail. And, a unified framework is proposed as the means to account for phonetic and phonological phenomena.

Chapter Four, in which the parameter Duration is incorporated into a feature geometry description of Intrusive Stop Formation, takes up the challenge of integrating phonological description with the language-specific experimental results obtained in this chapter.

NOTES

1. Lieberman (1976:92) notes that phonological descriptions were sometimes incorrect. He challenges the use of the parameters of position and height in the description of vowel sounds, based on the phonetic evidence from the radiographic studies made by Russell (1928). Cineradiographic studies of Stevens & House (1955) and Perkell (1969) also support the conclusions of Russell (1928). Yet, their phonetic conclusions have not been incorporated into phonology.
2. Experimental psychology is not dealt with in this dissertation.
3. The phonetic descriptions of Intrusive Stop Formation and affricates have an articulatory bias. For a detailed description of the acoustic characteristics of affricates cf. Stevens (2000:416-422). Inaccessibility to the necessary equipment to verify the acoustic characteristics of Zulu affricates has meant that this study is unable to comment all aspects of the acoustic dimension. Moreover, if one is to concentrate comprehensively on the articulatory-acoustic relationship, then one is gravitating towards Quantal Theory – cf. Stevens (1989, 1997). Quantal Theory integrates acoustic, articulatory and perceptual aspects. Given the narrow aims of this study, discussion on Quantal Theory is not pursued.
4. The experimental investigation in this study does not compare intrusive versus underlying stops. Rather, the entire affricate is compared. This is because the focus of the investigation is on the affricate per se as opposed to the stops. Moreover, the purpose of the experimental investigation is to enhance the phonological description of the Intrusive Stop Formation process, therefore the emphasis on the affricate.
5. [ts'] and [tS'] are separated from the rest of the affricates as these sounds are crossed i.e. they occur as pure and derived affricates. The same does not apply to the other affricate sounds.
6. Female subjects were readily available. Also, it was decided to maintain consistency in the subjects so as to standardize the results.
7. The frame sentences chosen are the infinitive form for pure affricates and the lexical form for derived affricates. The former are chosen because pure affricates occur as verbs. Derived affricates occur as nouns, therefore using a lexical frame sentence is appropriate.

8. RUEPUS is now known as Stellenbosch University – Centre for Language and Speech Technology (SU-CLaST).
9. As only duration was measured, it was deemed acceptable to use this sampling rate. If amplitude and pitch were also being measured, then it would have necessitated a higher sampling rate. Using the sampling rate of 11kHz, as opposed to 20kHz, also meant that the file size was smaller.
10. These closure and release phases correspond to Closure Duration and Voice Onset Time, respectively in some literature. Kent & Read (1992:106) explain Closure Duration as the interval between the previous vowel and the point of release of the oral closure. Kockaert & Godwin (1996:1) and Lieberman & Blumstein (1998:215) respectively explain Voice Onset Time as the time between the release of the closure (burst) and the onset of "regular laryngeal pulsation for the following vowel" or "the onset of glottal excitation".
11. For the equivalent of the Zulu derived affricate, Warner & Weber (2001:73) identify Closure Duration as the period of "silence from the cessation of voicing for the nasal to the onset of the epenthetic burst".
12. The assistance of Dr Henry Moolman, from the Department of Mathematics and Statistical Sciences at the University of KwaZulu-Natal, in conducting the statistical analysis is acknowledged. However, the writer assumes responsibility for any errors in interpretation.
13. Figure 3.3 assumes that the affricate is in an intervocalic position or is preceded by a continuant – therefore the closing of the articulators. In the environment of a preceding nasal the articulators would already be in a closed position.
14. The fall of the intensity line indicates that a 0dB measurement occurs i.e. a complete closure takes place.
15. The possibility that a low frequency noise, probably due to the recording device, contributes to the incomplete closures should not be discounted.
16. The sound [dZ] appears as [Z] on the spectrograms.
17. As the statistical investigation is a secondary component it was not necessary to use more examples.
18. The following total duration means are not significantly different:

- For sounds /ts'/ and /tS'/

The following means are not significantly different:

- For sounds /ts'/ and /tS'/ for both closure and release duration
- Between affricates for sounds /{v, φf', ts', dz, tñ', dL, tS'/ for the release duration
- For sounds within affricates for closure duration.

Chapter Four
Integrating Phonetics and Phonology

The use of models in phonology will not give a global explanation of a system, but will rather help to formulate a particular problem, discard unimportant details and specify the interactions between the variables.
Demolin (2002:463)

4.0. Introduction

In the history of Phonology the linear framework acknowledged the existence of segmental and suprasegmental levels. The nonlinear framework developed that and sought explanation on the interaction between these two levels. However, Feature Geometry Theory brought an entire new perspective to nonlinear representational structure. It began the trend of identifying discrete anatomical apparatus, each of which subsumed their relevant distinctive features. Thus phonetic representation was being incorporated, with greater accuracy, into phonological description. One of the aims of this study, identified in 1.3, is bridging the Phonetics-Phonology dichotomy. Thus far, these two areas have remained discrete in this study with Chapter Two focusing on the phonological description of Intrusive Stop Formation and Chapter Three constituting the experimental investigation into the acoustic phonetic factor of Duration. In Chapter Four the Phonetics-Phonology dichotomy is bridged by utilizing the experimental information to facilitate a feature geometry description of Intrusive Stop Formation in Zulu. The incorporation of the experimental results embraces the "hybrid methodology" perspective of Laboratory Phonology. The feature geometry structure now incorporates anatomical information together with experimentally verified acoustic information, in other words Phonetics and Phonology are integrated.

Chapter Four commences with a discussion on the concept of explanation in Phonology. This is followed by an examination of the issue of acoustic factors and the integration of the acoustic dimension into phonological description. A proposed feature geometry structure is then presented. Thereafter the Theory of Constraint and Repair Strategies, hereafter referred to as TCRS, is discussed. This paradigm

will be used to formalize the phonological description of Intrusive Stop Formation in Zulu.
The aims of this chapter are as follows:

- Establishing the validity of the use of the acoustic parameter Duration in a feature geometry structure
- Justifying the use of the distinctive feature [-long] in the description of derived affricates
- Formalizing a phonological description of Intrusive Stop Formation in Zulu, incorporating a constraint-based approach into Feature Geometry Theory.

4.1. Explanation in Phonology

One of the primary aims of this study (cf. 1.3) is "using the feature geometry framework, informed by the experimental results, to formalize a description of the Intrusive Stop Formation process" i.e. providing a phonological rule. However, even though linear and feature geometry rules were critiqued in Chapter Two, there has, thus far, been no discussion on rules and explanations per se. It was deemed prudent to defer discussion to this point as the concept of explanation in Phonology is a somewhat philosophical issue, and the preceding chapters were not amenable to such discussion. With the study now being at a point where a 'new' rule and explanation strategy is about to be introduced, it is apt to now discuss this issue.

Kaye (1989:ix) describes the phonological rule as "the formal basis of the description of phonological processes". Within different theoretical frameworks, the same rule can have different appearances. Consider the following formalizations of the Nasal Assimilation process:

Figure 4.1 A Linear Formalization of Nasal Assimilation

$$N \rightarrow [\propto \text{place}] / \_\_\_\_ \begin{bmatrix} +\text{consonantal} \\ \propto \text{place} \end{bmatrix}$$

Figure 4.2 A Feature Geometry Formalization of Nasal Assimilation

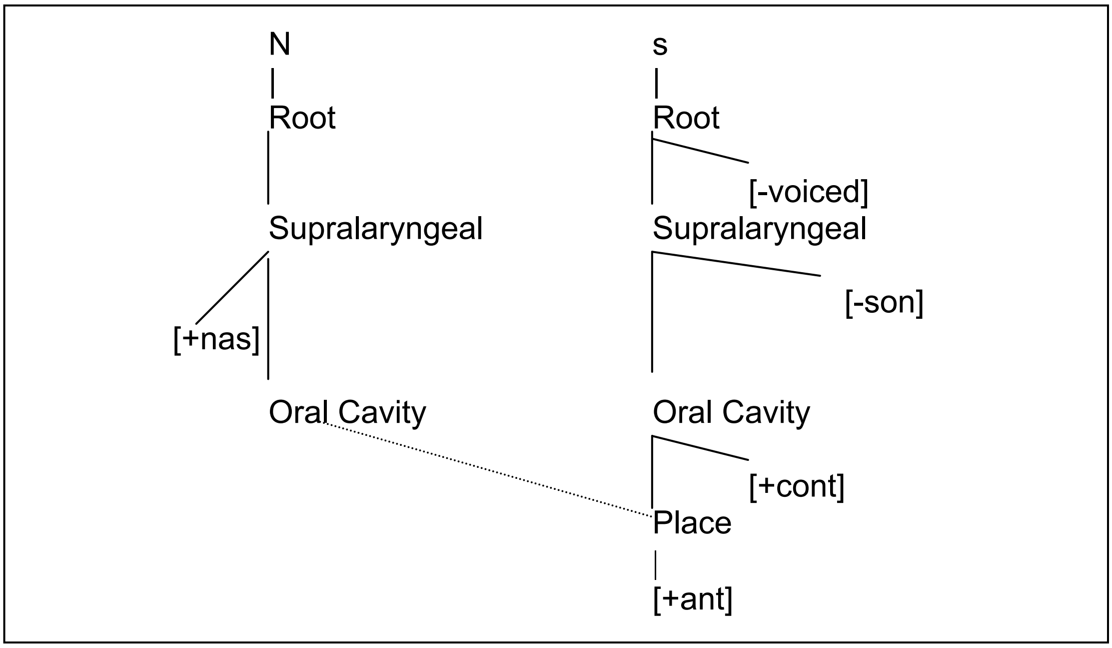


Figure 4.3 An Optimality Theory Formalization of Nasal Assimilation

ng	UICC[PL]	FAITH (PL) NA	FAITH(PL) OB
[ng]	*!		
[Ng]		*!	
☞ [nd]			*

In Figures 4.1 and 4.2 phonetic detail is crucial to explaining what occurs in the process. Figure 4.3, on the other hand, makes no explicit mention of phonetic detail as constraints take precedence in the explanation[1]. And therein is the dilemma for rules and explanations in Phonology – should the rule see phonetic explanation as motivating Phonology or should phonetic explanation be relegated. Hume & Johnson (2001:viii) describe these differences as functionalist and formalist explanations, respectively.

Formalist and functionalist explanations concur that language is acquired through “innate predispositions” and “experience of the ambient language” (Lindblom, 1995a:25). However, these explanations diverge on the matter of interpretation of linguistic facts. From the formalist perspective a Universal Grammar obtains i.e. “languages are underlyingly similar” (ibid.). Formalists would go so far as to propose that the brain possesses a “language organ” facilitating the learning of language. Functionalists, on the otherhand, believe that language learning occurs as a result of linguistic input and “innate behavioural predispositions” (ibid.). The latter constitute physical factors, for example, auditory, perceptual and neuro-motoric constraints on sound production.

Functionalist explanations, which contain phonetic information, often empirically based and experimentally validated, are influenced by the Phonetics Hypothesis i.e. Phonetics informs Phonology. Hardcore phonologists reject this notion of “Phonetics motivating Phonology”. For example, Kaye (1989) makes a strong argument against the Phonetics Hypothesis[2]. He explains that if theories are grounded in Phonetics, then how does one account for the dissimilarity in the world’s languages. Surely it is axiomatic that if all humans have the same physiological apparatus, then the sounds produced should be similar, particularly if ease of articulation motivates phonological processes. Clearly that is not what obtains – languages are complex and dissimilar. The UPSID inventory is probably the best testimony on the extent of variability among the basic sounds – cf. Maddieson (1984). Kaye (op.cit.) also looks at evolution within languages. He cites the example of tenth century English which bears little resemblance to Modern English. So, if phonetic factors are motivating Phonology, why does so much divergence occur? It is Kaye’s contention (op.cit.: 48) that “all phonological rules are expressible in phonetic terms” but the claim that “Phonetics motivates Phonology” is not acceptable to him and his followers (cf. Ploch:1999). The latter look to cognitive explanations. Such explanations are of a formalist nature. Hume & Johnson (2001:viii) explain that formalist explanation postulates an abstract model to account for data. According to Hume & Johnson (ibid.) formalism in Linguistics

> …is simply an expression of a methodologically respectable stance that helps minimize the problem of producing epiphenomenal descriptions inherent in exclusively data-driven theorizing.

It is the contention of this study that functionalist and formalist explanations co-exist in most paradigms. The two explanations are characterized by derivations and representational structures. Consider for example that Generative Phonology is a formalist explanation of processes. Phonetic detail is included but not to the same extent of identifying the various anatomical apparatus or isolating the articulator engaged in the process, as is typical of Feature Geometry Theory. The role of Phonetics in Generative Phonology is perhaps best described by Broë and Pierrehumbert (2000:1) as being the

> handmaiden to phonological theory, taking the entities suggested by phonologists as given and providing real-world referents for these entities through the use of measurements and perceptual tests.

So while no “data-driven theorizing” obtains in Generative Phonology, the Phonetics Hypothesis nevertheless plays a significant albeit impressionistic role. The existence of notational devices in formalist and functionalist explanation is another example of the co-existence of these forms. While Generative Phonology was instrumental in developing notational devices, other more functionalist frameworks like Autosegmental Phonology and Feature Geometry Theory also use such devices. Thus the boundaries between formalist and functionalist explanation is a lot more blurred than one might assume.

While mindful of the insights of Kaye (op.cit.), this study into Zulu intrusive stops is inclined towards a functionalist perspective. This is motivated firstly by the Laboratory Phonology approach and secondly by research (cf. 3.2) in other languages, which indicates that Phonetics has a prominent role in explaining the Intrusive Stop Formation process. Hence, the Phonetics Hypothesis is not rejected. Accepting that Phonetics plays a significant role has implications for the formalization of the process. However, as will become apparent in 4.3, empirical data must be incorporated into a phonological explanation, indicating a return to the formalist perspective of derivation and representation.

Why does this study attempt to integrate formalist and functionalist explanation? Beckman (1999:201) succinctly explains:

> A fully adequate phonological theory must account not just those aspects of language sound structure that are the way they are because speech is sound wave patterns produced by the human articulatory apparatus. It must also illuminate

> those aspects of sound structure that the way that they are because speech is a system of communication and cultural transmission among highly social, intelligent, tool-using animals.

Therefore, presenting the empirical data for Intrusive Stop Formation in Zulu achieves nothing. It is only within a formalist explanation that this data becomes useful. Feynman, quoted in Epstein & Seely (2002:3) states:

> …in the further development of science, we want more than just a formula. First we have an observation, then we have numbers,…, then we have a law which summarizes all the numbers. But the real glory of science is that we can find a way of thinking such that the law is evident.

Applying the Feynman quote to Intrusive Stop Formation in Zulu, the observation dating back to Bryant (1905) was that differences exist between pure and derived affricates. The experimental investigation in Chapter Three has verified this. In 4.3 a distinctive feature is introduced to encapsulate these differences i.e. a law. And finally, in terms of “a way of thinking” this study highlights the vital role of acoustic Phonetics in the explanation of a phonological process. Without wanting to pledge allegiance to a particular theoretical approach, it is becoming evident that the Emergent Phonology approach is applicable in this study. Demolin (2002:458) explains the crux of Emergent Phonology:

> Phonologists should derive fundamental units and processes deductively from independent premises anchored in physiological and physical realities.

Whatever perspective or approach one invokes, one should be critical of, to use the term coined by Epstein & Seely (2002:2), the “explanatory depth” of the theory. Formalist and functionalist explanations have their respective strengths, but it is only in combination that they become truly formidable. For that very reason, this study, from a philosophical stance, incorporates both formalist and functionalist explanation into Feature Geometry Theory.

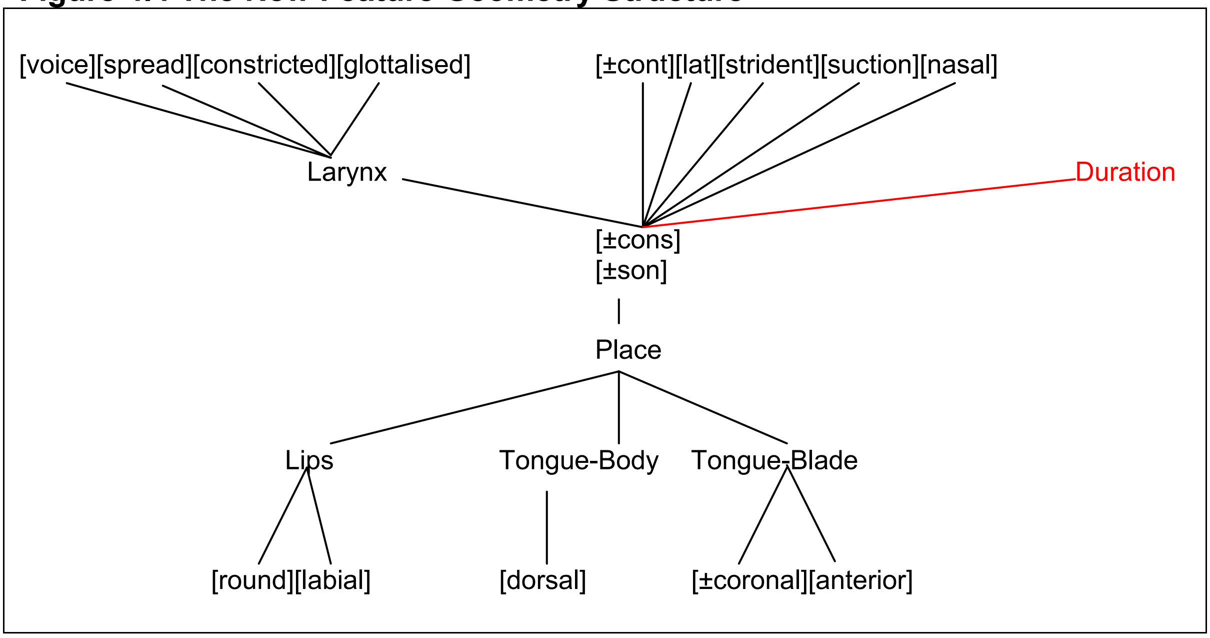
In the next section acoustic phonetics is examined.

4.2. Introducing the Acoustic Parameter Duration

The disciplines of Phonetics and Phonology have a common aim – the description and explanation of sound patterns. Pierrehumbert (1990:375) explains that phonetic representation is concerned with "describing speech as a physical phenomenon i.e. measurable property of articulation, acoustics and audition[3]" whereas phonological representation focuses on the description of "qualitative contrasts in sound."

From the outset this study has been cognizant of a fundamental problem with Distinctive Feature Theory and Feature Geometry Theory, namely the exclusion of acoustic phonetic detail (cf.2.3.1). While the *PSA* era incorporated acoustic and articulatory phonetics into the description of distinctive features, succeeding models ignored acoustic detail. The experimental results (cf.3.4.5.2) have confirmed the vital role of the acoustic parameter Duration. It would be anticipated that the next step would be the introduction of an acoustic tier. Concomitant with that tier should be acoustic features. But, as evidenced in Figure 4.4, although an acoustic tier Duration is introduced, a feature remains to be filled.

Figure 4.4 The New Feature Geometry Structure



The following section discusses the issues of mapping, interfacing or integrating acoustic features into phonological description within a feature geometry structure.

4.2.1. The Problems of Integrating or Interfacing Acoustic Features

The use of distinctive features in phonetic and phonological description is a controversial matter. Lindblom (1990:136) argues that the existence of the IPA and Distinctive Feature frameworks is based on the assumption that

> …the universal phonetic set from which languages draw their sound inventories is *finite*

However, given that only a very small percentage of languages have been phonetically and phonologically analyzed, it is inaccurate to assume that the IPA and Distinctive Feature frameworks are finite. It is apparent to Lindblom (op.cit.:137) that such frameworks have developed on account of "practical convenience and descriptive necessity" rather than "the existence of theoretical justification".

The experimental investigation in Chapter Three has proved that very point. In Zulu, affricate duration is context dependent, with derived affricates having a shorter duration than pure affricates. There is also evidence that within pure and derived affricates, durational differences may exist (cf.3.4.5.2. observations 3-5). While broadly classifying such sounds as affricates is correct, it nevertheless ignores the fact that there are significant inherent differences between the two groups and possibly within groups. And, a descriptive framework not acknowledging that is tantamount to misrepresentation. The articulatory framework is undoubtedly lacking in descriptive accuracy, particularly as it ignores acoustic dimension. But herein lies a difficulty. Unlike articulatory features, which are associated with a physical articulator, acoustic features are value-based, making them precise and complex. Shoup & Pfeifer (1976:175) identify the following acoustic phonetic parameters:

- Gap
- Broad-band continuous spectrum
- Formant frequency
- Formant amplitude
- Formant bandwidth
- Antiresonance

Finding an appropriate manner to incorporate these parameters into a descriptive framework poses a perennial challenge to linguists. The next section examines the Clements & Hertz (1996) suggestion for depicting durational information.

4.2.2. Proposals for Acoustic Features

During the height of Generative Phonology, Klatt (1974:61) recognized that duration was a vital factor that was excluded in the *SPE* formalisms and stated:

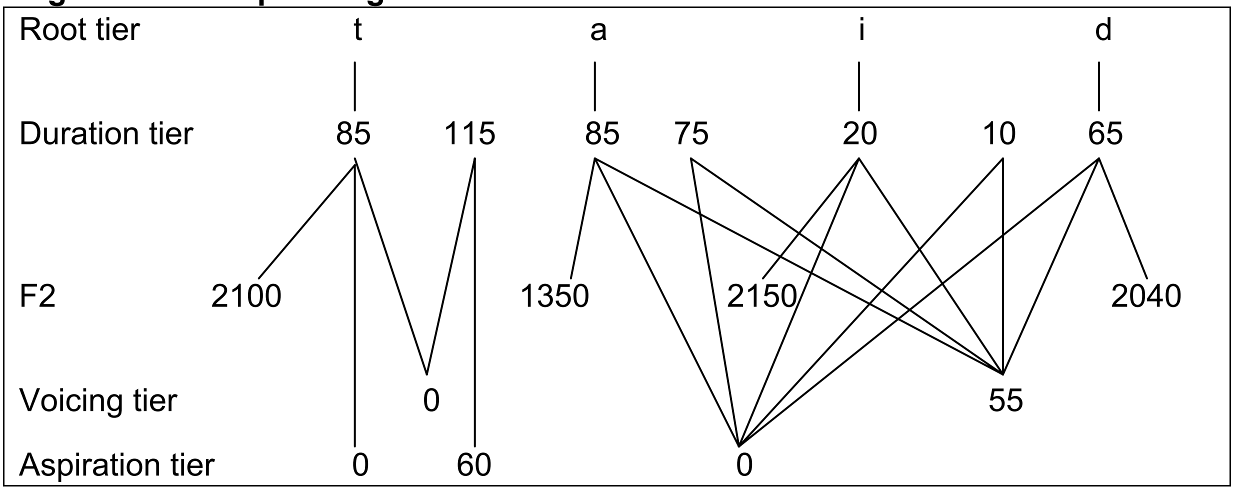
> A phonological rule system must assign a duration to each phonetic segment in an utterance (or explain how durations are derived from other linguistic and physiological constraints).

Clements & Hertz have been the main proponents for the introduction of acoustic levels in phonological description. The idea originates from the work of Hertz (1982) in the development of the Speech Research System (SRS), a computer system for creating text-to-speech rules for languages. Subsequent research has been discussed in Hertz (1990, 1991); Clements (1991a and 1991b, 1995a) and Clements & Hertz (1991, 1996). Clements & Hertz (1996:34) believe it is essential to depict

> …how acoustic values sufficient for deriving natural-sounding synthetic speech can be directly assigned to surface phonological representations, creating a composite phonological and phonetic representation

Figure 4.5 is an example of how Clements & Hertz (op.cit.:48) visualize the incorporation of acoustic tiers. This figure differs from the studies reported in 3.3 where the factor Duration was measured and its implications noted, but without any attempt to include it in phonological description.

Figure 4.5 Incorporating Acoustic Tiers



In the depiction above, “quantitatively-specified acoustic parameters”, namely Duration, F2, Voicing and Aspiration are introduced. The latter two are generally found in distinctive feature descriptions, but not with value specifications.

Even though it is based on empirical and verified data, the Clements & Hertz proposal for the use of actual values is overly ambitious. As this study finds this method untenable and rejects the use of actual values, then an alternative must be found. That alternative is the use of a distinctive feature that is able to capture significant phonetic information for the Intrusive Stop Formation process. Therefore, the choice made is one of identifying a Duration tier and using a traditional feature [long] to differentiate the pure and derived affricates. While such a choice may be considered ‘unscientific’, it is not without support. Ladefoged (1997:595) states:

> The simplification of the physiological phonetic facts allows us to see patterns of sounds that are otherwise not evident, and it is therefore fully justified.

In the following section the distinctive feature [long] is discussed.

4.3. Introducing the Distinctive Feature [±long]

The study of length or duration has its roots in the Classical Tradition. Classical Greek linguists were the first to distinguish between long and short vowels. Henderson (1971:138) records Sweet’s description of the phonetics of length in the nineteenth century. Fox (2000:18) notes that during the same century, Brücke (1856) and Viëtor (1894) conducted experimental investigation into length. The

Prague School, Structuralists and the Generative Phonologists further examined the issue. Fox (op.cit.:12) explains the concept of length as follows:

> Speaking is time-dependent activity;…, and although articulatory events are not necessarily discrete…- there is nevertheless a temporal order to both the production and perception of the speech signal. Thus, any part of this signal will occupy a finite portion of time, which can be measured, and the length of any such part is simply the time taken to utter it.

Crystal (1997:218) explains the terms 'length/long' as follows:

> …physical duration of a sound or utterance…Sometimes the term is restricted to phonological contexts, the phonetic dimension being referred to as 'duration'

Fox (ibid.) concurs with the Crystal definition above, stating that phonetic length is the "absolute physical length of a sound or syllable, for which we may use the term duration".

The concept of length is not simple to formalize in a phonological representation. Based on Fox (op.cit.:13-14) the following problems with this concept are identified:

- As explained in 3.3 and 3.4.3.3.2 measuring the length of a segment is not a straightforward matter. It is difficult to detect the acoustic or articulatory properties of length. For example, the distinctive features [voice] or [nasal] have specific attributes (vibrating vocal cords and air in the nasal cavity, respectively), the equivalent of which is not found in the concept of length.
- From a phonological perspective, length is a difficult comparison to articulate.

This led to length, instead of having a distinctive feature, being accorded a diacritic feature [:]. Nevertheless, other attempts were made by twentieth century linguists to use distinctive features to describe length. These features included [±tense], [±lax], [±ATR], [±long] and [±short]. Of the five distinctive features identified, [±long] and [±short] appear to be the least controversial in that they can be phonetically verified. On account of that [-long] has been selected to describe the derived affricates in Zulu. The use of a negative feature is not conventional and such a suggestion is clearly courting controversy. Essentially the choice of

distinctive features was between [±long] and [±short]. Affricates show no phonetic motivation for being described as [+short][4], so the alternative is [+long]. It has been experimentally established that the derived affricates are durationally shorter than the pure affricates. This implies that the former have the value [-long]. A privative feature would be the ideal, but such a feature has never been identified, nor does it seem viable to coin another feature. Instead, [-long] could be interpreted as being a privative value on the Duration tier. Lombardi (1995:40) mentions that in a privative feature system, negative values are not used, making [short] a better option. But given that historically this feature has limited occurrence, [-long] is adopted.
The next section examines the theoretical framework within which Intrusive Stop Formation in Zulu will be formalized.

4.4. The Theory of Constraint and Repair Strategies (TCRS)

Two crucial shortcomings exist in Feature Geometry Theory, with regard to the formalization of Intrusive Stop Formation. Firstly, the exclusion of the acoustic dimension impacts on the phonetic description of affricates. In an attempt to redress this, the distinctive feature [long] has been proposed. Secondly, the formalization techniques used in Feature Geometry Theory do not accurately illustrate the formation of the intrusive stop. This study proposes that by invoking TCRS, the latter problem can be resolved. The following discussion explains the constraint-based TCRS approach.

4.4.1. TCRS Explained

Constraint-based frameworks have been in vogue for nearly two decades. Declarative Phonology and Optimality Theory are probably the most well-known versions of the constraint-based approach. But the problem with the afore-mentioned theories is that phonetic information is relegated to a secondary position[5]. It is the contention of this study that Phonetics and Phonology must be successfully integrated into any framework. Hence, the combined Feature Geometry Theory cum TCRS framework.

LaCharite & Paradis (1993:127) identify the following advantages of a constraints paradigm:

- Reduce the number of sources and/or causes of a given phenomenon
- Link apparently unrelated facts
- Make more predictions, if formulated adequately and related to Universal Grammar.

Clements (1995b:127) adds the following advantages:

- It extracts a single anti-hiatus constraint from a set of rules which was forced, in standard theory, to state it twice
- It accounts for underlying constraints, surface regularities and alternations by the same set of principles
- It interprets the structural description and structural change of two arbitrary rules in terms of a set of phonetically plausible universal constraints and repair operations.

Fundamental to TCRS are the concepts of "constraint" and "repair". Béland & Paradis (1993:285) explain that "languages are governed by constraints, which are themselves preserved by repair strategies." Paradis (1993:215) further explains:

> When a constraint is violated, a repair strategy must apply which, in repairing the violation, produces a phonological alternation.

With regard to Intrusive Stop Formation in Zulu, the language has a constraint disallowing the occurrence of a prenasalized fricative i.e. such an occurrence is a violation[6]. While the violation is tolerated[7] at the lexical level i.e. /mf, mv, ns, nz, nhl, ndl/ sequences occur, a repair strategy occurs to create a /nasal + affricate/ sequence at the phonetic level. Paradis (1988a:71) explains:

> A repair strategy as opposed to a rule is an operation that applies to a phonological unit or structure in order to repair the violation of a structural or segmental phonological constraint of universal or language-particular type.

This study merely uses the TCRS logic as the catalyst for the feature geometry description of Intrusive Stop Formation in Zulu. It could be said that the explanatory depth of TCRS enhances the feature geometry description. Given that it is an accompaniment to Feature Geometry Theory, there is no critique of TCRS, per se. However, for the purpose of providing the governing principles of TCRS, the following the basic tenets, as explained by LaCharite & Paradis (1993:146-147), are included:

Repair A universal context-free phonological operation that inserts or deletes content or structure to make a phonological unit or structure conform to a constraint. Preservation Principle Preserve as much of the input as possible, according to the constraints of the language. Minimality Principle A repair must apply at the lowest phonological level to which the violated constraint it preserves refers.

The next section illustrates how the TCRS approach is incorporated into a feature geometry description of the Intrusive Stop Formation process.

4.4.2. Formalization of the Description of Intrusive Stop Formation in Zulu

Discussion in this section commences with distinguishing pure and derived affricates. Thereafter the Intrusive Stop Formation is formalized (cf. Appendices C –E for descriptions of all affricates).

Figure 4.6 provides a basic distinction between the pure and derived affricates /ts/.

Figure 4.6 Distinguishing Pure and Derived Affricates

Pure Affricate /ts/	Derived Affricate /ts/
[ts] | [-cont,+cont]	[ts] [-cont] [+cont]

The depiction of the pure affricate with a single line linking the enclosed distinctive features [-cont,+cont] implies that the sound is a single entity. However, the derived affricate is shown to have separate constituents [-cont] and [+cont]. The implication is that these constituents are loyal to separate grammatical categories i.e. [t] to the preceding nasal prefix, and [s] to the verbal root, as in the example
iN + salel + o → insalelo [ints'alElO].

The focus of this study was the role of Duration in affricate description. Therefore, if one wanted to provide a more detailed feature geometry distinction between the pure and derived affricates /ts/, then Figures 4.7 and 4.8, respectively, would fulfill that.

Figure 4.7 A Description of the Pure Affricate /ts/

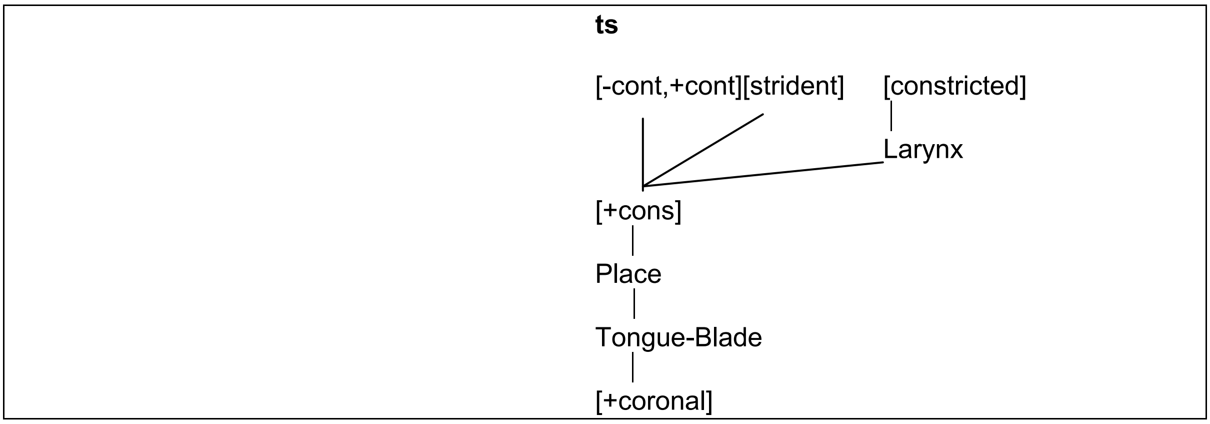
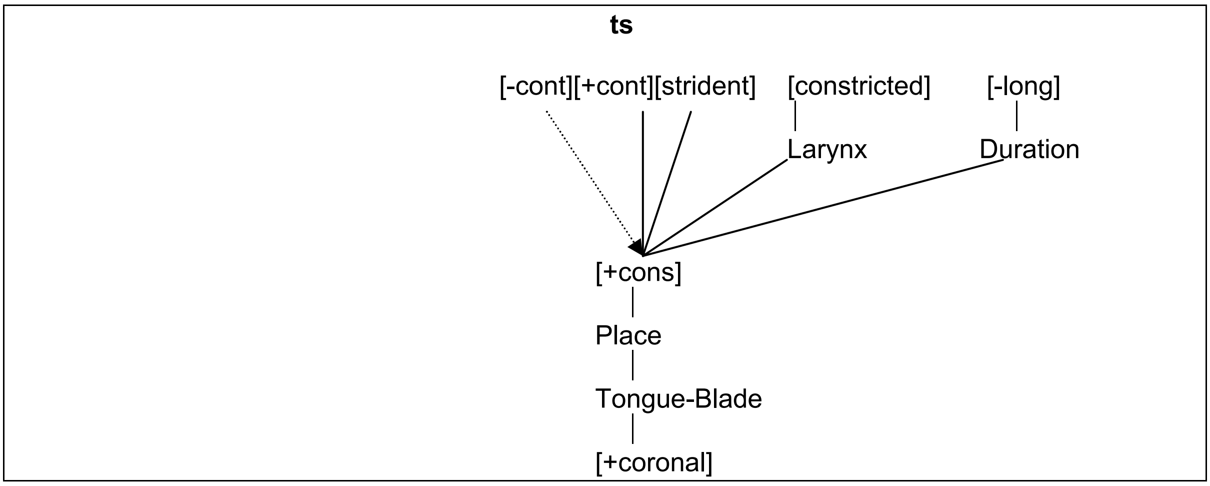


Figure 4.8 A Description of the Derived Affricate /ts/



In Figure 4.8 a Duration node specifies the derived affricate. In addition, the distinctive feature [-cont] is inserted using a broken arrow. This indicates the intrusive nature of this sound.

Figure 4.9 illustrates the formalization of the Intrusive Stop Formation process in Zulu. Aspects of the representational structure of Steriade (1993) are adopted (cf. 2.7.2.; Figures 2.28 and 2.29). The use of the superscript star symbol indicates that there is a constraint on this N + s* combination or a violation is in progress. Therefore a repair occurs. At the repair level the fundamental TCRS tenet – inserting an element that aids conforming to a constraint – is realized with the depiction of the insertion of the intrusive stop. The following depictions are significant:

- A Duration tier, subsuming the distinctive feature [-long], is used to identify derived affricates.
- The broken line linking the Place node of the nasal to the distinctive feature [+coronal] illustrates that Nasal Assimilation has occurred.
- The Larynx node is specified indicating with the feature [constricted] that this particular affricate is ejective.
- The sequence of [-cont][+cont] remains problematic. Notwithstanding the criticisms leveled at this configuration, the writer is of the opinion that the introduction of a new distinctive feature [stop] would be superfluous. Also, the concept of Headedness and Dominance has been discussed (cf.2.7). It is the position of this study that the use of this concept does not contribute to bringing about greater clarity to the phonetics of the affricate or even the process of Affrication. The affricate is primarily a sequence of stop and continuant. The juxtaposing of the distinctive features [-cont] and [+cont] adequately captures that description.

Figure 4.9 A Phonological Description of Intrusive Stop Formation /N + s/

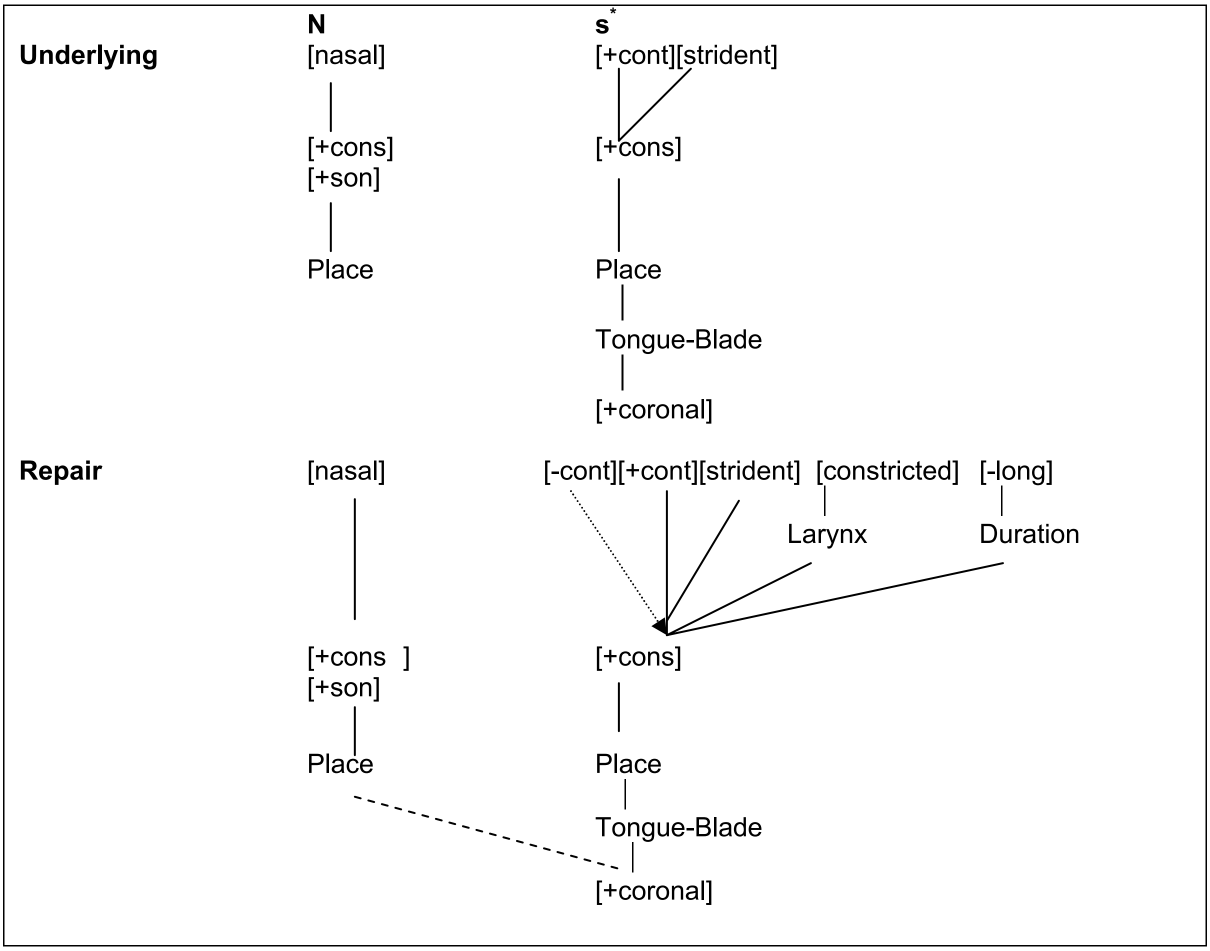


Figure 4.9 is a visual representation of the Intrusive Stop Formation in Zulu. It borrows from TCRS to show that there is a constraint on prenasalized fricatives. The illustration then proceeds to repair the violation. Figure 4.9 adheres to the Preservation Principle of TCRS, namely input is reproduced in the representation. The Minimality Principle is also adhered to. The Place node of the nasal is shown to assimilate the place feature of the fricative. And, the intrusive stop is depicted. Thus repairs are shown at the levels where they occur.

As to the question of why linguists persist in formalizing phonological processes, that answer is rooted in the study of Phonology itself - describing of the sound system and processes of languages is what Phonology is all about. But, the relevance of this will be discernable in Chapter Five when the discussion examines the aspects of Human Language Technology and Disordered Phonologies.

4.5. Summary

Chapter Four has brought this study the full circle. It is this chapter that has illustrated the capacity of Phonology to accommodate experimental information, and the capacity of phonetic information to enhance phonological description. In integrating Phonetics and Phonology Chapter Four has brought a new perspective to the following issues in Zulu:

- Description of affricates
- Choice of distinctive features
- The formalization technique

The acoustic values, obtained in Chapter Three, were deemed cumbersome. Therefore a distinctive feature [-long] was chosen to describe the durational differences that obtain between pure and derived affricates. This has not been done in Feature Geometry Theory. Also, as the distinctive feature is experimentally informed, it lends greater authenticity to the description of the Intrusive Stop Formation process. According to Wetzels (2002:618):

> A fully-fledged linguistic theory should not only deal with issues regarding distinctive phonological features and their organization in abstract structural units but also addresses questions regarding subphonemic phonetic details.

The formalization technique developed in this study - a combinatory feature geometry structure cum constraint-based description - evolved from the critique of six feature geometry descriptions of Intrusive Stop Formation. The principle flaw (apart from Padgett:1995) was that the intrusive stop per se was not illustrated. Therefore Steriade's (1993) structure was adapted in Figure 4.5.

But the crux of this study was incorporating the results of the Laboratory Phonology approach into Feature Geometry Theory. The tendency in Laboratory Phonology has been to merely verify or reject impressionistic phonetic assumptions. Goldsmith & Laks (2000:2) are particularly critical of such "data-driven descriptivism" which typifies experimental phonetics. But, discussion in 4.3 and 4.4 has illustrated that interfacing at the practical level is achievable.
Einstein quoted in (Epstein & Seely: 2002:3) states:

> …the grand aim of all science, which is to cover the greatest possible number of empirical facts by logical deduction from the smallest possible number of hypotheses and axioms.

Chapter Four is the expository component of this study. Apart from dealing with the concept of explanation in Phonology, this chapter has illustrated how the empirical data from the experimental investigation could be integrated into the feature geometry framework. Chapter Four has shown the advantages of an eclectic approach – not only in describing the Intrusive Stop Formation process in Zulu through the use of the feature geometry and constraint-based framework – but also through the use of formalist and functionalist explanation to achieve optimal description and explanation.

The discipline of Phonology is a dynamic area. The scholar is constantly aware of developing frameworks and paradigms. But what remains paramount is the search for lucid explanation in accounting for processes that occur in languages.
Chapter Five examines the practical uses of Feature Geometry Theory and acoustic factors.

Notes

1. The Optimality Theory account of Nasal Assimilation is based on Jokweni (1999). As per Figure 4.3, Jokweni (op.cit.:152) ranks the universal constraint Identity Cluster Constraints (ICC) over Faithfulness (FAITH) in order to explain the process for Xhosa.
2. Kaye (1989) does not use this term but his argument is undeniably linked to this concept.
3. Flemming (2001) makes a compelling case for the inclusion of the auditory dimension in phonological description. He identifies (op.cit.:17) the following dimensions or parameters for auditory features: Formant Frequencies; Noise Frequency; Diffuseness; Noise Loudness, Loudness and VOT. Flemming acknowledges the overlap between the acoustic and auditory and the fact that within each of these dimensions features will be scalar or multi-valued. As will be apparent from the discussion on Duration in 4.2.2, such features which bear a numerical value are really untenable in phonological description. Moreover, each language would need to develop an acoustic and auditory database for the various dimensions prior to attempting to incorporate such values into phonological description. Complexities of this nature have contributed to the decision in this study to focus on the tenable and ignore the auditory dimension.
4. The use of the distinctive feature [long] would also facilitate the description of the vowel lengthening process in Zulu. This process occurs when the penultimate vowel is lengthened in certain environments. For example, in the final versus non-final position:

   Ngiyaha:mba [Ngijahaːmba] versus *Ngiyahamba manje* [Ngijahamba ma´dZE].

   The same case cannot be made for the distinctive feature [short].
5. New developments in Optimality Theory now indicate a bias towards incorporating a greater degree of phonetic detail (cf. Padgett: 2002; Flemming: 2002).

6. The violation can result from a “morphological operation, underlying ill-formedness or a constraint conflict” (Paradis, 1993:215).
7. Paradis (1988b:1) explains that constraints can “block a phonological process” or “permit a violation….and then trigger a repair strategy”. Therefore in Zulu, the lexical tolerance of nasal + fricative sequences, but the repair manifesting itself in the pronunciation of the words.

Chapter Five
Conclusions

Integrative phonology does not solve problems by unchecked proliferation of novel theoretical entities, rather, it attempts to keep the theoretical entities to a minimum and draws most of the building blocks of its theories from the realm of the previously established – often that which has substantial empirical support. Its theories tend to contain within them an indication of how they could be tested.

Ohala (1991: 11)

5.0. Introduction

Chapter Five, while concentrating on consolidating the discussion from the preceding chapters, also focuses on explaining the indirect benefits and implications of having an optimal description.

The chapter commences with a discussion on how the original aims of the study and the results achieved relate. Thereafter the broader significance of this study for other disciplines – Human Language Technology (HLT) and Language Disorders – is discussed. Often the sentiment is expressed that disciplines like Phonetics and Phonology have limited value. They challenge the cognitive skills of scholars but are essentially academic pursuits confined to an ivory tower. However, discussion on HLT and Language Disorders will show that the experimental investigation and the feature geometry application have practical value. In fact, without such theoretical pursuits the practical component would never be realized. While the discussion on HLT and Language Disorders is not exhaustive, it aims to present a broad picture of developments in the respective fields.

Human-machine communication, which is the crux of HLT, is an integral part of global communication. Any language, which is outside of this method of communication, is severely lagging behind. The research into the duration of affricates has implications for the development of speech recognition and speech synthesis programs.

While the experimental dimension of this study influences HLT, the theoretical aspects of Feature Geometry Theory have implications for the study of speech disorders. The hierarchal structure and identification of nodes assists in isolating areas of speech difficulty. The following sections expand on these aspects.

5.1. Achieving the Aims

In 1.3 the aims of the study were outlined. At the Phonetic Level the **first aim** was determining the durational differences between the pure and derived affricates in Zulu. The experimental investigation determined the following statistically significant observations:

- The mean total duration and closure duration for pure affricates is significantly greater than that for derived affricates for all the sounds used in the experiment
- Durational differences exist within pure affricates. There is some evidence that the total duration mean for /tS'/ in the word *ukutshuma* is greater than that of *ukutshaza* (cf. Table 3.14)
- Durational differences exist within derived affricates. The total duration means for sounds /þf', tñ' and dL/ are significantly greater than that for sound /{v/ (cf. Tables 3.23 and 3.26)..

The **second aim** was establishing the ejective status of voiceless affricates. Qualitative evidence from the spectrograms conclusively indicated that the sounds [ts', φf', tñ'] were ejectives. While the proximity of the glottal and velar releases is a logical explanation of why [kl] does not typify the ejective burst pattern, the status of [tS] warrants further investigation.

The **Phonological Level** had three aims. The **first aim** regarding the assessment of the traditional distinctive feature description of affricates and the formalization of the Intrusive Stop Formation process within the Generative framework, entailed presenting the flaws, identified by linguists working in the post-Generative period (cf. 2.2.2 and 2.3). In an attempt to bring a new perspective to the age-old distinctive feature inventory issue, a detailed critique and proposal for a new distinctive features inventory was undertaken (cf. 2.5.4). The ideal inventory was presented in Table 2.9.

Proceeding onto the **second aim** of assessing the formalization of the Affrication/Intrusive Stop Formation process in the contemporary Feature

Geometry framework, six feature geometry structures were critiqued (cf. 2.4). The phonetic-phonological arguments that underpinned these structures were discussed. It was concluded that the formalizations of the Intrusive Stop Formation process, facilitated by these six structures, were flawed (cf. 2.5). While the discussion in 2.5.3 and 2.6.1 identified the main components of a proposed feature geometry structure, it is only in Chapter Four that a comprehensive feature geometry structure is put forth, together with a formalization of the Intrusive Stop Formation process. The latter was the outcome of the experimental investigation of Chapter Three. In addition, 2.7 examined three proposals for the description of affricates and two formalizations of the Intrusive Stop Formation process. These proposals, although nonlinear in form, were not feature geometry based descriptions. Nevertheless, these proposals guided the development of the new experimentally informed feature geometry structure.

This leads the discussion to the **third aim,** namely incorporating the experimental results into a phonological description of Intrusive Stop Formation. Chapter Four was devoted to that aspect and Figure 4.4 illustrates a feature geometry structure that is phonetically-based, inclusive of articulatory features and an acoustic tier Duration. The inclusion of the latter facilitates the distinction between pure and derived affricates. The introduction of the acoustic tier (based on experimental results) reaffirms the proposals of Hertz (1982; 1990; 1991), Clements (1991; 1995) and Clements & Hertz (1991; 1996). But, Figure 4.4 is a more tenable alternative to the Clements & Hertz proposal (cf. Figure 4.5).

Discussion in 3.1 dealt with the **first aim** of the **Integrated Level**, namely examining theoretical perspectives on the relationship between Phonetics and Phonology. There has been one major move in Phonology and that is the development from the linear to the nonlinear framework. Within the latter framework several theoretical perspectives have developed (cf. Chapter 2, endnote 3). But, it is the Laboratory Phonology approach that has truly brought Phonology into the realm of a 'scientific study'. This approach has outlined the need for not only phonetic information but experimentally verified empirical data. In that sense integration obtains. But die-hard phonologists have not dissipated. The debate on the status of Phonetics and Phonology continues to rage in the 21st century. Ploch (2003:7) places Phonology at the top of the hierarchy:

> Phonetics is not an independent discipline. Without phonology there is no phonetics, but without phonetics as a scientific discipline, there *is* phonology. In other words, the importance of phonetics in phonology is greatly overrated.

The Ploch position is not one that this study subscribes to. The more tempered Emergent Phonology perspective, touted by Lindblom (2000) is perhaps a better description of the position of this study i.e. the phonological description of Intrusive Stop Formation is based on the results of an experimental investigation. In other words the phonetic results inform the phonological description or to use the Emergent Phonology hypothesis, this is "deriving phonology from phonetics" (MacNeilage & Davis, 2000:284).

The point of this study was not to propose another theoretical perspective - rather it was concerned elucidating that an extremely successful theoretical perspective, Feature Geometry Theory, was weakened because it did not take cognizance of acoustic parameters. But, if such parameters were to be introduced, then it had to be based on empirical evidence. In order to do that the Laboratory Phonology approach was invoked. Gelling the Laboratory Phonology approach and Feature Geometry Theory was a challenging exercise. When it was found that duration differences did occur between pure and derived affricates, it meant that the feature geometry structure would have to depict this i.e. an acoustic tier would need to be introduced. The very nature Intrusive Stop Formation also meant that the conventional formalization rules would need to be reviewed. Both these issues were successfully resolved. While this study is not couched in the Emergent Phonology approach, it nevertheless coincides with the principles of Emergent Phonology. The critical factor that arises from all this is the fundamental aim of Phonology, one that has endured through the ages, that of describing sound processes, persists. And this leads to the discussion of the second aim.

The **second aim** at the integrated level was the presentation of an eclectic phonological formalization of Intrusive Stop Formation, one which is a constraint-based, experimentally verified, Feature Geometry description of the process. This was achieved through the TCRS cum Feature Geometry Theory.

The next section discusses the practical implications of Feature Geometry Theory.

5.2. Human Language Technology (HLT)

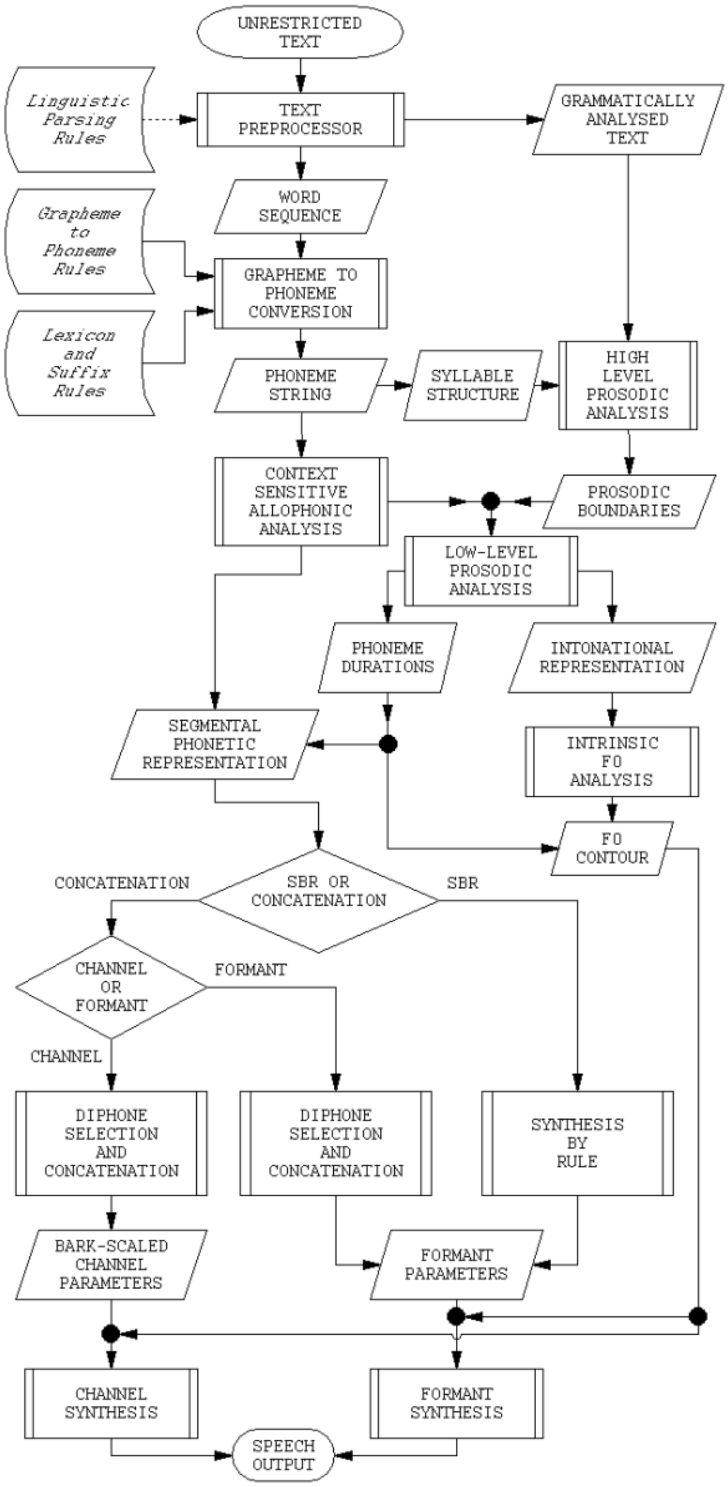
Technology and computers specifically, have become an integral part of human communication. The Sydney University Language Technology Research Laboratory[2] comments:

> …most of what is stored on computers, just like most of what lives on the web, is information in the form of various human languages, regardless of whether it is stored as text, images, sound files, hand movements, or multimedia presentations.

Figure 5.1[3] illustrates the amount of information that is required at the level of developing a text-to-speech system (TTS).

[2] www.sultry.arts.usyd.edu.au
[3] www.ling.mq.edu.au/home/rmannell/mutalk/main/index.html

Figure 5.1 The MU-Talk Text-to-Speech System



Of particular significance is the recognition of Phoneme Durations during the processing stage. Hertz (1997)[4] states:

[4] www.eloq.com/SuePap.htm

> The precise duration and frequencies of a sound depend on many factors – which segments precede and follow it, its position in the word ….

Chung & Seneff (1999:113) also identify duration as a vital factor in speech recognition systems but acknowledge:

> …our current understanding of durational patterns and the many sources of variability which affect them, is still sparse.

The authors explain that while speech synthesis programmes can cope with rudimentary models of duration, speech recognition systems require a more sophisticated understanding of Duration. Using ANGIE – "a flexible, unified sublexical representation designed for speech applications" (ibid.) – Chung & Seneff found that the manipulation of the parameter duration resulted in improved speech recognition.
From the Hertz (1997) and Chung & Seneff (1999) comments one can surmise that if duration is significant for distinguishing between pure and derived affricates then this factor will also have important implications for the development of HLT systems in Zulu.

HLT has tremendous benefits (cf. Jurafsky & Martin:2000 for further discussion on machine-human interaction). That is self-evident from the following systems listed on the HLT website[5]:

- CAVE – Caller Verification in Bank and Telecommunication
- IDAS – Interactive Telephone-based Directory Assistance Services
- MAY – Multilingual Access to Yellow Pages
- MULTIMETEO – Multilingual Production of Weather Forecasts
- PICASSO – Pioneering Caller Authentication for Secure Service Operation
- RECALL – Repairing Errors in Computer-Aided Language Learning
- SENSUS – Language Technologies for Police and Emergency Services
- SPEEDATA – Speech Recognition for Data-entry applications

HLT has had limited application in the South African context. The African Speech Technology (AST) project at the Research Unit for Experimental Phonetics, University of Stellenbosch (RUEPUS) is one such endeavor. This project has been

[5] www.hltcentral.org/projects/list_programme.php?id=3

designed for the hotel industry and is an automated multilingual voice-based information retrieval system. One of the objectives of this project was:

> To assess and adapt current state of the art speech recognition and speech synthesis technologies to account specifically for the acoustic and perceptual qualities of the languages spoken in this country which differ in many respects from other described languages.

This experimental investigation, which has identified durational differences between pure and derived affricates, would complement such a project. The identification of the subtle acoustic characteristics of phones can firstly create more natural sounding speech and secondly, from a speech recognition perspective, it is vital for a system to interpret the range of sounds and variations thereof.

HLT development cannot proceed in the absence of an in-depth comprehension of the Phonetics and Phonology of the language in question. The fact that South Africa does not have a fraction of the automated services (in all of the official languages) available in developed countries is testimony to how far behind we lag. Such services are perhaps even more necessary in this context given that a large percentage of the population is not literate and might therefore find voice interaction systems more user-friendly. It is therefore imperative that experimental research into the sound systems of the South African languages be undertaken to hasten progress in the field of HLT.

Another area where development is vital is that of disordered speech. The next section examines the role of phonetics and phonology in this area.

5.3. The Role of Phonetics and Phonology in Disordered Speech

According to Bernhardt (1992b:238)

> Application of phonological theory to phonological intervention in the past 20 years has resulted in acceleration of progress in therapy. Describing speech output in terms of coherent phonological systems has enabled clinicians to design intervention programmes which result in generalizations within the system.

Several components of Phonology impact on the study of disordered speech - the illustrative nature of Feature Geometry Theory, the rule formalization technique and the debate on universal versus language-specific phonology. These are briefly alluded to in the following discussion.

Edwards & Shriberg (1983) offer a comprehensive account of research into the application of Phonology in the study of speech disorders. Albeit that the Edwards & Shriberg work predates nonlinear Phonology, the role of Phonology cannot be overstated. In fact, as far back as 1963 the Structuralist paradigm was invoked in the study of speech disorders. Distinctive Feature Theory also played a significant role. Edwards & Shriberg (1983: 149-156) list the following studies which invoked Distinctive Feature Theory: Menyuk (1968); Crocker (1969) and Cairns & Williams (1972). Menyuk's work echoes the more recent study by Dinnsen et al. (1992). The latter (op.cit.:221) concluded that the hierarchical structure is extremely relevant to the study of acquisition[1] difficulties. Figure 5.2 illustrates the order in which acquisition is attained. For example, acquiring the ability to distinguish between voiced and voiceless segments presumes an ability to differentiate among sonorants, consonants and vowels. And, an inability to distinguish the voicing quality implies an inability to differentiate at the manner, nasal and stridency/laterality levels. Therefore in attempting to correct any misarticulation, the clinician needs to identify the level at which error occurs.

Figure 5.2 The Hierarchy of Acquisition (Dinnsen et al.: 1992)

Major Classes ↓ Voicing ↓ Manner ↓ Nasal/NonNasal ↓ Stridency or Laterality

Tyler & Saxman (1991) also acknowledge the benefits of diagrammatic phonological representations, reiterating that underlying representations provided by phonological descriptions identify the source of the error. Their study focused on the acquisition of the voicing contrast in normal and disordered phonologies. Using phonological formalizations Tyler & Saxman (1991:475) concluded that where imperceptible acoustic distinction occurred i.e. an attempt at voicing, the speaker had "difficulty in translating underlying knowledge into the appropriate motor actions to achieve perceptibly distinct productions." However, where there was nonproduction of any acoustic distinction the speaker had difficulty "organizing and accurately representing knowledge about phonemes or in translating that knowledge into appropriate motor actions."

Bernhardt (1992a & 1992b)[2] reiterates the position that the feature geometry framework provides a graphic representation of a disordered phonological system. The latter can be compared to a normal phonological system and intervention strategies can be designed to achieve specific goals. For example, Bernhardt (1992b:288) cites the case of a child who has difficulty articulating the /s/ phoneme in an /st/ cluster. Dependent on whether the child distorts, omits or substitutes the /s/, appropriate exercises, designed on the basis of a feature geometry representation of the misarticulation, can be used.

The study of phonological rules and processes has also found application in the study of speech disorders. Edwards & Shriberg (op.cit.:215-248) list the following studies: Compton (1970); Oller (1971); Edwards & Bernhardt (1973); Lorentz (1974); Grunwell (1975); Ingram (1976); Dinnsen et al. (1979); Maxwell (1979); Leonard et al. (1980); Schwartz et al. (1980); Weiner (1981); Hodson & Paden (1981). Edwards & Shriberg (op.cit.:216) identify Compton as the first to use the principles of Generative Phonology to analyze articulation disorders. In the study the Generative rules were used to describe the misarticulation of the two subjects. The intention was to identify whether there was an underlying pattern in the misarticulations i.e. rule formalizations were used as a diagnostic tool. Given that Compton was attempting to identify an underlying error pattern, the Generative use of distinctive feature classes is useful. In therapy correcting the underlying error would imply rectifying the entire class of errors.

The study of disorders also has links to the theoretical issue of language-specific investigation. The Generative trend and several subsequent trends (Autosegmental Phonology, Dependency Phonology, Optimality Theory) have been preoccupied with describing language processes using a universal inventory or universal constraints. Clinicians note that disorders can have both language-specific and universal application. For example, Yavas & Lamprecht (1988) investigated speech errors in Brazilian children with the specific aim of contributing "to the discussion of universal versus language-specific features in disordered phonology" (op.cit.:330). Similarly, Bortolini & Leonard (1991) examined phoneme acquisition in Italian children with normal and disordered phonologies. The results of the Bortolini & Leonard (1991:2) study confirmed that of other studies, namely "the errors of children with phonological disorders are also somewhat sensitive to the phonological details of the ambient language." It follows that if the African languages wish to develop intervention strategies to aid children and adults with language-specific disorders, an intensive phonetic and phonological analysis of errors must be undertaken.

However, there are indications of universal tendencies with certain disorders. A study by Dogil & Mayer (1998) examines a Xhosa subject who, following a cerebral vascular accident, was afflicted with Apraxia[3]. Their conclusion (op.cit.:182) is that

> …very clear and statistically significant tendencies which single out the degree of phonological specification as a main factor defining the syndrome of apraxia of speech.

In this study the subject was required to read out loud a corpus of words. The results[4] reflected that a higher number of errors occurred for the sounds /b, t, k, s, z, d, ph, th, kh/ as opposed to clicks and affricates. Dogil & Mayer (1998) explain this as simple, underspecified sounds posing greater difficulty than overspecified sounds. Acknowledging the limitations of the study, Dogil & Mayer (1998:180) nevertheless state that a study of this nature can make predictions about errors that are found in "underspecified and highly coarticulated units of speech". So there is room for the inclusion of universal applications.

In this section phonological representational structures (the basis of Feature Geometry Theory) were shown to have a positive role in the study of disordered phonologies. Citing the Tyler & Saxman (1991) and Bernhardt (1992a & 1992b) examples demonstrates the usefulness of phonological representation not only in the study of disordered phonologies but also in intervention strategies. But, it is equally vital for the phonological representation to be comprehensive i.e. include articulatory and acoustic information. And that information can only be obtained using the experimental approach. Essentially a cycle operates. The experimental approach informs phonological representation which in turn facilitates the study of disordered phonologies. Based on the nature of the disorder, intervention strategies can be developed. Chen et al. (2000:304), commenting in general about the link between models of speech production and the study of speech disorders, state:

> The study of individuals with speech disorders gives one an opportunity to examine situations where some components of the models are presumed to operate in an atypical or deviant manner. If the nature of the dysfunctioning component can be assessed, then there is an opportunity to deepen our knowledge of how this component might function in the overall speech production process.

At the theoretical level the universal versus language-specific debate also impacts on the study of disordered phonologies. The discussion of the Yavas & Lamprecht (1988), Bortolini & Leonard (1991) and Dogil & Mayer (1998) studies illustrate that both language-specific and universal applications have their benefits.

5.4. Future Research

The experimental nature of this study has limitless possibilities for the Bantu languages. Firstly, the results of this study apply to Zulu only. It would interesting to conduct a similar study for the other Nguni languages and the Bantu languages, in which Intrusive Stop Formation obtains, to determine whether the results of this study can be generalized. Secondly experimental work can examine other phonological processes. For example:

- Differences in the duration of the lexical nasal and the nasal which is a product of the Nasal Assimilation process
- The effects of the vowel on the duration of consonants and nasals
- Full investigation into diachronic epenthesis in Zulu and other Bantu languages
- Duration of nasals during the derivation of clicks
- Perception studies focusing specifically on intrusive stops have had limited application elsewhere – cf. Warner (1998) and Warner & Weber (2001). Given that it has been experimentally determined that durational differences

obtain between pure and derived affricates, it would be interesting to determine if listeners perceive these differences.

5.5. Concluding Remarks

In summary, *Intrusive Stop Formation in Zulu: An Application of Feature Geometry Theory,* which was a combinatory qualitative-quantitative study, has achieved the following:

- Highlighted the flaws of Generative Phonology and identified the main reasons which motivated for the development of Feature Geometry Theory
- Offered a critical analysis of Feature Geometry Theory
- Based on the Laboratory Phonology approach, conducted an experimental investigation into the duration of pure and derived affricates
- Utilized the experimental results on the factor Duration to disambiguate pure and derived affricates and inform an integrated description of the Intrusive Stop Formation process
- Explained that an experimental approach is crucial for the development of HLT systems.
- Discussed the implications of phonological representation for the study of disordered phonologies

This study has sought what Kawasaki-Fukumori (1992:84) terms a "physically-based phonological" theory. Hence, the adoption of an eclectic framework – one which includes the Laboratory Phonology approach, constraint-based approach and Feature Geometry Theory. While some may be critical of eclecticism and suggest that this is a breeding ground for a hotchpotch of theories, one can deduce from 4.4.2 that very cogent explanation is demanded of the eclectic approach used in this study. Ohala (1995b:88) suggests that Phonology is about the

> establishment of sound philosophical and scientific criteria for what constitute valid explanations in the first place i.e. ones that avoid circularity, that exclude unknown ("occult") entities and forces, and ones subject to empirical evaluation".

All those criteria are fulfilled in this study. Moreover, while the explanatory technique, acoustic phonetics and empirical data is new, many traditional concepts are present in the eclectic framework. Firstly, Distinctive Feature Theory is paramount. This theory, which has its origins in *PSA*, remains dynamic in Phonology (cf. Mielke:2004). Secondly, notational conventions, although metamorphosized, endure. Thirdly, the articulatory bias remains.

This study is a modest contribution towards not just an eclectic framework but an approach which has been gaining momentum since the publication of *Papers in Laboratory Phonology 1* (1990). In this century that approach is going to forge ahead, particularly as the aspect of speech perception rises in prominence (cf. Lindblom:1995, Fowler:1995 and Warner:2002). But what this study has not lost sight of is developing the explanatory power of Phonology. All the eclecticism in this study has facilitated a more lucid explanation of the Intrusive Stop Formation process in Zulu. For now there is more insight into the process as there was previously. But as any student of Phonetics and Phonology is ever aware of - theoretical development is rapid. It seems appropriate, in the year which the field of Experimental Phonetics honours John Ohala[5] to conclude with his words which succinctly sum up the position of the scholar in Phonology:

> The history of science tells us (if our philosophy does not) that solutions which seem to merit our allegiance at one time are likely to be overthrown eventually and replaced by other solutions. All we can hope for are viable candidate solutions which avoid certain well known flaws and which possess certain advantages.
>
> Ohala (1990:158-159)

Notes

1. Gierut, Cho & Dinnsen (1993) reiterate the need for the use of feature geometry representations in the study of phonological acquisition. Their position is that a mismatch exists between the phonological representation of a child and an adult, with the adult system being the target for the child. Therefore using the illustrative feature geometry structure the process of language acquisition can be documented. Gierut, Cho & Dinnsen (ibid.) also note that the hierarchical representation in feature geometry mirrors the order of acquisition.
2. Chin & Dinnsen (1991) also use the feature geometry framework in the study of the phonologies of forty misarticulating children.
3. Apraxia is a condition that affects speech production. Speech comprehension, reading and writing pose no difficulty.
4. Standard statistical tests of chance estimation were applied to the results to determine whether phonological specification (as opposed to chance) influenced the error corpus. The statistical tests revealed that errors between coronal and dorsal sounds were not random. Similarly, significant differences existed between coronal and labial sound errors. However, errors between dorsal and labial sounds were random.
5. A conference organized by the Institut de la Communication Parlée, Université Stendhal entitled “A Century of Experimental Phonetics: Its History and Development from Théodore Rosset to John Ohala” (24-25 February 2005) pays tribute to Ohala’s contribution to the development of the experimental paradigm in Phonetics and Phonology.

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APPENDIX A

A1 – Spectrograms – *ukutsavuza*

Figure One (A1)
Speaker One - *Ngithi ukutsavuza manje*

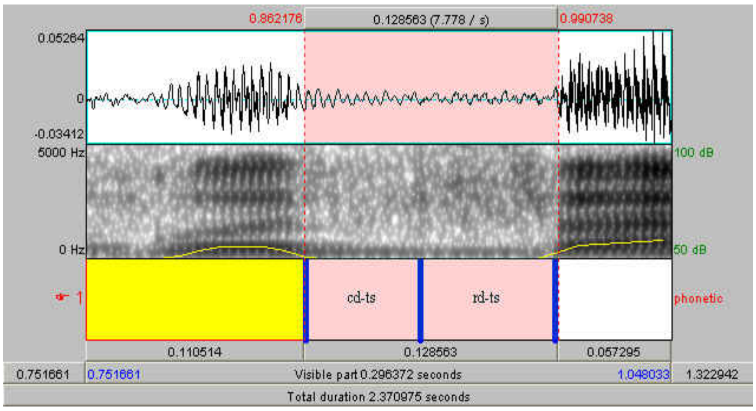


Figure Two (A1)
Speaker Two - *Ngithi ukutsavuza manje*

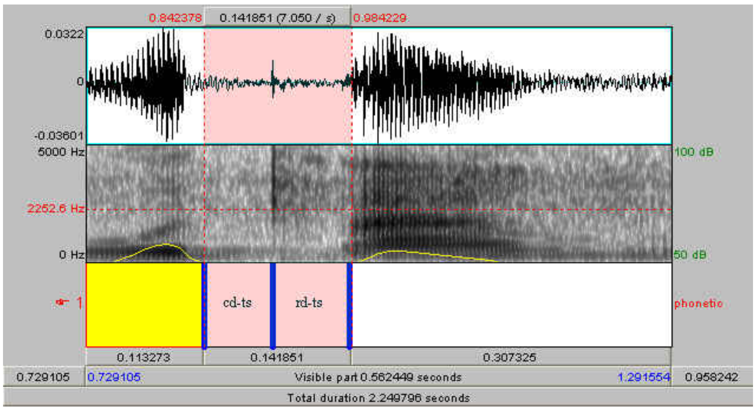


Figure Three (A1)
Speaker Three - *Ngithi ukutsavuza manje*

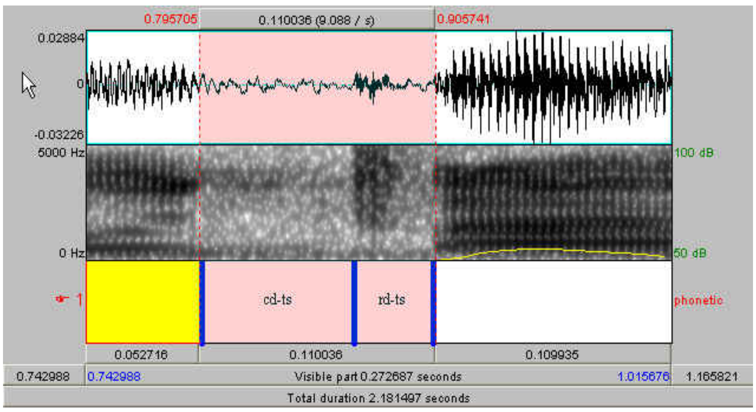


Figure Four (A1)
Speaker Four - *Ngithi ukutsavuza manje*

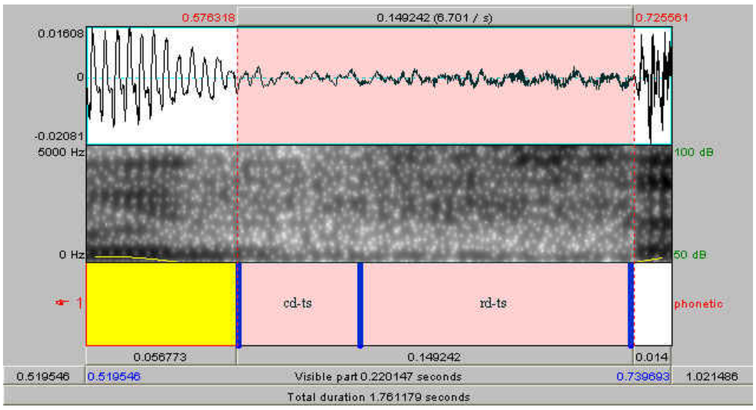
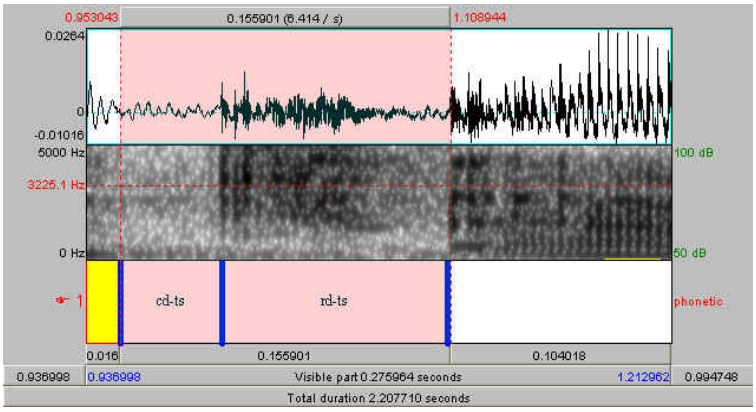


Figure Five (A1)
Speaker Five - *Ngithi ukutsavuza manje*



A2 – Spectrograms – *ukutsaka*

Figure Six (A2)
Speaker One - *Ngithi ukutsaka manje*

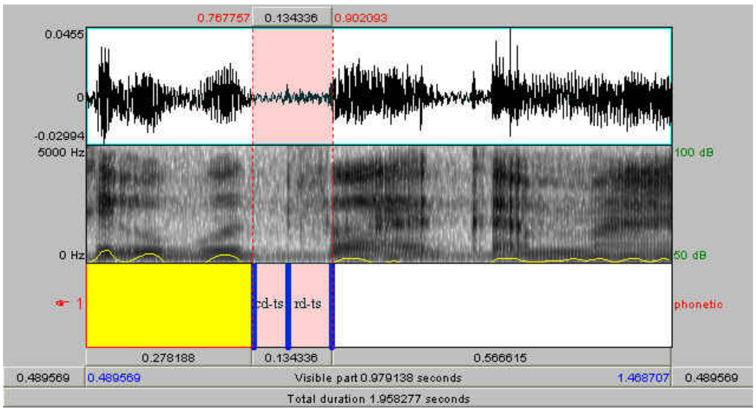


Figure Seven (A2)
Speaker Two - *Ngithi ukutsaka manje*

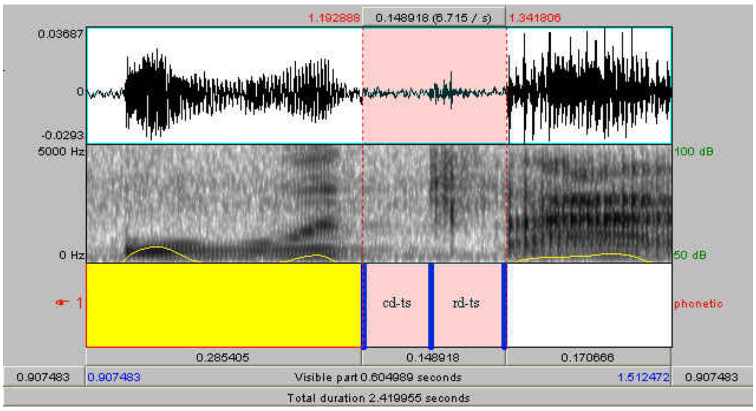


Figure Eight (A2)
Speaker Three - *Ngithi ukutsaka manje*

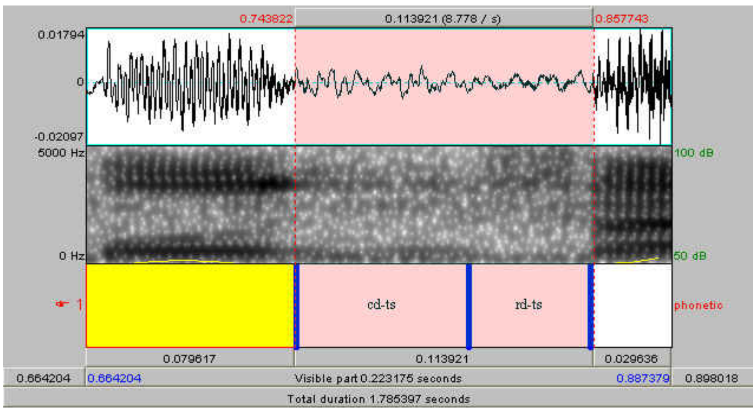


Figure Nine (A2)
Speaker Four - *Ngithi ukutsaka manje*

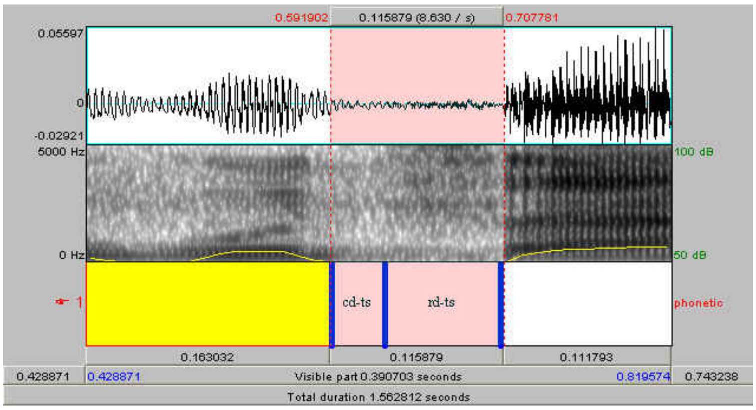
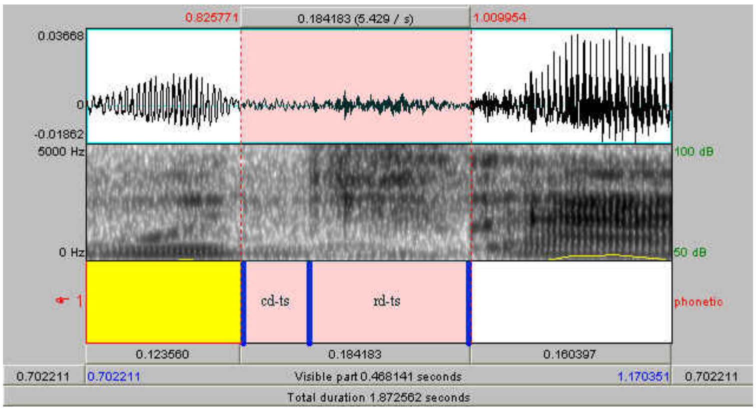


Figure Ten (A2)
Speaker Five - *Ngithi ukutsaka manje*



A3 – Spectrograms – *insalelo*

Figure Eleven (A3)
Speaker One - *Ngithi insalelo manje*

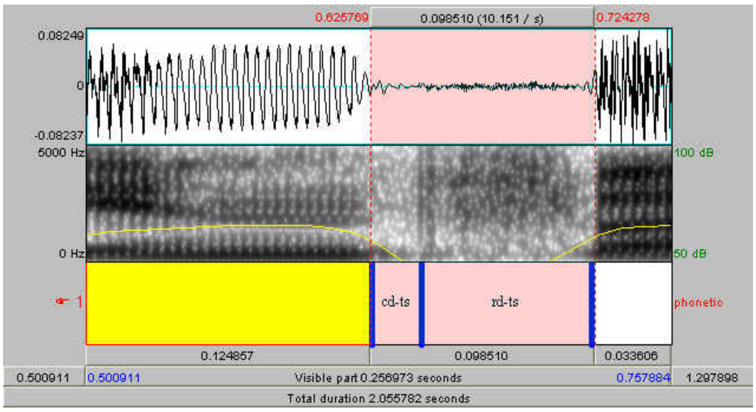


Figure Twelve (A3)
Speaker Two - *Ngithi insalelo manje*

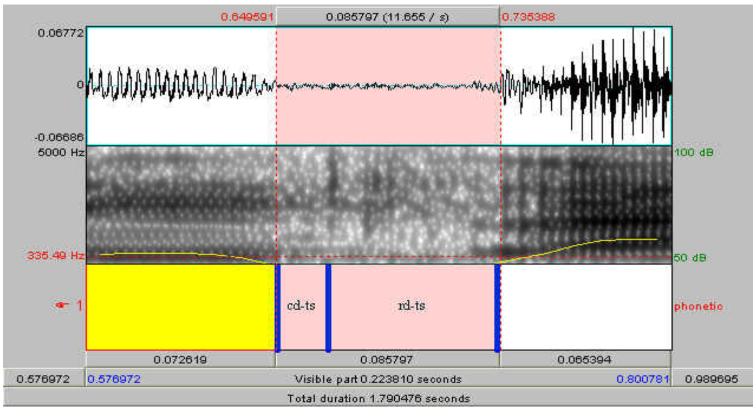


Figure Thirteen (A3)
Speaker Three - *Ngithi insalelo manje*

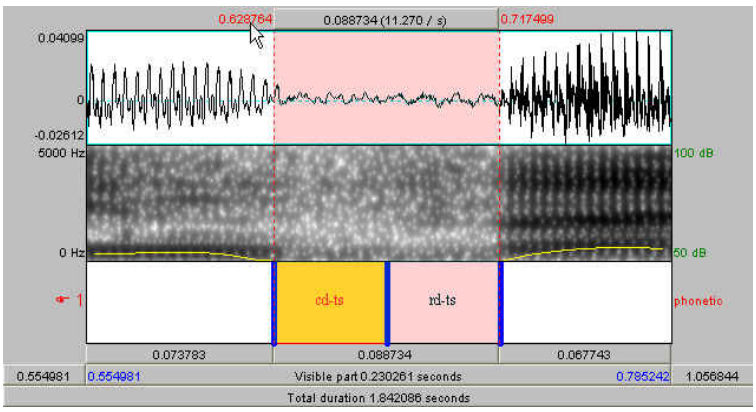


Figure Fourteen (A3)
Speaker Four - *Ngithi insalelo manje*

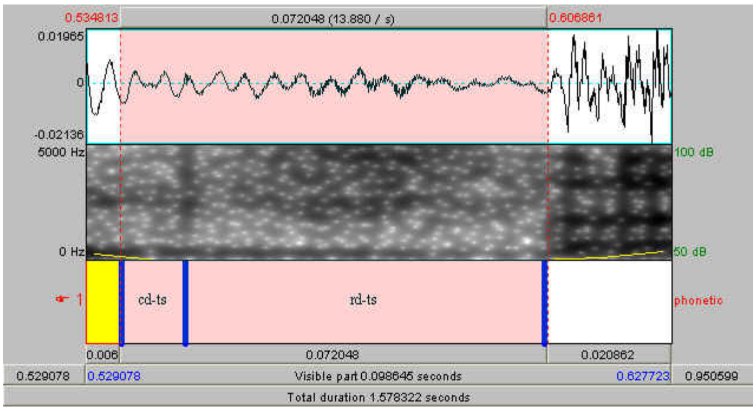
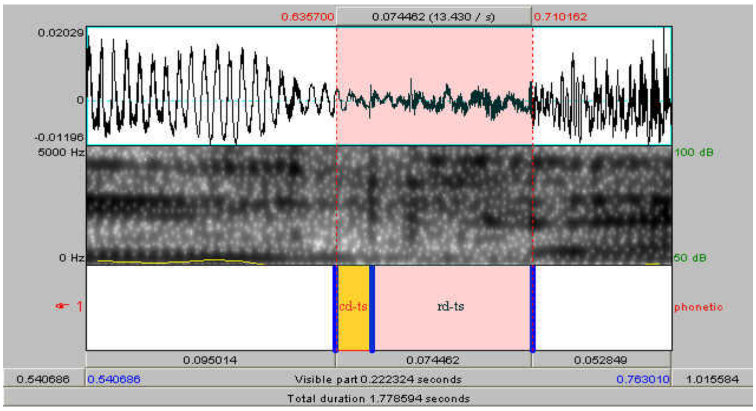


Figure Fifteen (A3)
Speaker Five - *Ngithi insalelo manje*



A4 – Spectrograms - *insangano*

Figure Sixteen (A4)
Speaker One - *Ngithi insangano manje*

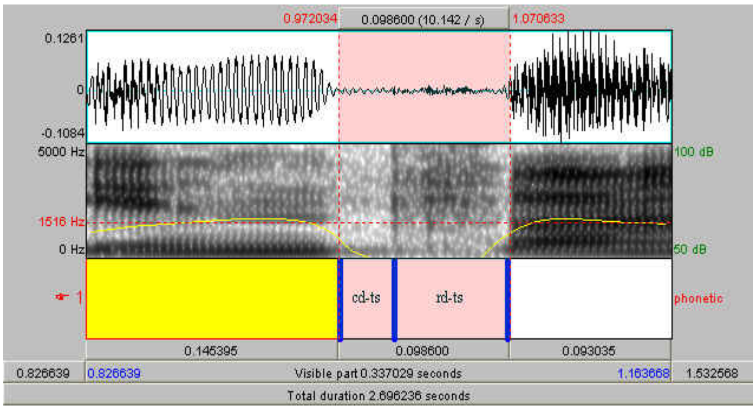


Figure Seventeen (A4)
Speaker Two - *Ngithi insangano manje*

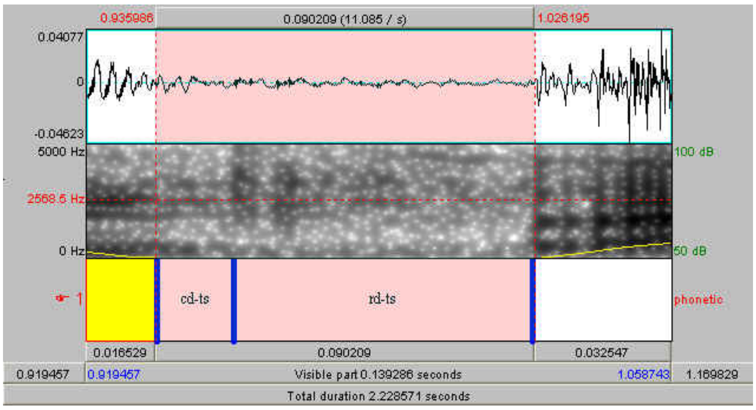


Figure Eighteen (A4)
Speaker Three - *Ngithi insangano manje*

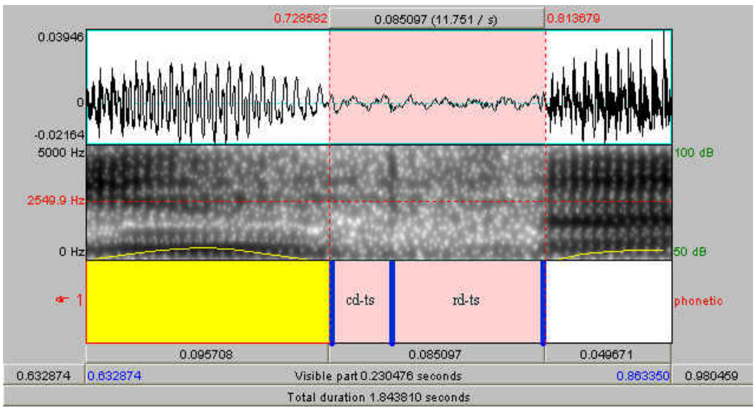


Figure Ninteen (A4)
Speaker Four - *Ngithi insangano manje*

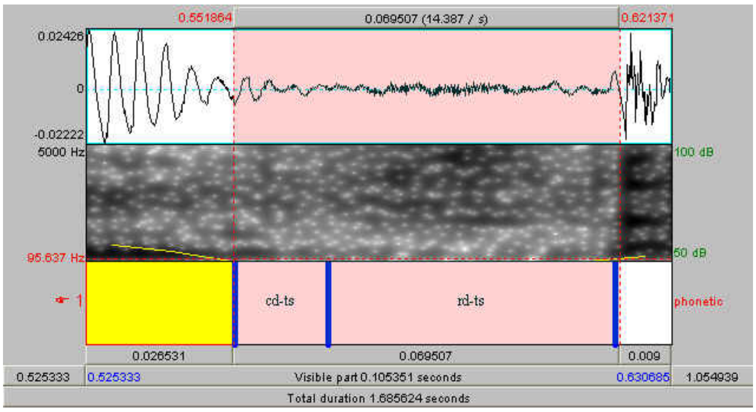
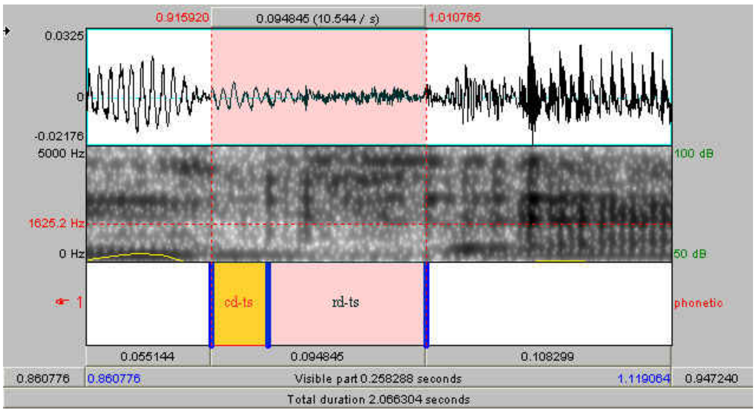


Figure Twenty (A4)
Speaker Five - *Ngithi insangano manje*



A5 – Spectrograms – *ukutshuma*

Figure Twenty One (A5)
Speaker One – *Ngithi ukutshuma manje*

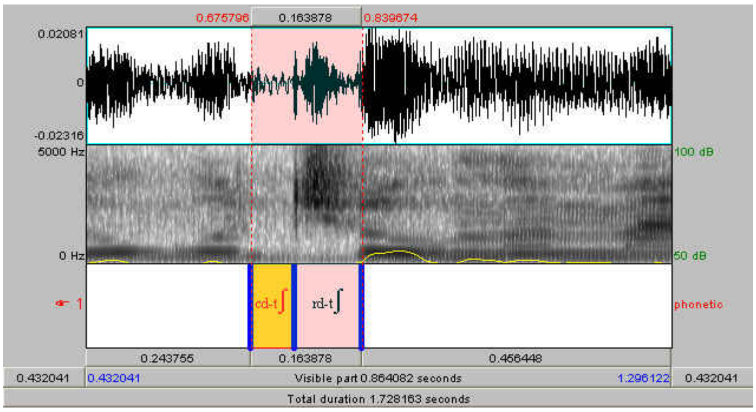


Figure Twenty Two (A5)
Speaker Two – *Ngithi ukutshuma manje*

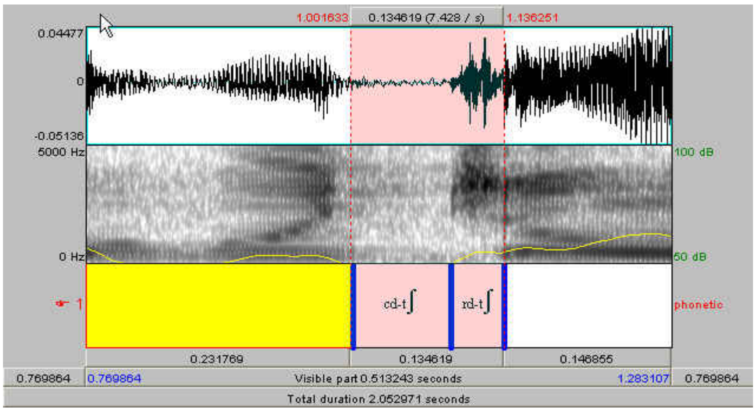


Figure Twenty Three (A5)
Speaker Three – *Ngithi ukutshuma manje*

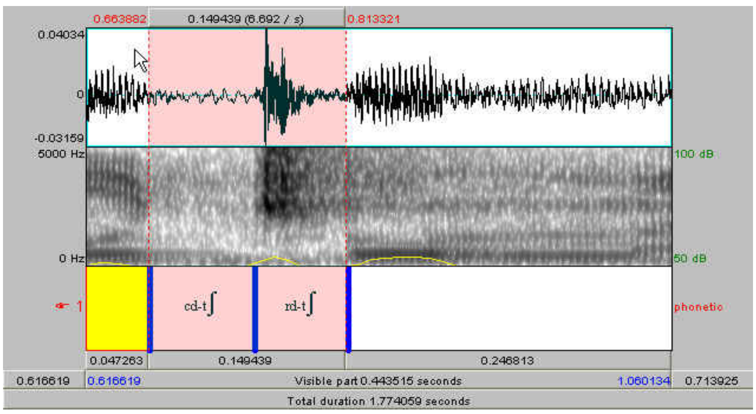


Figure Twenty Four (A5)
Speaker Four – *Ngithi ukutshuma manje*

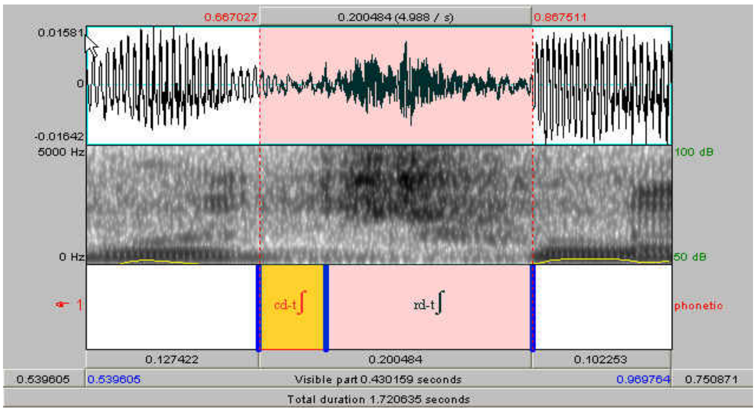
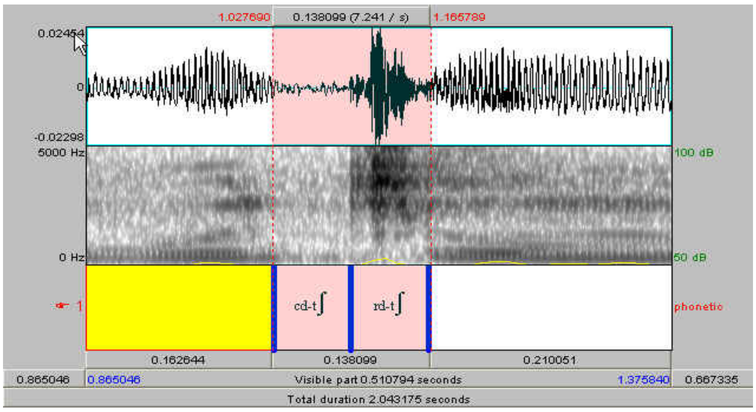


Figure Twenty Five (A5)
Speaker Five – *Ngithi ukutshuma manje*



A6 – Spectrograms - *ukutshaza*

Figure Twenty Six (A6)
Speaker One – *Ngithi ukutshaza manje*

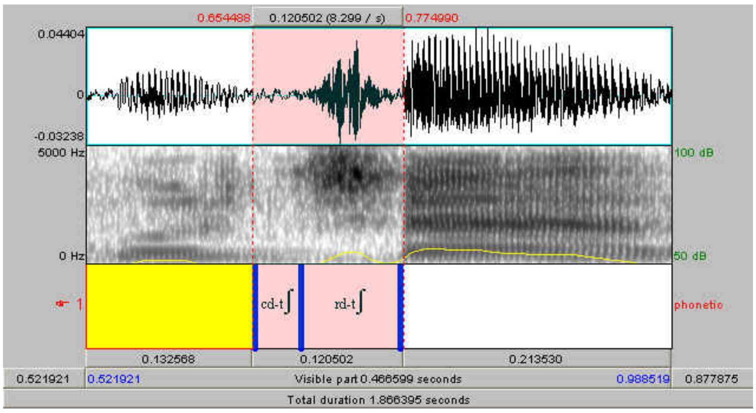


Figure Twenty Seven (A6)
Speaker Two – *Ngithi ukutshaza manje*

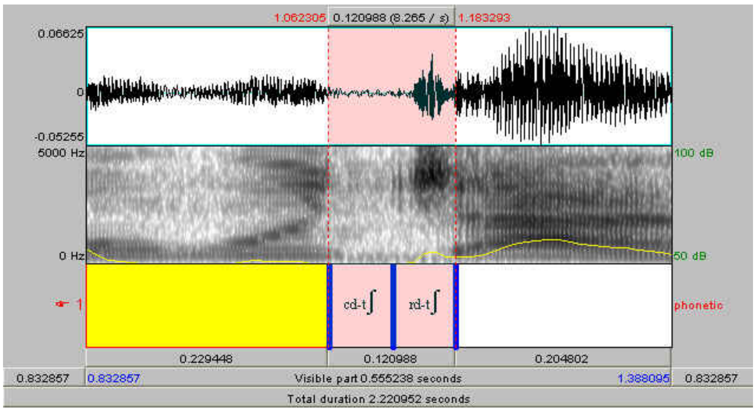


Figure Twenty Eight (A6)
Speaker Three – *Ngithi ukutshaza manje*

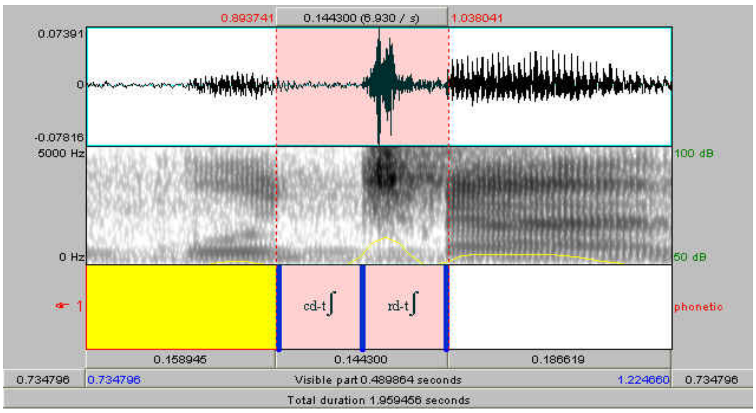


Figure Twenty Nine (A6)
Speaker Four – *Ngithi ukutshaza manje*

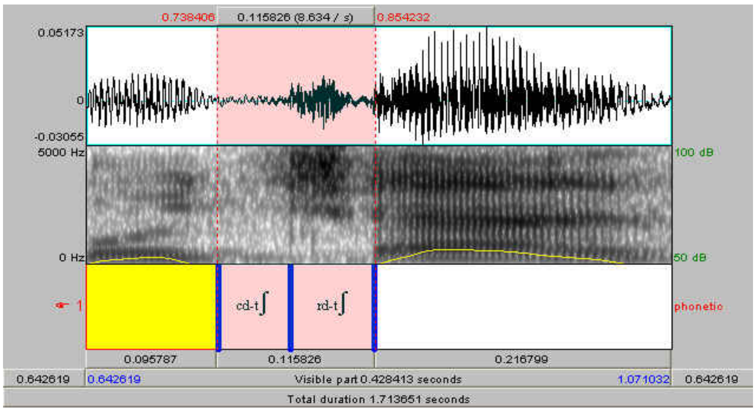
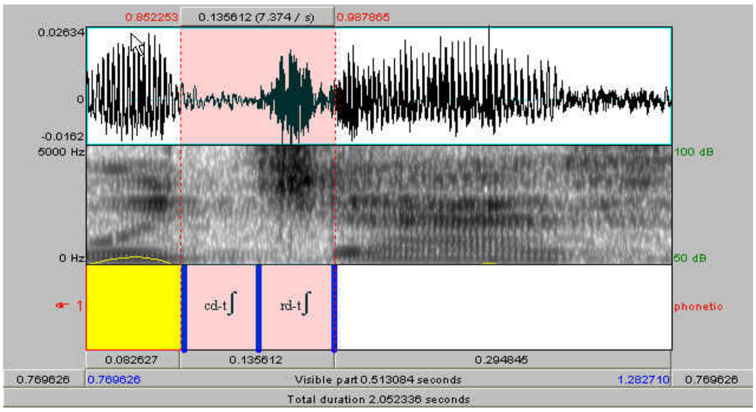


Figure Twenty Thirty (A6)
Speaker Five – *Ngithi ukutshaza manje*



A7 – Spectrograms - *intshawula*

Figure Thirty One (A7)
Speaker One – *Ngithi intshawula manje*

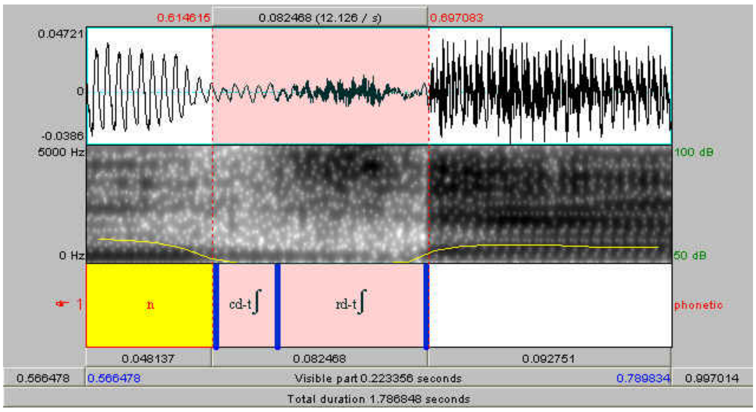


Figure Thirty Two (A7)
Speaker Two – *Ngithi intshawula manje*

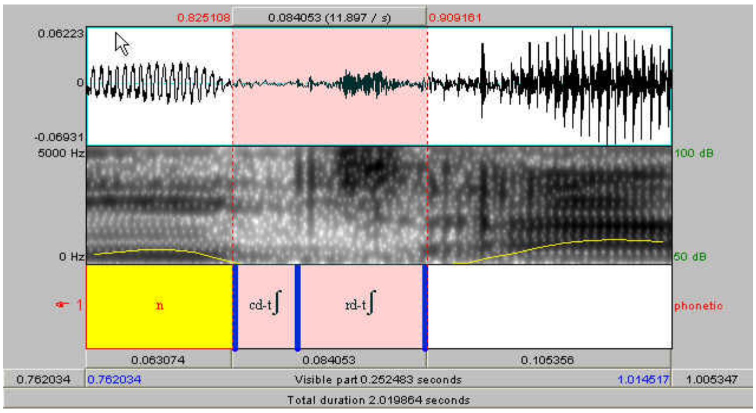


Figure Thirty Three (A7)
Speaker Three – *Ngithi intshawula manje*

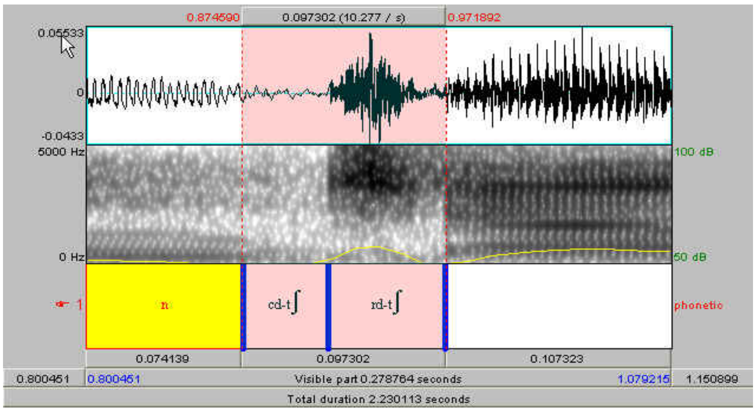


Figure Thirty Four (A7)
Speaker Four – *Ngithi intshawula manje*

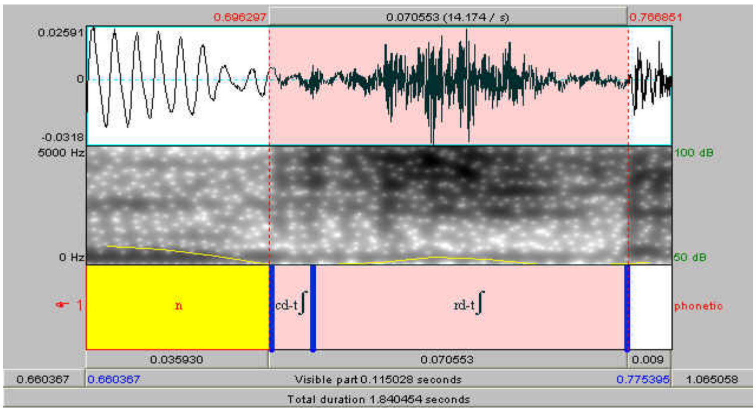
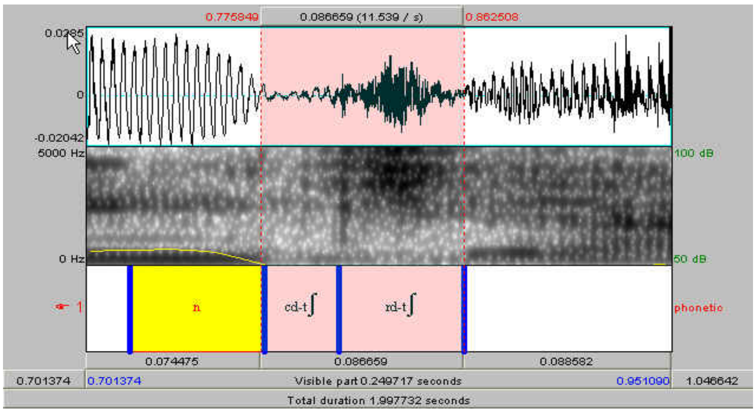


Figure Thirty Five (A7)
Speaker Five – *Ngithi intshawula manje*



A8 – Spectrograms - *intshumayelo*

Figure Thirty Six (A8)
Speaker One – *Ngithi intshumayelo manje*

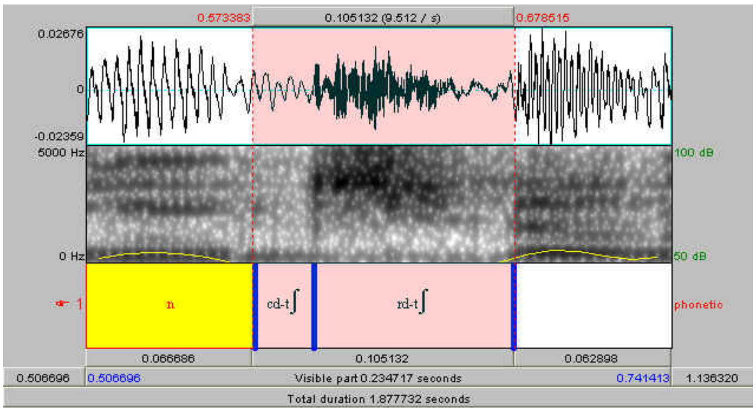


Figure Thirty Seven (A8)
Speaker Two – *Ngithi intshumayelo manje*

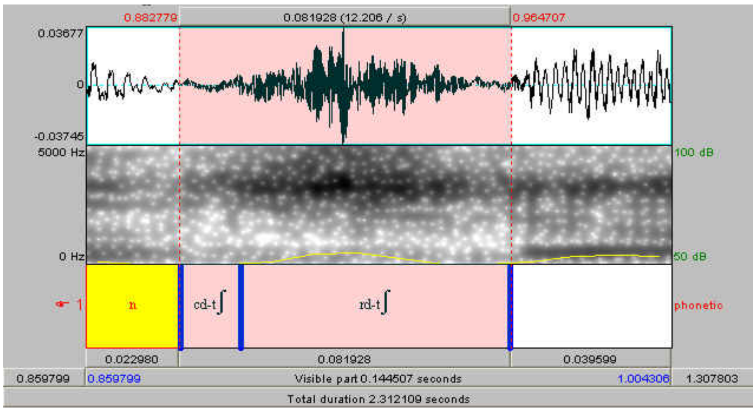


Figure Thirty Eight (A8)
Speaker Three – *Ngithi intshumayelo manje*

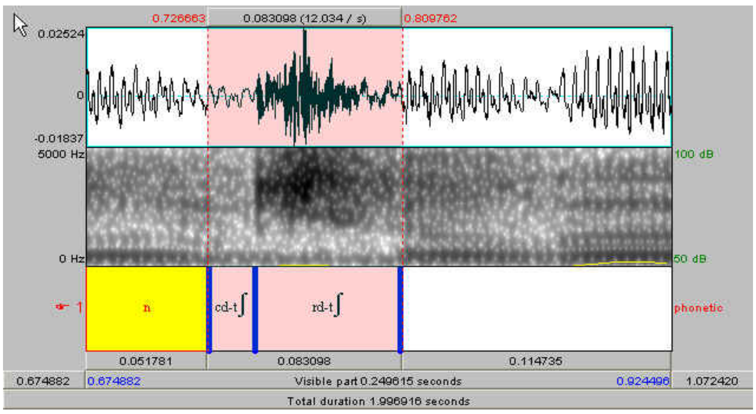


Figure Thirty Nine (A8)
Speaker Four – *Ngithi intshumayelo manje*

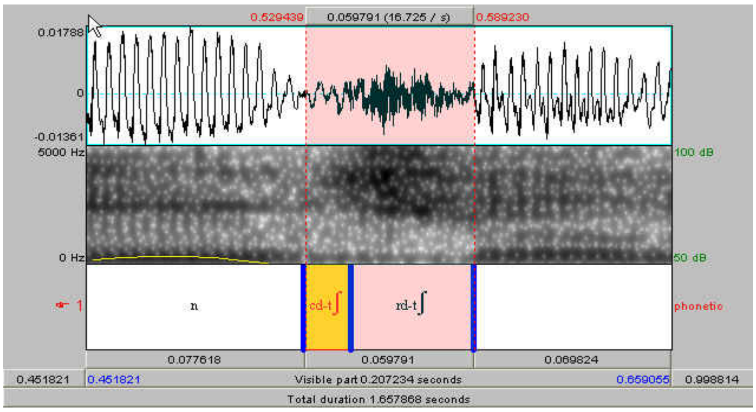
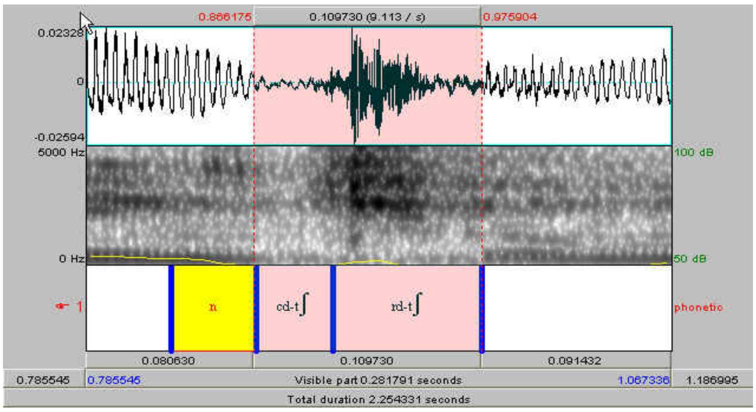


Figure Forty (A8)
Speaker Five – *Ngithi intshumayelo manje*



A9 – Spectrograms – *ukuklaza*

Figure Forty One (A9)
Speaker One – *Ngithi ukuklaza manje*

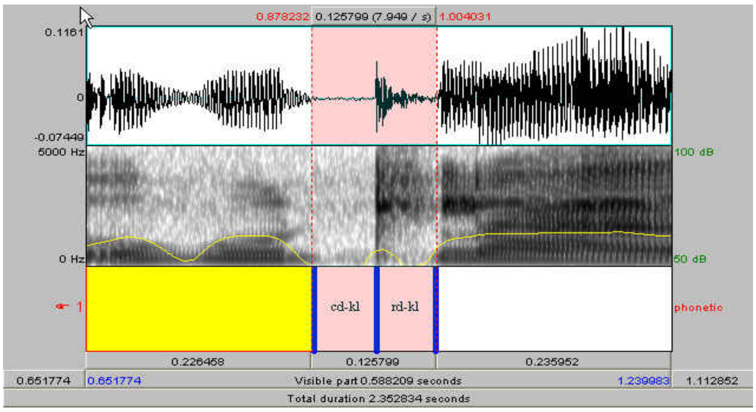


Figure Fourty Two (A9)
Speaker Two – *Ngithi ukuklaza manje*

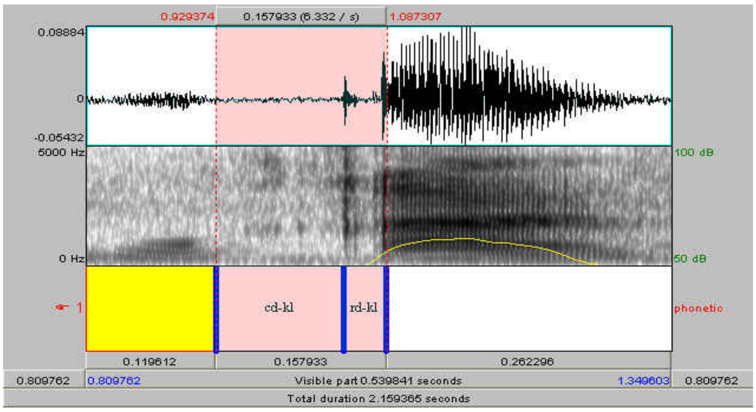


Figure Forty Three (A9)
Speaker Three – *Ngithi ukuklaza manje*

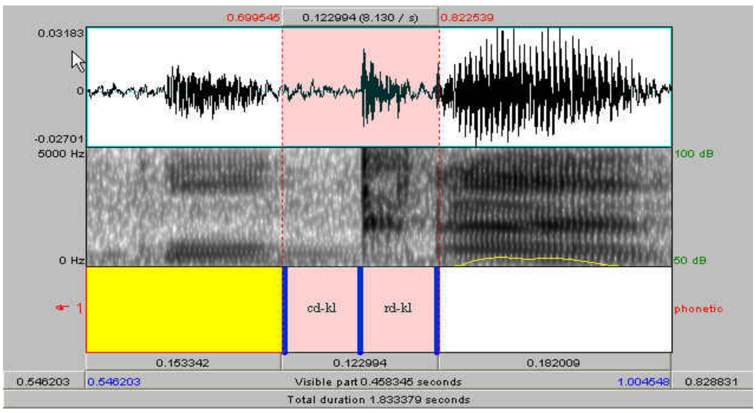


Figure Forty Four (A9)
Speaker Four – *Ngithi ukuklaza manje*

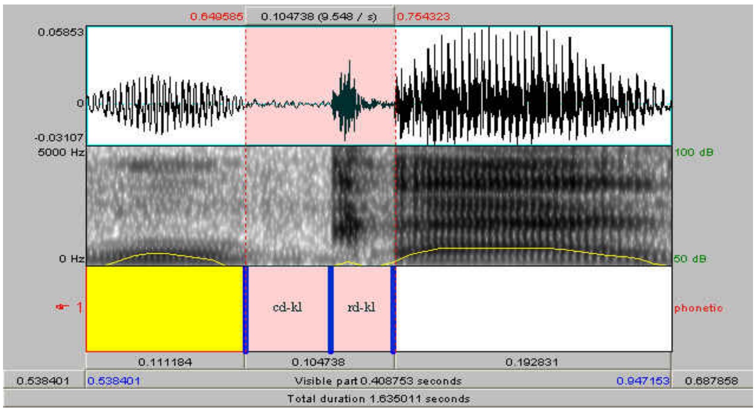
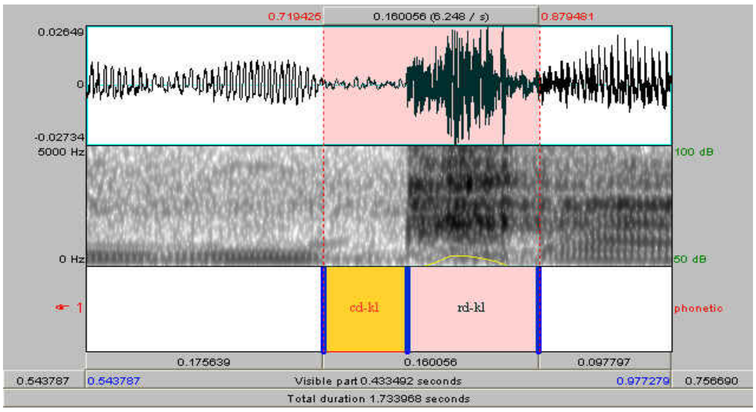


Figure Forty Five (A9)
Speaker Five – *Ngithi ukuklaza manje*



A10 – Spectrograms – *ukujabula*

Figure Forty Six (A10)
Speaker One – *Ngithi ukujabula manje*

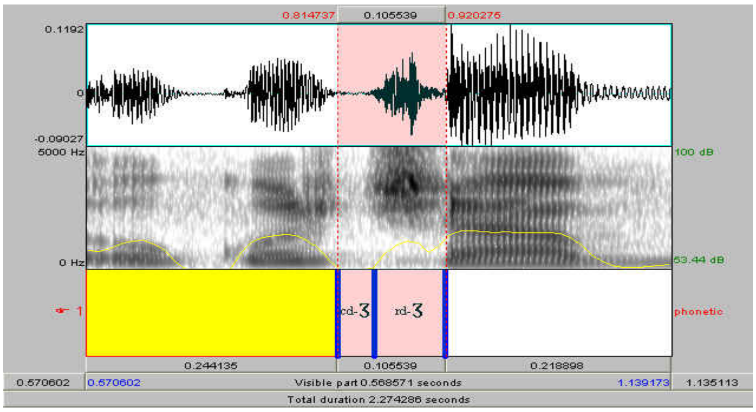


Figure Forty Seven (A10)
Speaker Two – *Ngithi ukujabula manje*

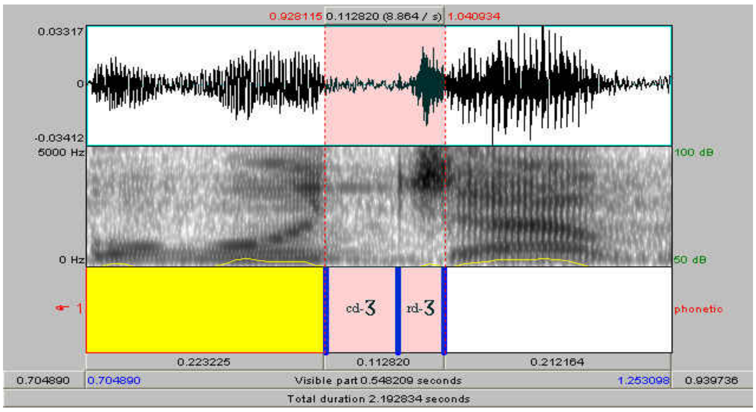


Figure Forty Eight (A10)
Speaker Three – *Ngithi ukujabula manje*

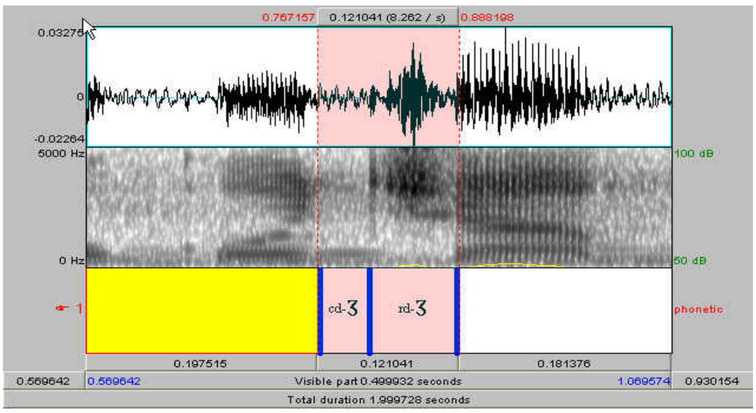


Figure Forty Nine (A10)
Speaker Four – *Ngithi ukujabula manje*

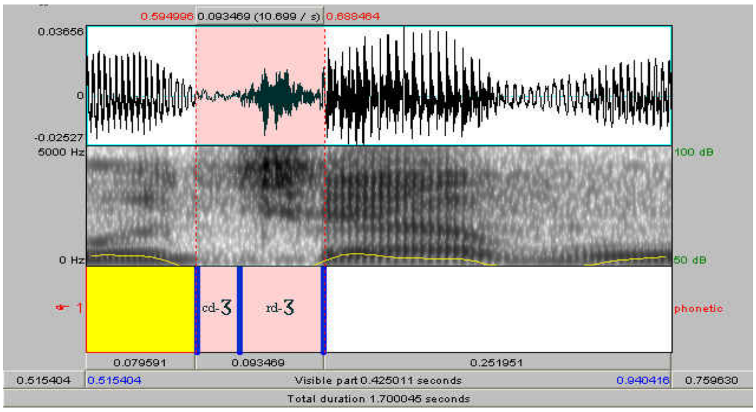
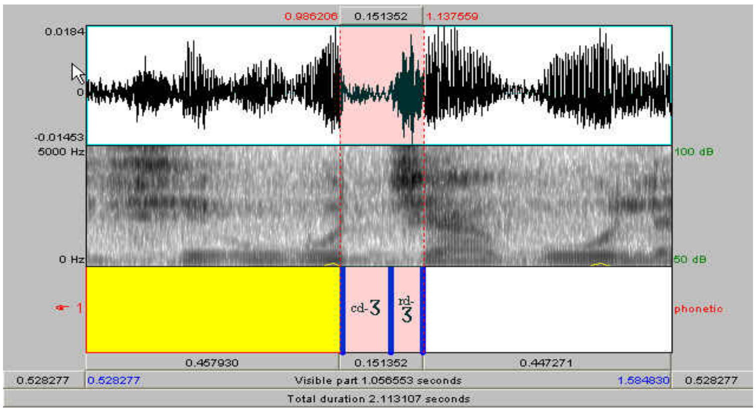


Figure Fifty (A10)
Speaker Five – *Ngithi ukujabula manje*



A11 – Spectrograms – *imfanelo*

Figure Fifty One (A11)
Speaker One - *Ngithi imfanelo manje*

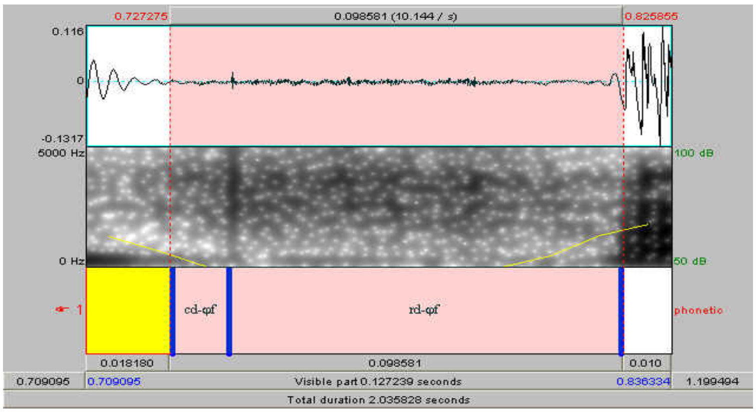


Figure Fifty Two (A11)
Speaker Two - *Ngithi imfanelo manje*

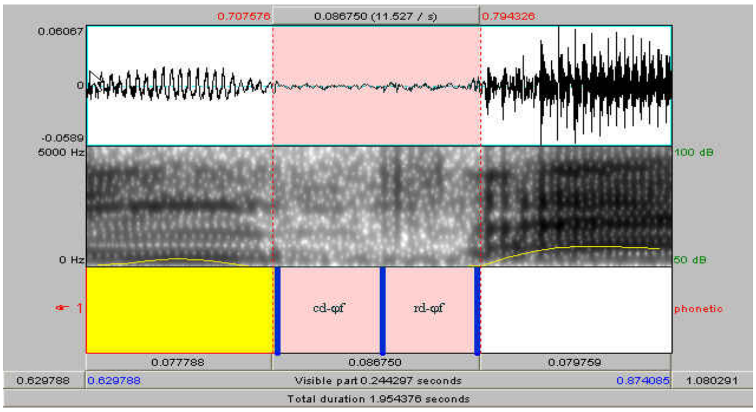


Figure Fifty Three (A11)
Speaker Three - *Ngithi imfanelo manje*

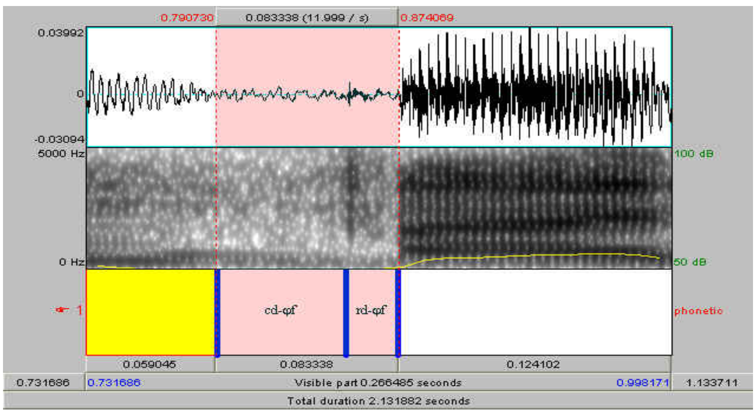


Figure Fifty Four (A11)
Speaker Four - *Ngithi imfanelo manje*

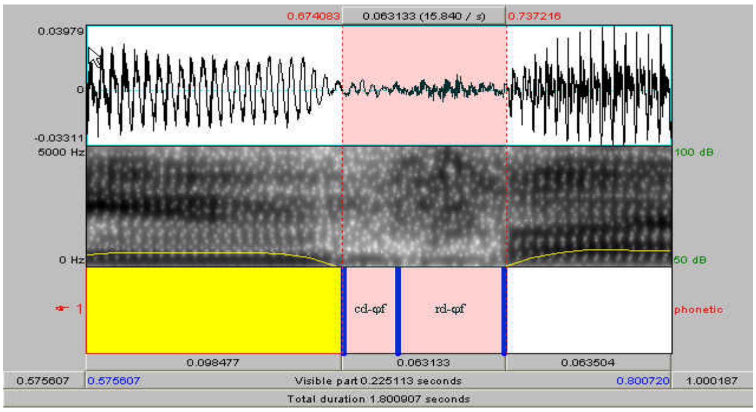
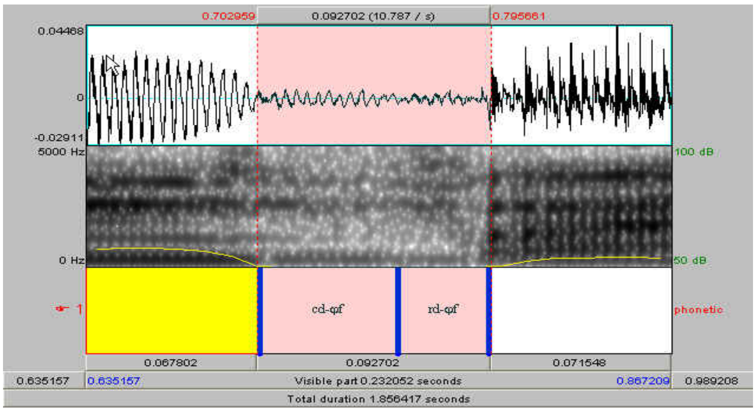


Figure Fifty Five (A11)
Speaker Five - *Ngithi imfanelo manje*



A12 – Spectrograms – *imvakazi*

Figure Fifty Six (A12)
Speaker One – *Ngithi imvakazi manje*

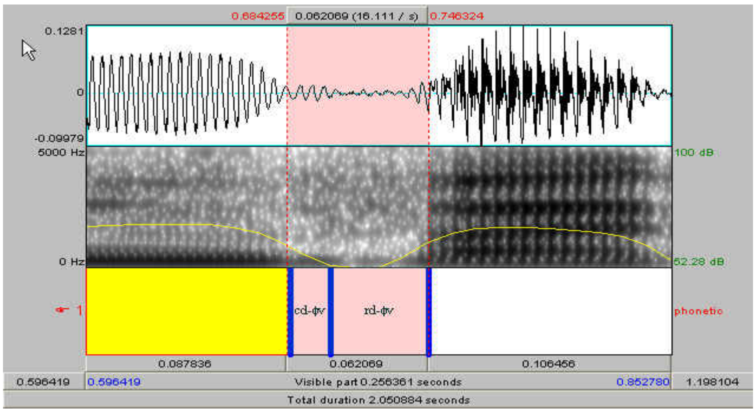


Figure Fifty Seven (A12)
Speaker Two – *Ngithi imvakazi manje*

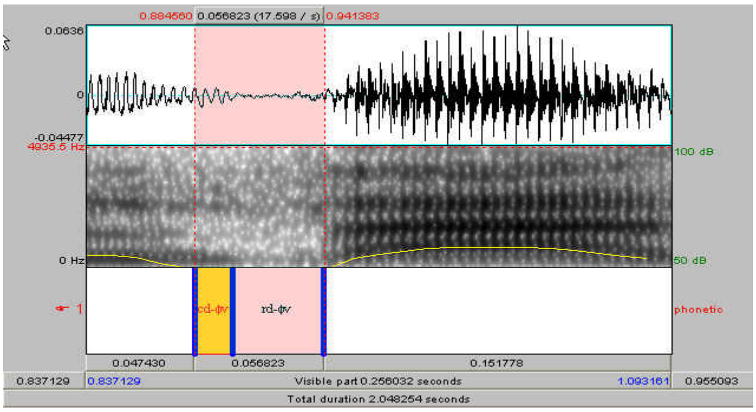


Figure Fifty Eight (A12)
Speaker Three – *Ngithi imvakazi manje*

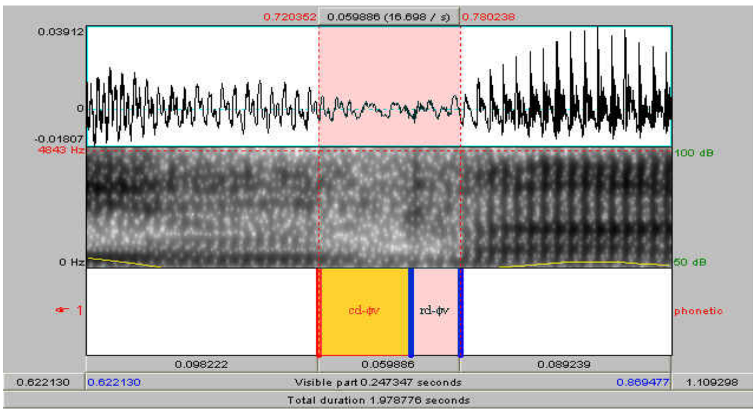


Figure Fifty Nine (A12)
Speaker Four – *Ngithi imvakazi manje*

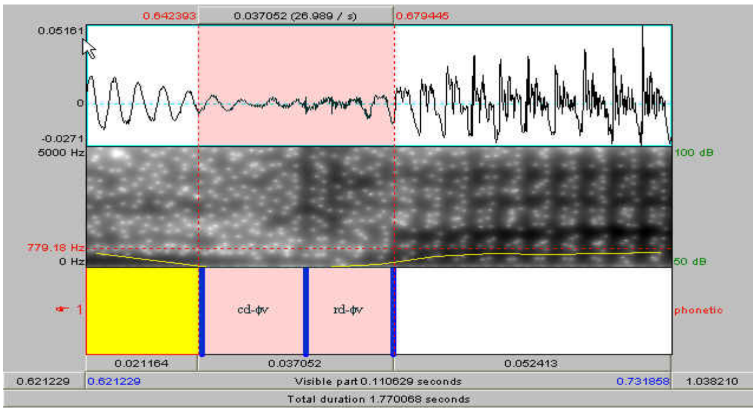
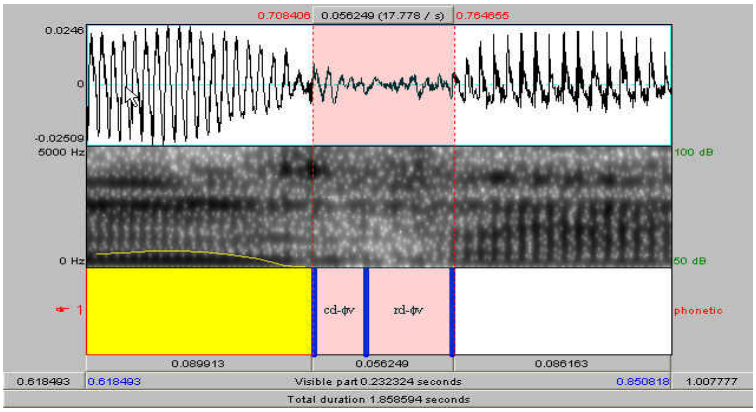


Figure Sixty (A12)
Speaker Five – *Ngithi imvakazi manje*



A13 – Spectrograms – *inzala*

Figure Sixty One (A13)
Speaker One – *Ngithi inzala manje*

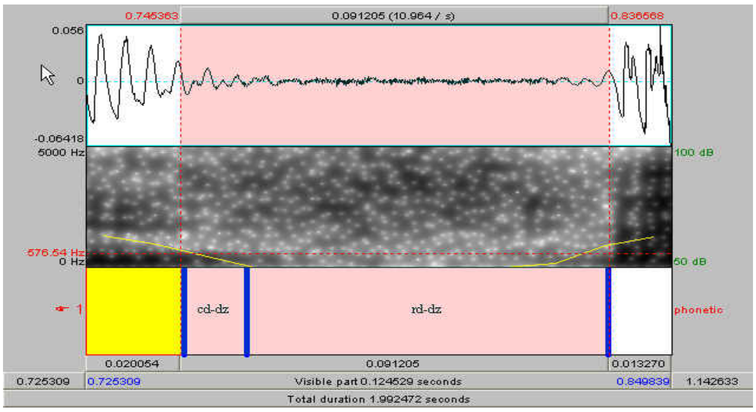


Figure Sixty Two (A13)
Speaker Two – *Ngithi inzala manje*

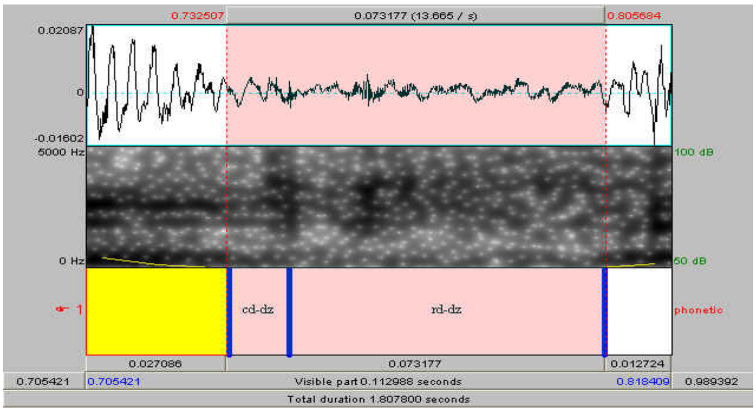


Figure Sixty Three (A13)
Speaker Three – *Ngithi inzala manje*

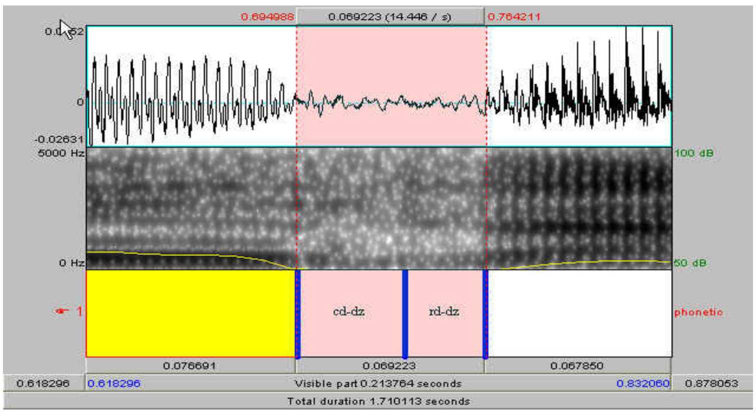


Figure Sixty Four (A13)
Speaker Four – *Ngithi inzala manje*

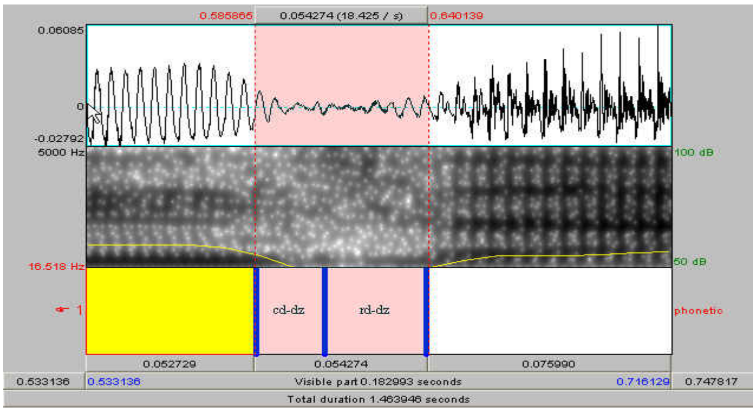
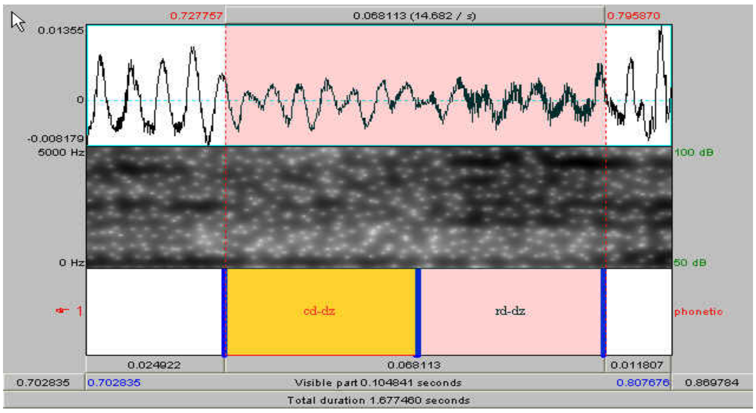


Figure Sixty Five (A13)
Speaker Five – *Ngithi inzala manje*



A14 – Spectrograms – *inhlaba*

Figure Sixty Six (A14)
Speaker One – *Ngithi inhlaba manje*

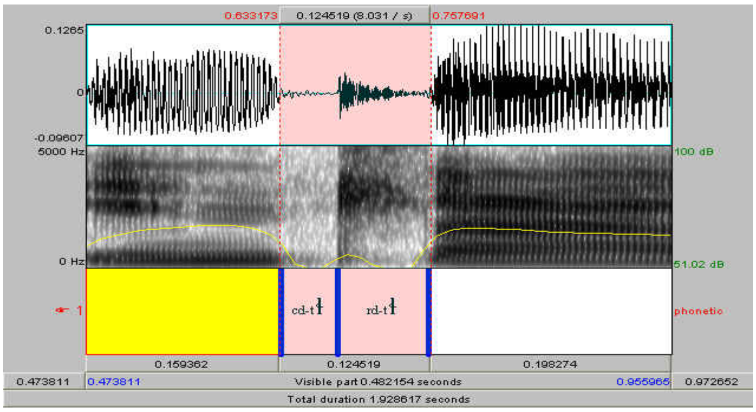


Figure Sixty Seven (A14)
Speaker Two – *Ngithi inhlaba manje*

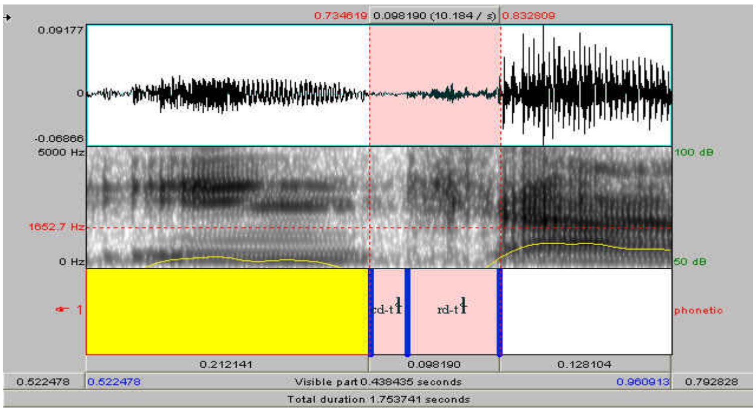


Figure Sixty Eight (A14)
Speaker Three – *Ngithi inhlaba manje*

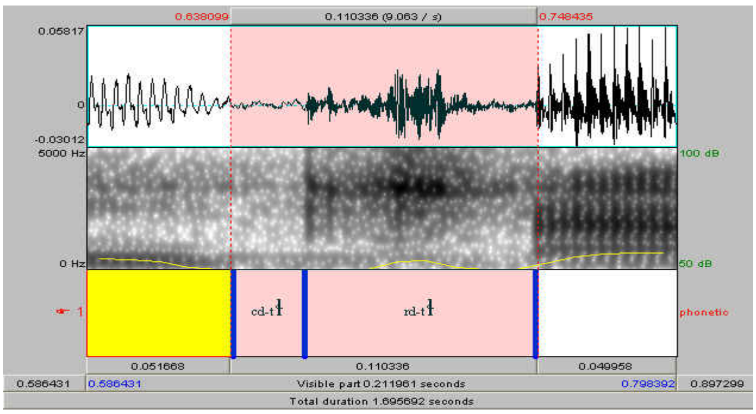


Figure Sixty Nine (A14)
Speaker Four – *Ngithi inhlaba manje*

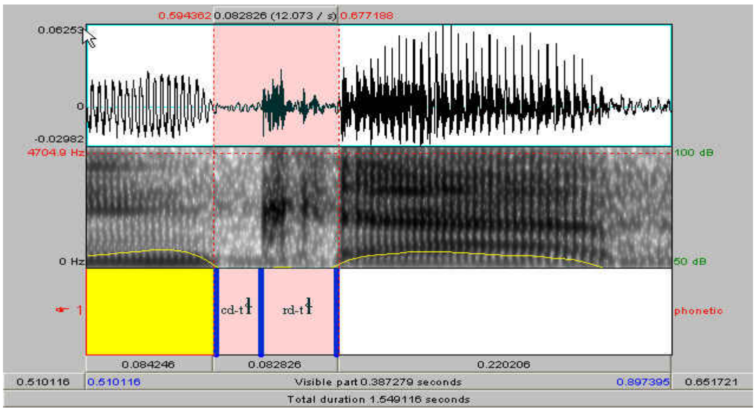
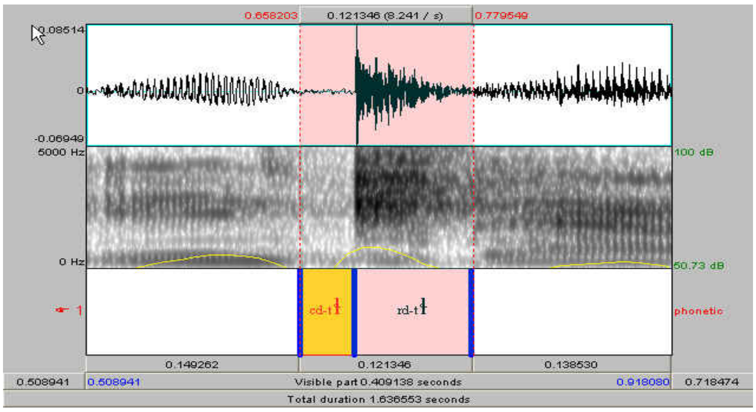


Figure Seventy (A14)
Speaker Five – *Ngithi inhlaba manje*



A15 – Spectrograms – *indlozi*

Figure Seventy One (A15)
Speaker One – *Ngithi indlozi manje*

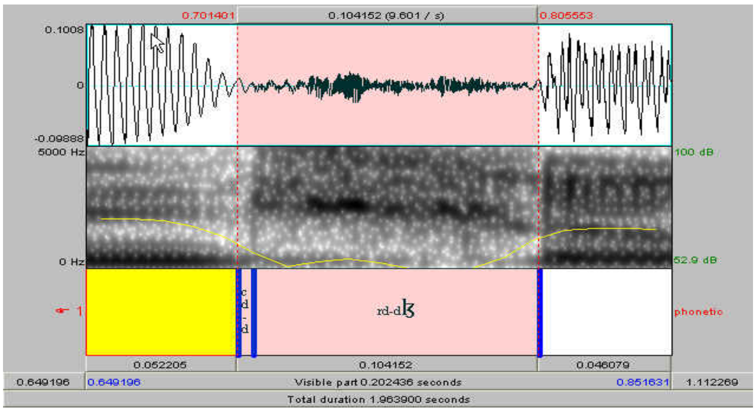


Figure Seventy Two (A15)
Speaker Two – *Ngithi indlozi manje*

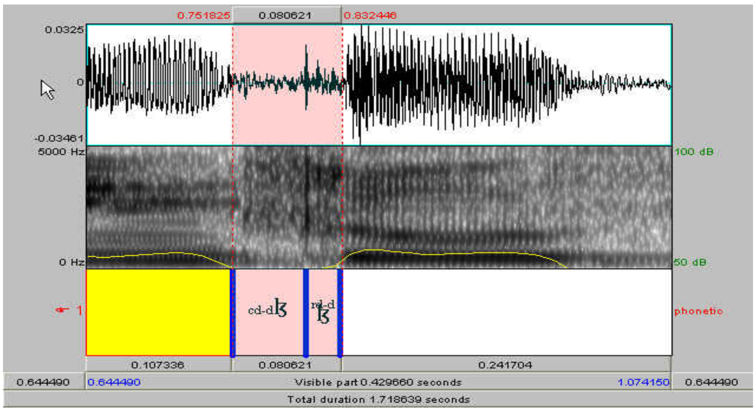


Figure Seventy Three (A15)
Speaker Three – *Ngithi indlozi manje*

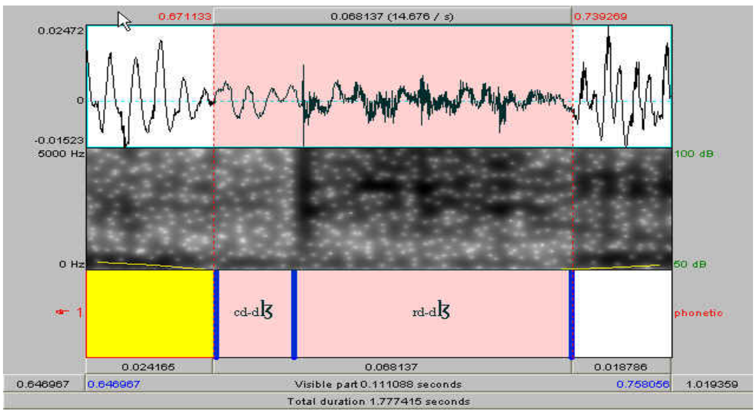


Figure Seventy Four (A15)
Speaker Four – *Ngithi indlozi manje*

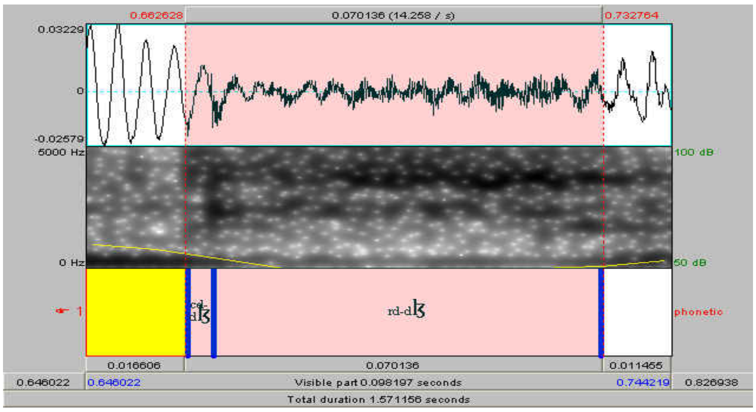
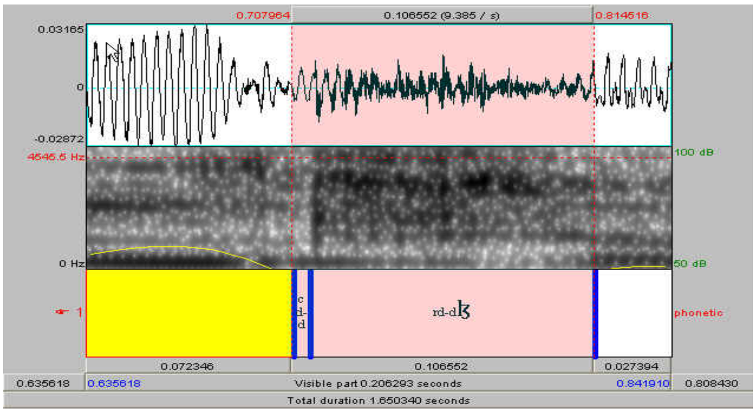


Figure Seventy Five (A15)
Speaker Five – *Ngithi indlozi manje*



APPENDIX B

CALCULATION OF DURATION

B1 Group One /ts'/

Pure /ts'/ in uku**ts**avuza						
Closure Duration		**Speaker 1**	**Speaker 2**	**Speaker 3**	**Speaker 4**	**Speaker 5**
	xmin	0.862534	0.842468	0.796885	0.576716	0.953259
	xmax	0.92085	0.908595	0.867759	0.622572	1.001004
	Total	0.058316	0.066127	0.070874	0.045856	0.047745
Release Duration		**Speaker 1**	**Speaker 2**	**Speaker 3**	**Speaker 4**	**Speaker 5**
	xmin	0.92085	0.908595	0.867759	0.622572	1.001004
	xmax	0.988929	0.981748	0.904621	0.723844	1.107273
	Total	0.068079	0.073153	0.036862	0.101272	0.106269
Total Duration		***0.126395***	***0.13928***	***0.107736***	***0.147128***	***0.154014***

Pure /ts'/ in uku**ts**aka						
Closure Duration		**Speaker 1**	**Speaker 2**	**Speaker 3**	**Speaker 4**	**Speaker 5**
	xmin	0.767756	1.194718	0.744301	0.592384	0.827868
	xmax	0.826258	1.26373	0.810217	0.628248	0.880188
	Total	0.058502	0.069012	0.065916	0.035864	0.05232
Release Duration		**Speaker 1**	**Speaker 2**	**Speaker 3**	**Speaker 4**	**Speaker 5**
	xmin	0.826258	1.26373	0.810217	0.628248	0.880188
	xmax	0.899438	1.341806	0.858925	0.705259	1.008065
	Total	0.07318	0.078076	0.048708	0.077011	0.127877
Total Duration		***0.131682***	***0.147088***	***0.114624***	***0.112875***	***0.180197***

Derived /ts'/ in insalelo						
Closure Duration		**Speaker 1**	**Speaker 2**	**Speaker 3**	**Speaker 4**	**Speaker 5**
	xmin	0.626050339	0.649942	0.628552	0.534932	0.635434
	xmax	0.647936	0.669462	0.673251	0.545823	0.648987
	Total	0.021885661	0.01952	0.044699	0.010891	0.013553
Release Duration		**Speaker 1**	**Speaker 2**	**Speaker 3**	**Speaker 4**	**Speaker 5**
	xmin	0.647936	0.669462	0.673251	0.545823	0.648987
	xmax	0.72268	0.734102	0.717963	0.606264	0.710369
	Total	0.074744	0.06464	0.044712	0.060441	0.061382
Total Duration		***0.096629661***	***0.08416***	***0.089411***	***0.071332***	***0.074935***

Derived /ts'/ in insangano						
Closure Duration		**Speaker 1**	**Speaker 2**	**Speaker 3**	**Speaker 4**	**Speaker 5**
	xmin	0.972759	0.936267	0.729511	0.552076	0.915736
	xmax	1.002601	0.954533	0.752994	0.568868	0.940912
	Total	0.029842	0.018266	0.023483	0.016792	0.025176
Release Duration		**Speaker 1**	**Speaker 2**	**Speaker 3**	**Speaker 4**	**Speaker 5**
	xmin	1.002601	0.954533	0.752994	0.568868	0.940912
	xmax	1.06924	1.025633	0.812527	0.62052	1.010765
	Total	0.066639	0.0711	0.059533	0.051652	0.069853
Total Duration		***0.096481***	***0.089366***	***0.083016***	***0.068444***	***0.095029***

B2 Group Two /tS'/

Pure /tS'/ in ukutshaza						
Closure Duration		**Speaker 1**	**Speaker 2**	**Speaker 3**	**Speaker 4**	**Speaker 5**
	xmin	0.656593	1.062894	0.895768	0.73927	0.855583
	xmax	0.693478	1.124161	0.965968	0.791894	0.920582
	Total	0.036885	0.709438	0.0702	0.052624	0.064999
Release Duration		**Speaker 1**	**Speaker 2**	**Speaker 3**	**Speaker 4**	**Speaker 5**
	xmin	0.693478	1.124161	0.965968	0.791894	0.920582
	xmax	0.771648	1.183514	1.035607	0.853572	0.987345
	Total	0.07817	0.059353	0.069639	0.061678	0.066763
Total Duration		***0.115055***	***0.768791***	***0.139839***	***0.114302***	***0.131762***

Pure/tS'/ in ukutshuma						
Closure Duration		**Speaker 1**	**Speaker 2**	**Speaker 3**	**Speaker 4**	**Speaker 5**
	xmin	0.674873	1.003295	0.664691	0.666015	1.02872
	xmax	0.73905	1.089738	0.743987	0.715677	1.095571
	Total	0.064177	0.086443	0.079296	0.049662	0.066851
Release Duration		**Speaker 1**	**Speaker 2**	**Speaker 3**	**Speaker 4**	**Speaker 5**
	xmin	0.73905	1.089738	0.743987	0.715677	1.095571
	xmax	0.83871	1.136562	0.815441	0.867511	1.163301
	Total	0.09966	0.046824	0.071454	0.151834	0.06773
Total Duration		***0.163837***	***0.133267***	***0.15075***	***0.201496***	***0.134581***

Derived /tS'/ in intshumayelo						
Closure Duration		Speaker 1	Speaker 2	Speaker 3	Speaker 4	Speaker 5
	xmin	0.574245	0.883201	0.727125	0.528841	0.867427
	xmax	0.597783	0.898034	0.746876	0.545316	0.904047
	Total	0.023538	0.014833	0.019751	0.016475	0.03662
Release Duration		Speaker 1	Speaker 2	Speaker 3	Speaker 4	Speaker 5
	xmin	0.597783	0.898034	0.746876	0.545316	0.904047
	xmax	0.677867	0.964415	0.808785	0.588711	0.975896
	Total	0.080084	0.066381	0.061909	0.043395	0.071849
Total Duration		***0.103622***	***0.081214***	***0.08166***	***0.05987***	***0.108469***

Derived /tS'/ in intshawula						
Closure Duration		Speaker 1	Speaker 2	Speaker 3	Speaker 4	Speaker 5
	xmin	0.61596	0.82611	0.875194	0.696804	0.777557
	xmax	0.639619	0.853292	0.91571	0.704884	0.809195
	Total	0.023659	0.027182	0.040516	0.00808	0.031638
Release Duration		Speaker 1	Speaker 2	Speaker 3	Speaker 4	Speaker 5
	xmin	0.639619	0.853292	0.91571	0.704884	0.809195
	xmax	0.696183	0.908142	0.971329	0.766618	0.862298
	Total	0.056564	0.05485	0.055619	0.061734	0.053103
Total Duration		***0.080223***	***0.082032***	***0.096135***	***0.069814***	***0.084741***

B3 Group Three /þf'/, /{v/, /dz/, /tñ'/, /dL/

Derived affricate /φf/ in imfanelo						
Closure Duration		Speaker 1	Speaker 2	Speaker 3	Speaker 4	Speaker 5
	xmin	0.727839	0.709438	0.791169	0.674375	0.703675
	xmax	0.740128	0.75336	0.849925	0.695424	0.758851
	Total	0.012289	0.043922	0.058756	0.021049	0.055176
Release Duration		Speaker 1	Speaker 2	Speaker 3	Speaker 4	Speaker 5
	xmin	0.740128	0.75336	0.849925	0.695424	0.758851
	xmax	0.825362	0.7929	0.873656	0.736314	0.794661
	Total	0.085234	0.03954	0.023731	0.04089	0.03581
Total Duration		***0.097523***	***0.083462***	***0.082487***	***0.061939***	***0.090986***

Derived affricate /{v/ in imvakazi						
Closure Duration		Speaker 1	Speaker 2	Speaker 3	Speaker 4	Speaker 5
	xmin	0.68569	0.884408	0.720352	0.642976	0.708762
	xmax	0.70361	0.901114	0.759278	0.66273	0.729518
	Total	0.01792	0.016706	0.038926	0.019754	0.020756
Release Duration		Speaker 1	Speaker 2	Speaker 3	Speaker 4	Speaker 5
	xmin	0.70361	0.901114	0.759278	0.66273	0.729518
	xmax	0.746533	0.940765	0.780292	0.679222	0.763932
	Total	0.042923	0.039651	0.021014	0.016492	0.034414
Total Duration		***0.060843***	***0.056357***	***0.05994***	***0.036246***	***0.05517***

Derived affricate /dz/ in inzala						
Closure Duration		**Speaker 1**	**Speaker 2**	**Speaker 3**	**Speaker 4**	**Speaker 5**
	xmin	0.746109	0.732915	0.695272	0.586234	0.727632
	xmax	0.75943	0.744695	0.734505	0.607539	0.762236
	Total	0.013321	0.01178	0.039233	0.021305	0.034604
Release Duration		**Speaker 1**	**Speaker 2**	**Speaker 3**	**Speaker 4**	**Speaker 5**
	xmin	0.75943	0.744695	0.734505	0.607539	0.762236
	xmax	0.836316	0.805454	0.763891	0.6394	0.79546
	Total	0.076886	0.060759	0.029386	0.031861	0.033224
Total Duration		***0.090207***	***0.072539***	***0.068619***	***0.053166***	***0.067828***

Derived affricate /tñ’/ in inhlaba						
Closure Duration		**Speaker 1**	**Speaker 2**	**Speaker 3**	**Speaker 4**	**Speaker 5**
	xmin	0.633756	0.735125	0.638864	0.596072	0.65786
	xmax	0.68091	0.763279	0.664631	0.625451	0.696461
	Total	0.047154	0.028154	0.025767	0.029379	0.038601
Release Duration		**Speaker 1**	**Speaker 2**	**Speaker 3**	**Speaker 4**	**Speaker 5**
	xmin	0.68091	0.763279	0.664631	0.625451	0.696461
	xmax	0.755364	0.831633	0.747729	0.675991	0.777938
	Total	0.074454	0.068354	0.083098	0.05054	0.081477
Total Duration		***0.121608***	***0.096508***	***0.108865***	***0.079919***	***0.120078***

Derived affricate /dL/ in indlozi						
Closure Duration		**Speaker 1**	**Speaker 2**	**Speaker 3**	**Speaker 4**	**Speaker 5**
	xmin	0.701638	0.751937	0.671691	0.663052	0.70881
	xmax	0.707062	0.805897	0.686442	0.66732	0.714693
	Total	0.005424	0.05396	0.014751	0.004268	0.005883
Release Duration		**Speaker 1**	**Speaker 2**	**Speaker 3**	**Speaker 4**	**Speaker 5**
	xmin	0.707062	0.805897	0.686442	0.66732	0.714693
	xmax	0.805759	0.83075	0.738936	0.732441	0.814763
	Total	0.098697	0.024853	0.052494	0.065121	0.10007
Total Duration		***0.104121***	***0.078813***	***0.067245***	***0.069389***	***0.105953***

B4 Group Four /kl' /, /dZ/

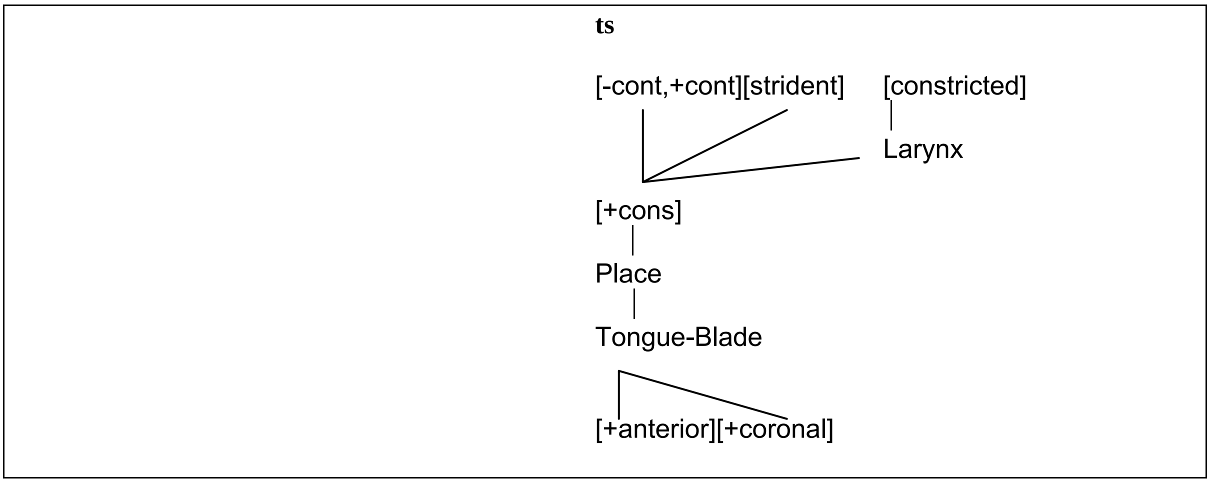
Pure affricate /kl'/ in ukuklaza						
Closure Duration		**Speaker 1**	**Speaker 2**	**Speaker 3**	**Speaker 4**	**Speaker 5**
	xmin	0.881052	0.929909	0.701248	0.649742	0.718991
	xmax	0.94318	1.046571	0.760977	0.709077	0.781112
	Total	0.062128	0.116662	0.059729	0.059335	0.062121
Release Duration		**Speaker 1**	**Speaker 2**	**Speaker 3**	**Speaker 4**	**Speaker 5**
	xmin	0.94318	1.046571	0.760977	0.709077	0.781112
	xmax	1.002435	1.085871	0.820529	0.753071	0.879016
	Total	0.059255	0.0393	0.059552	0.043994	0.097904
Total Duration		***0.121383***	***0.155962***	***0.119281***	***0.103329***	***0.160025***

Pure affricate /dZ/ in ukujabula						
Closure Duration		**Speaker 1**	**Speaker 2**	**Speaker 3**	**Speaker 4**	**Speaker 5**
	xmin	0.815056	0.929238	0.76946	0.595677	0.989932
	xmax	0.849987	0.996801	0.811586	0.626445	1.078734
	Total	0.034931	0.067563	0.042126	0.030768	0.088802
Release Duration		**Speaker 1**	**Speaker 2**	**Speaker 3**	**Speaker 4**	**Speaker 5**
	xmin	0.849987	0.996801	0.811586	0.626445	1.078734
	xmax	0.919115	1.039853	0.886381	0.68728	1.135286
	Total	0.069128	0.043052	0.074795	0.060835	0.056552
Total Duration		***0.104059***	***0.110615***	***0.116921***	***0.091603***	***0.145354***

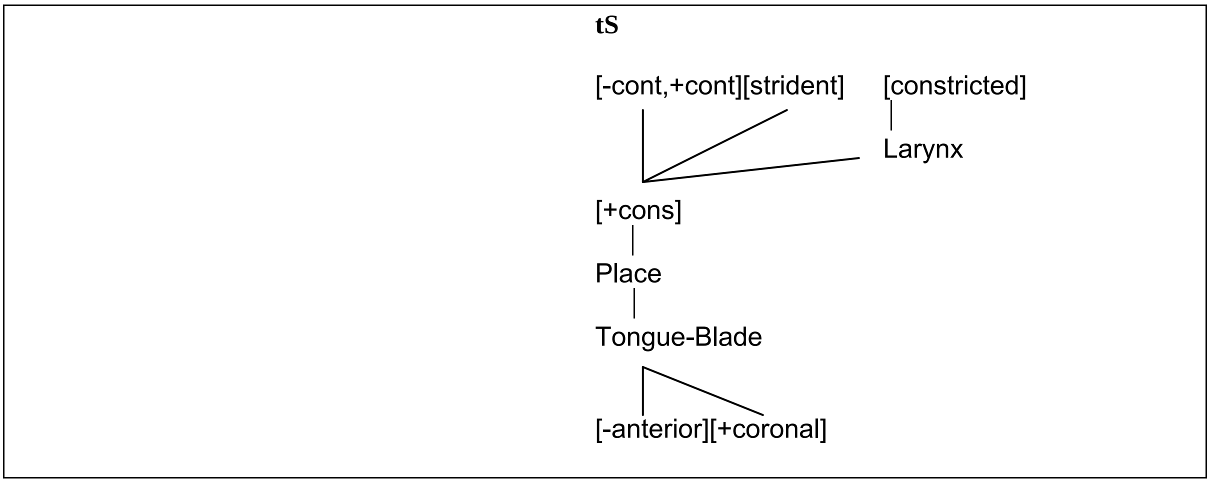
APPENDIX C

A Feature Geometry Description of Pure Affricates

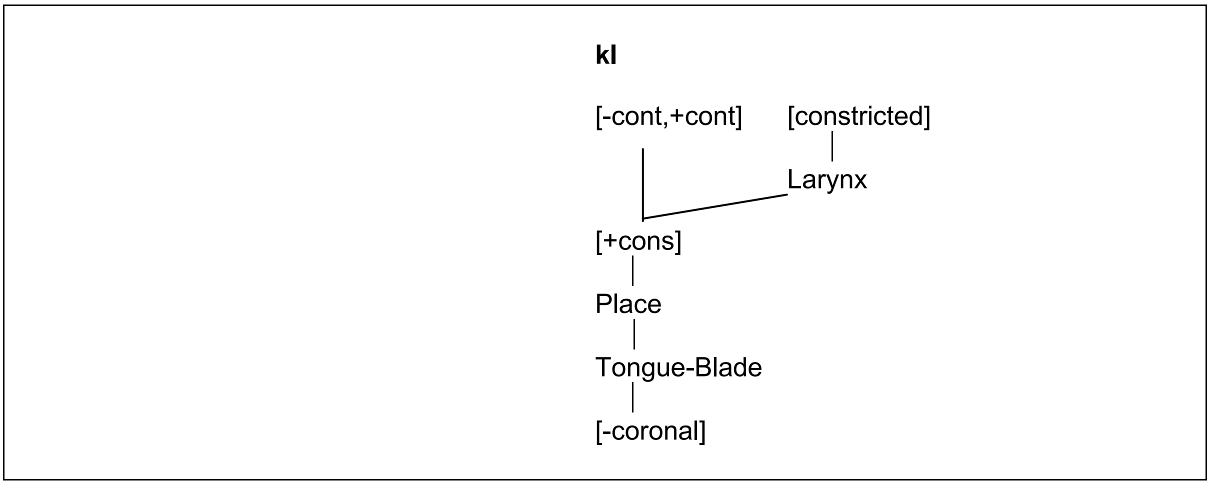
C1 A Description of the Pure Affricate /ts'/



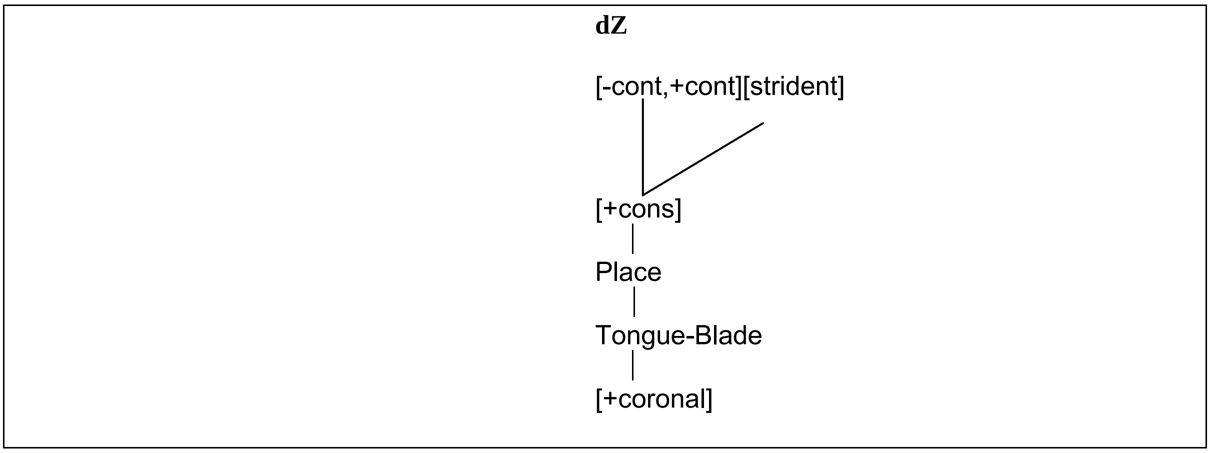
C2 A Description of the Pure Affricate /tS'/



C3 A Description of the Pure Affricate /kl'/



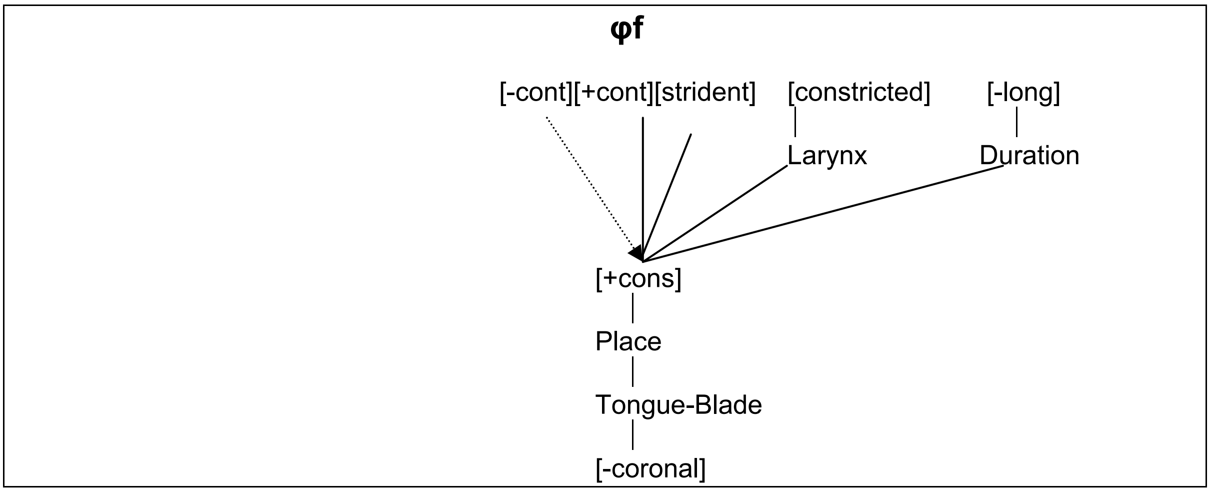
C4 A Description of the Pure Affricate /dZ/



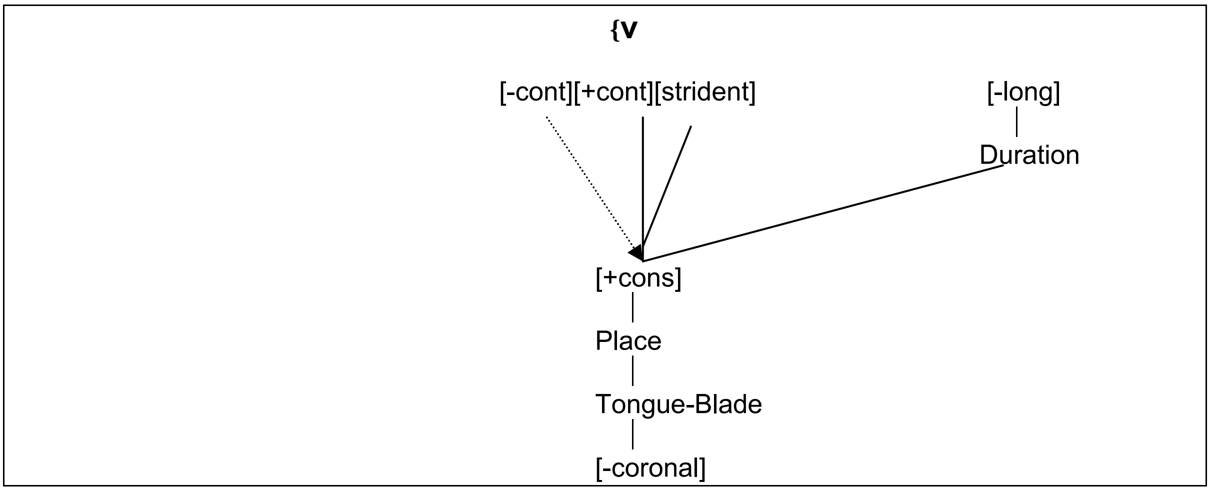
APPENDIX D

A Feature Geometry Description of Derived Affricates

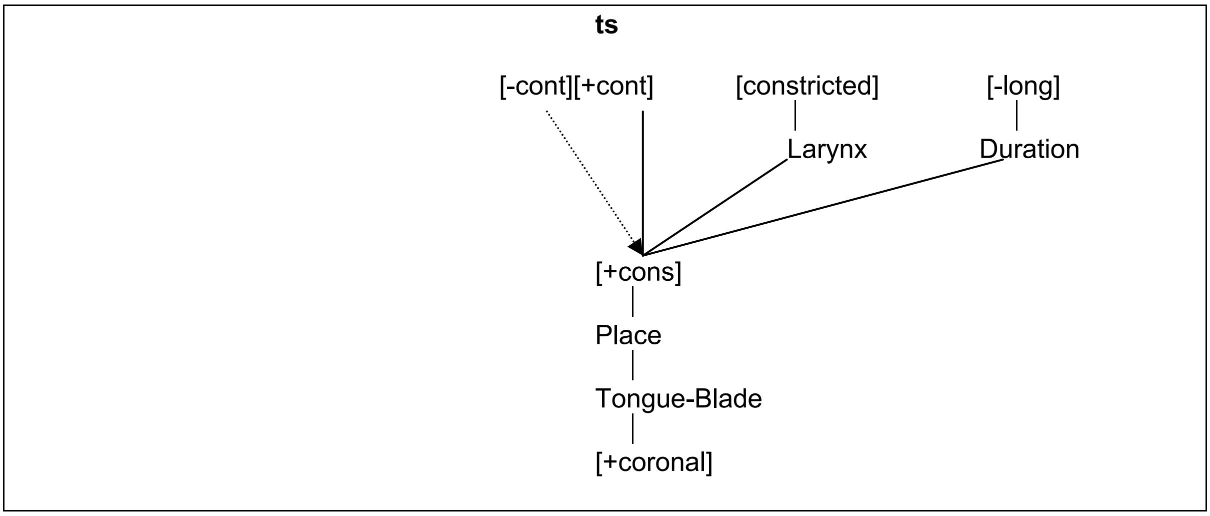
D1 A Description of the Derived Affricate [φf']



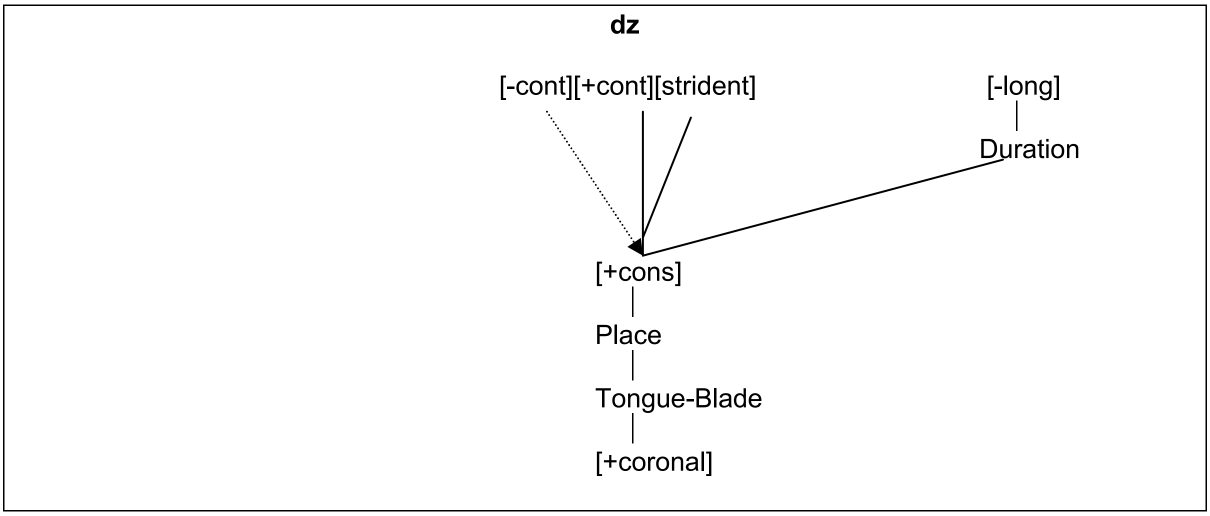
D2 A Description of the Derived Affricate [{v]



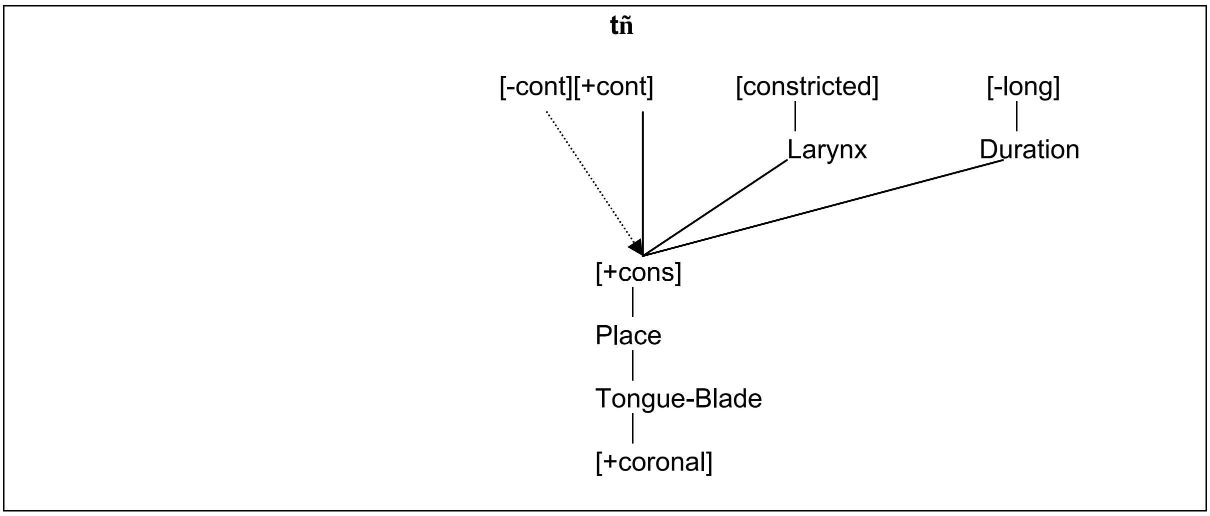
D3 A Description of the Derived Affricate [ts’]



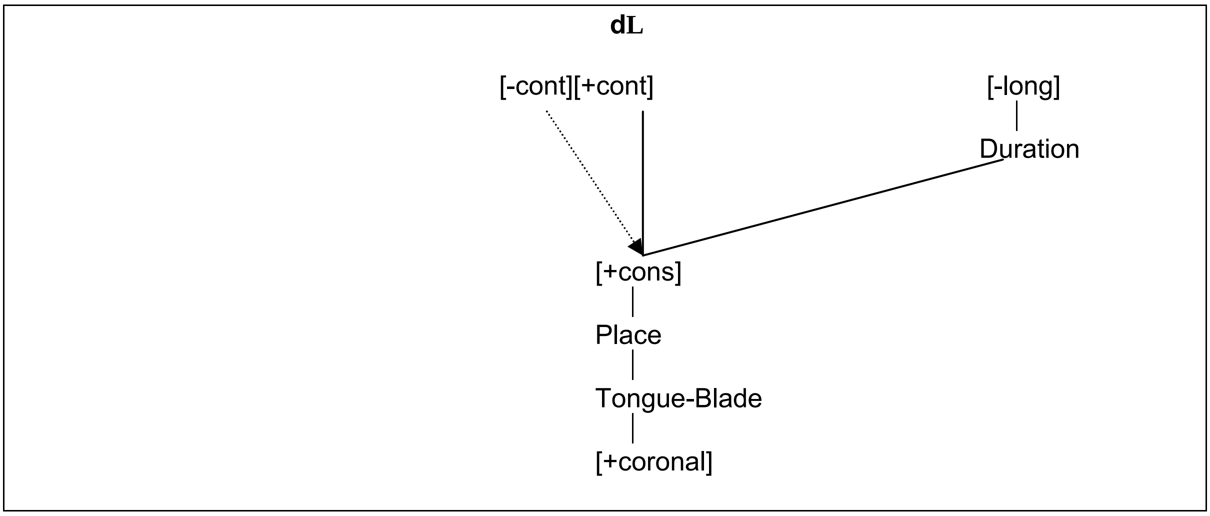
D4 A Description of the Derived Affricate [dz]



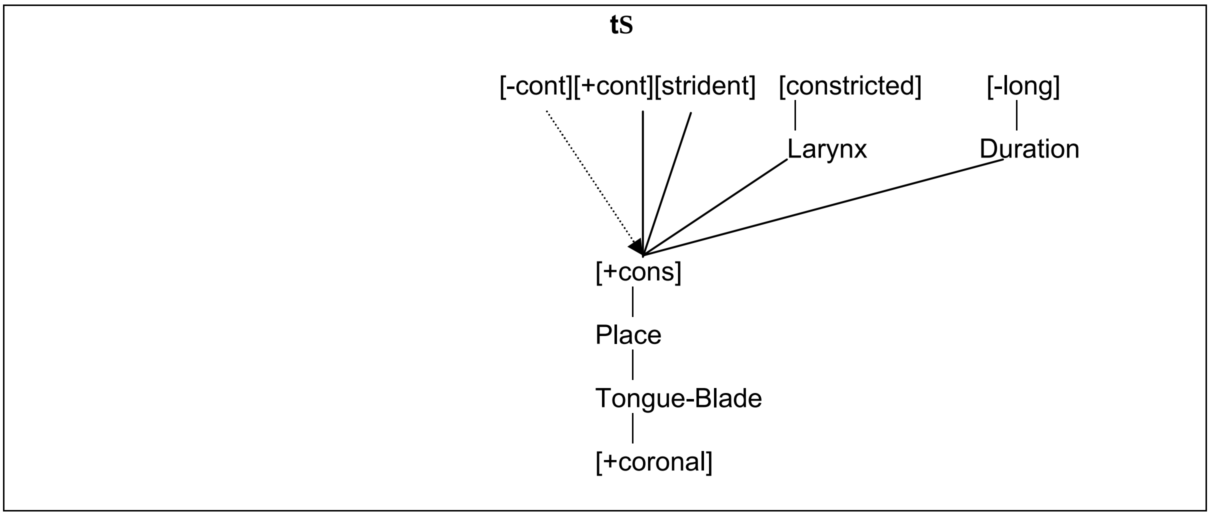
D5 A Description of the Derived Affricate [tñ’]



D6 A Description of the Derived Affricate [dL]



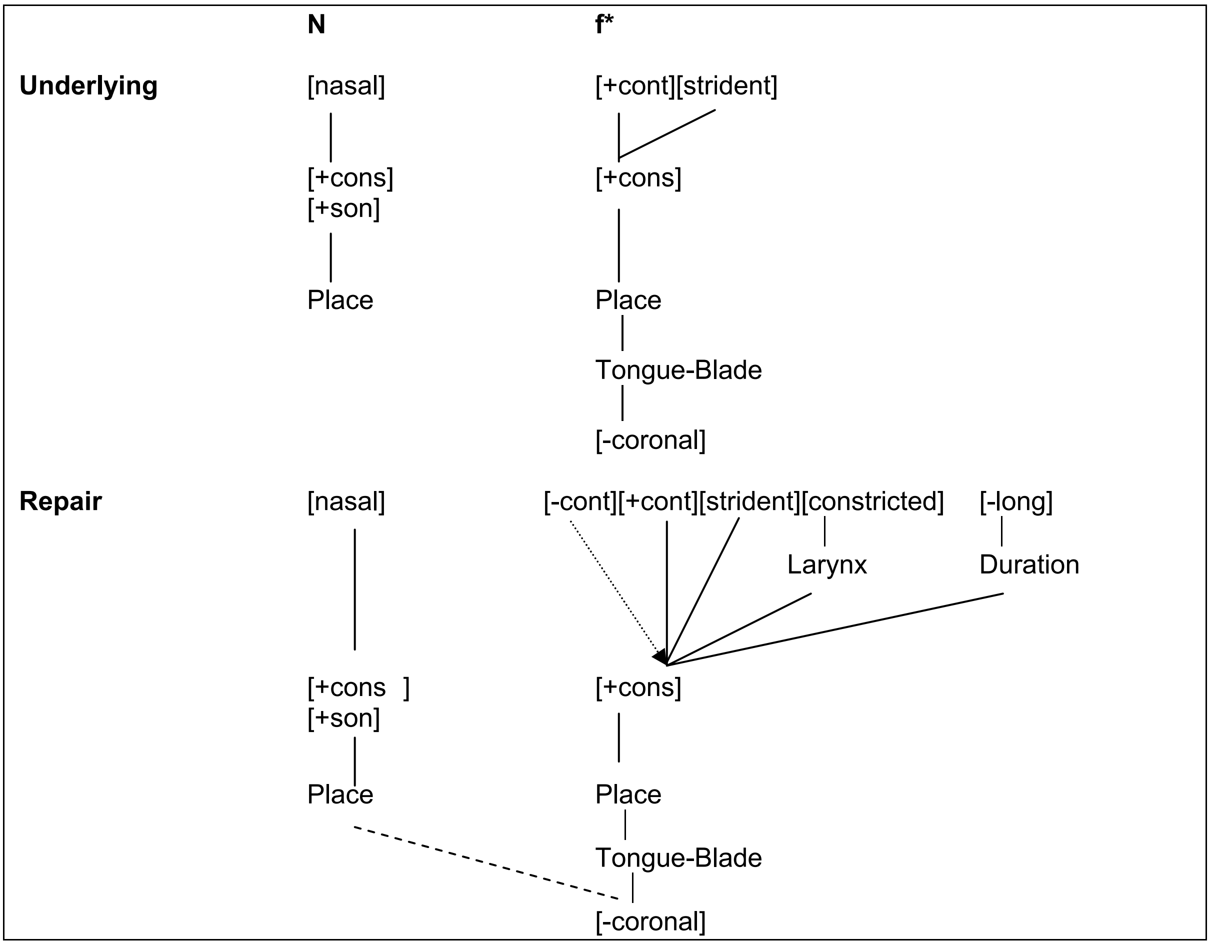
D7 A Description of the Derived Affricate [tS’]



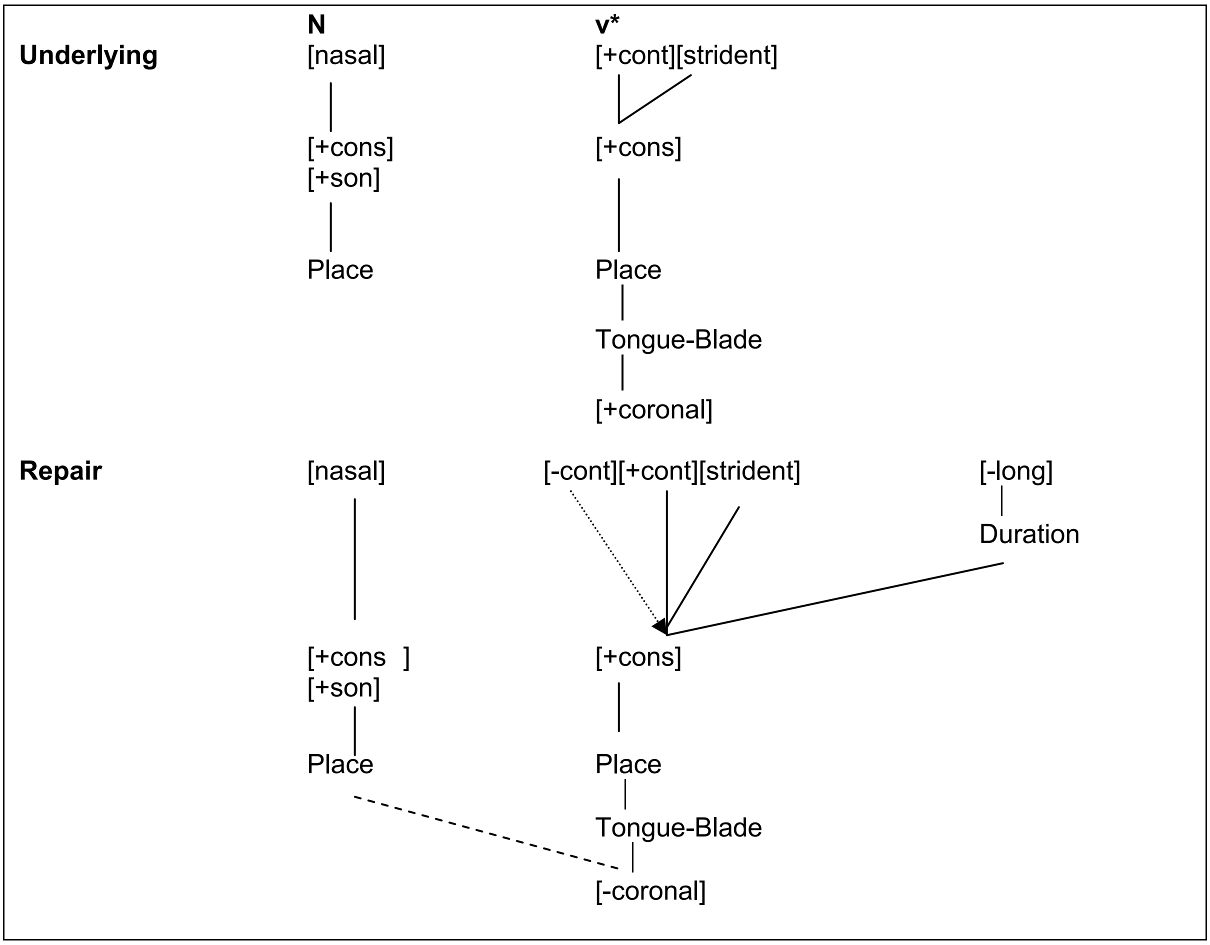
APPENDIX E

A Phonological Description of Intrusive Stop Formation

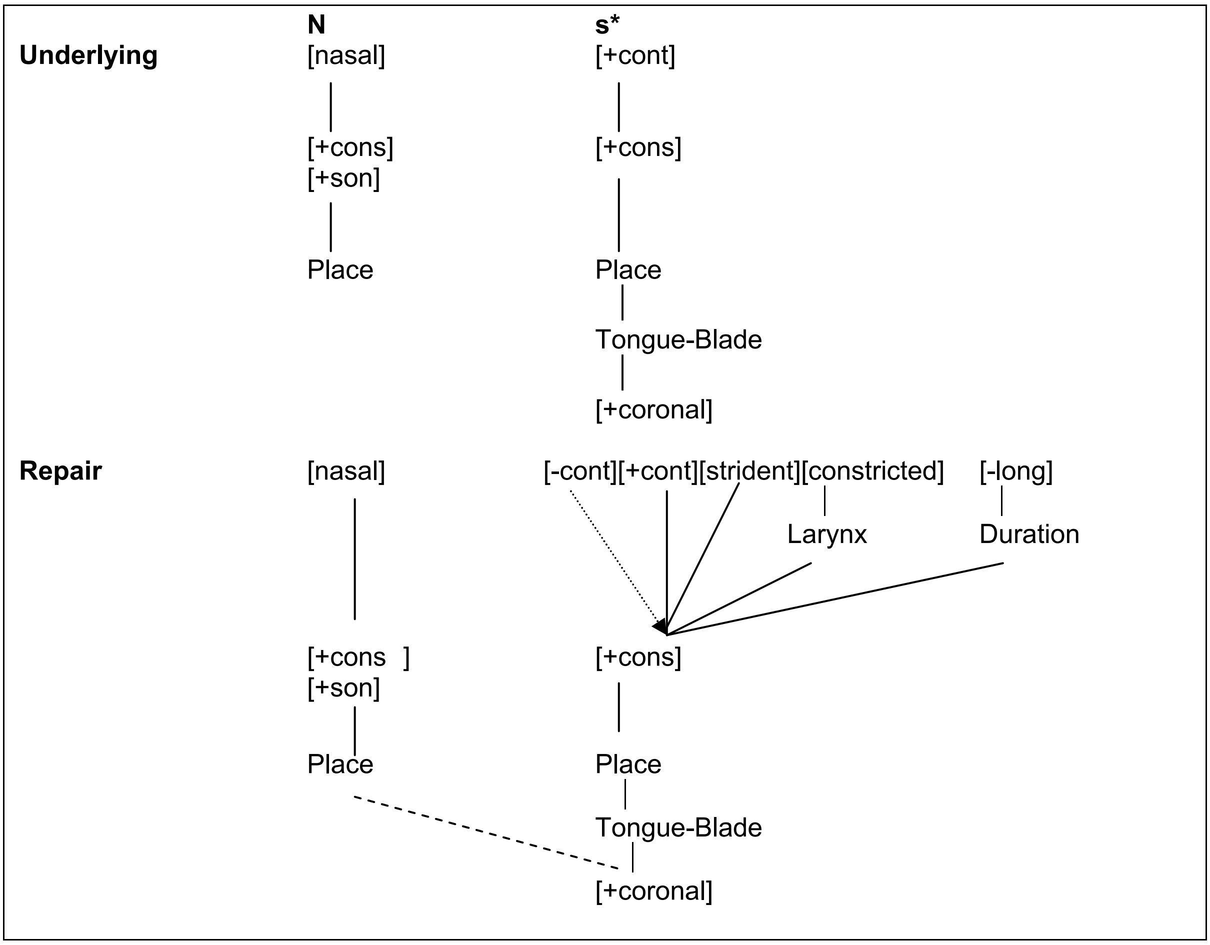
E1 A Phonological Description of /N + f*/



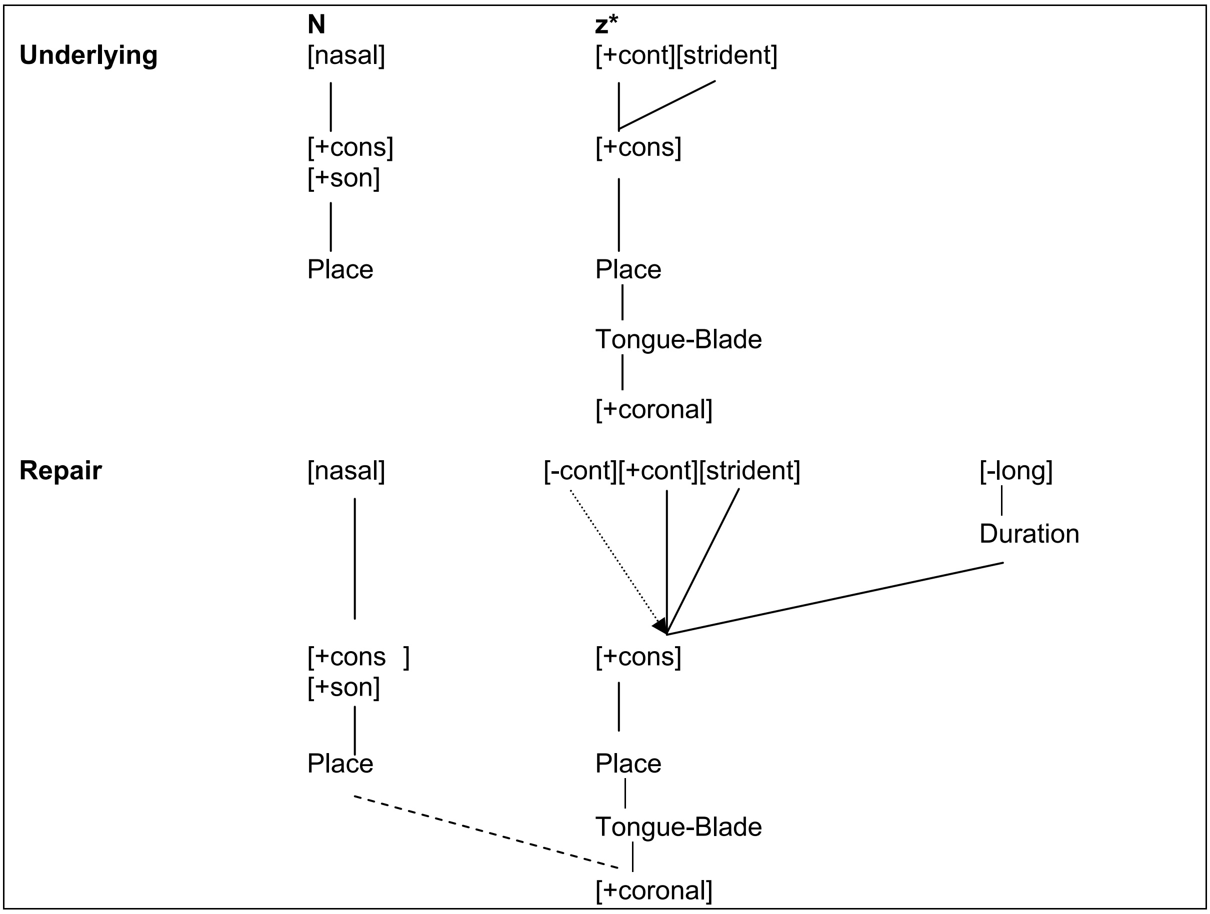
E2 A Phonological Description of /N + v*/



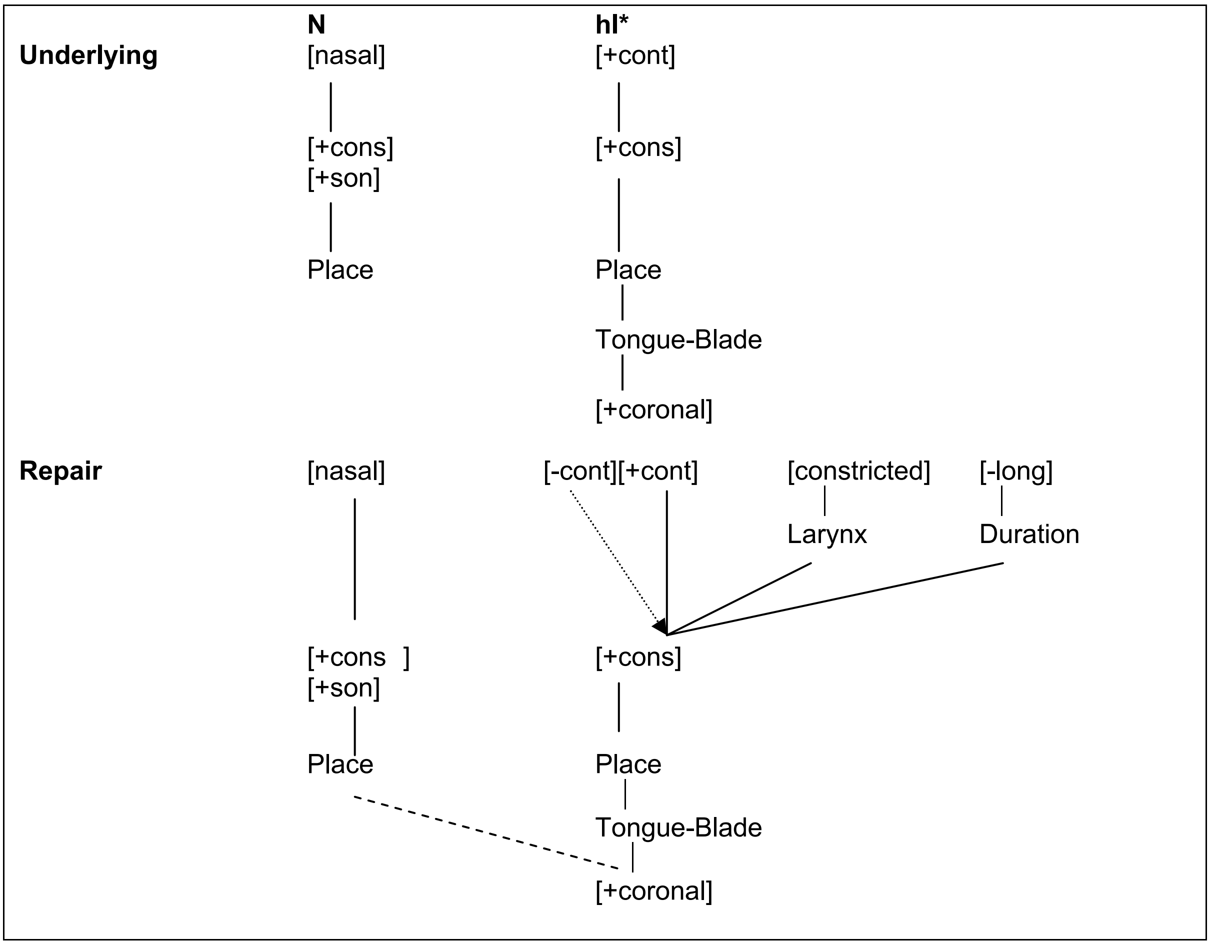
E3 A Phonological Description of /N + s*/



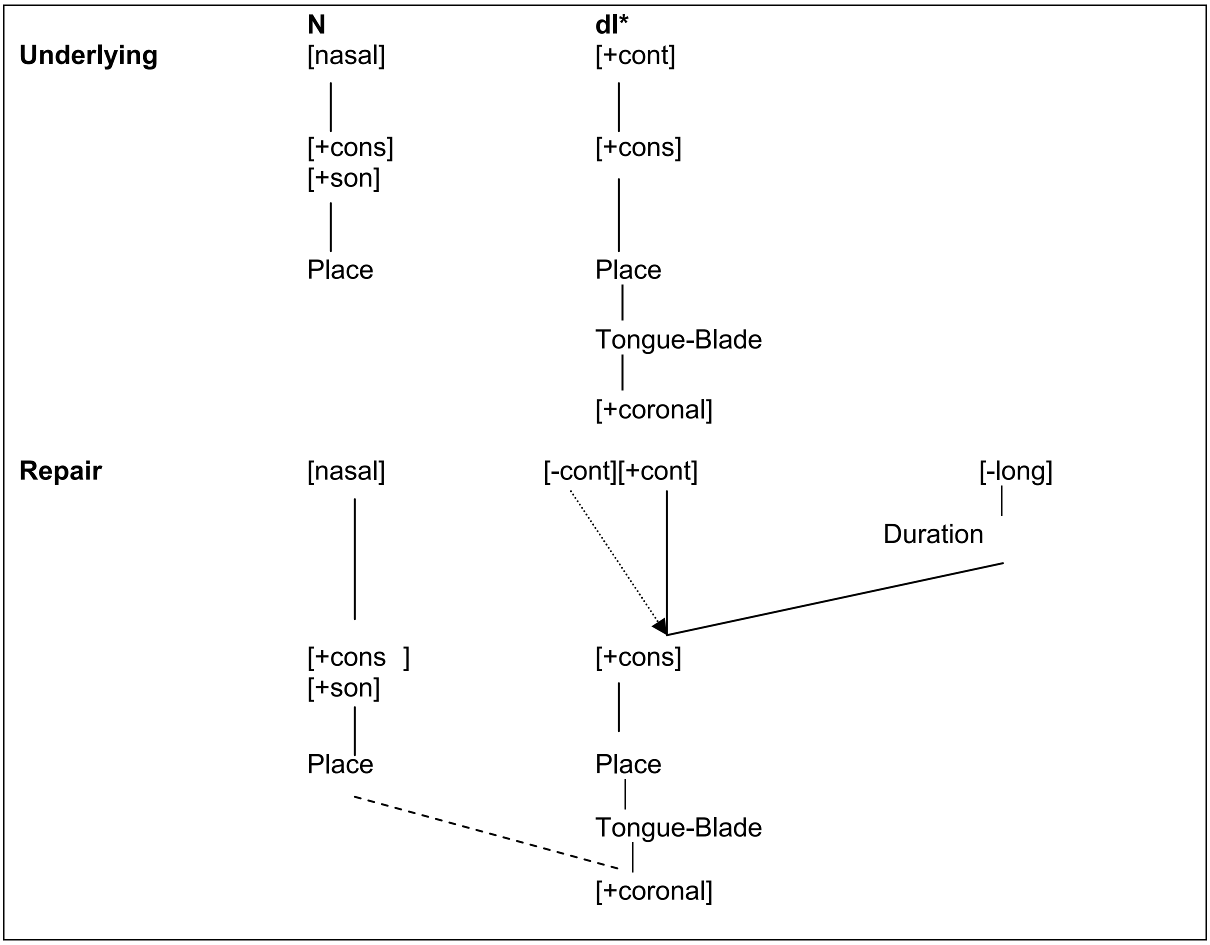
E4 A Phonological Description of /N + z*/



E5 A Phonological Description of /N + hl*/



E6 A Phonological Description of /N + dl*/



E7 A Phonological Description of /N + sh*/