AN AUDITORY AND ACOUSTIC STUDY OF LIQUIDS IN MALAYALAM

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ABSTRACT

This thesis aims to describe the auditory and acoustic characteristics of the rhotics in Malayalam. There is disagreement in the limited literature that exists on the language regarding the manner of articulation of the rhotics. Some refer to them as one tap and one trill (Kumari, 1972) while others describe both as trills differing slightly in place of articulation (Ladefoged and Maddieson, 1996; Srikumar and Reddy, 1988). The two rhotics are lexically contrastive, e.g. /kaɾi/ *soot* -/kari/ *curry*. One of the objectives of the present study is to describe the phonetic characteristics of the two rhotics and the contrast maintenance strategies used by speakers to distinguish between them. Apart from the two uncontested rhotics, there is a fifth liquid, an allegedly similar sound in Tamil and Malayalam that has previously been referred to as being a rhotic by some (Asher and Kumari, 1997; Krishnamurti, 2003, 152) and a lateral by others (Kumari, 1972). Recent studies on Tamil liquids (McDonough and Johnson, 1997; Narayanan et al. 1999) have described the fifth liquid as being a retroflex central approximant, i.e. another rhotic. The second objective of this study is to explore the possibility of the fifth liquid being a third rhotic in Malayalam. Eight male speakers were recorded reading out words, containing at least one of the five liquids in all permissible word-positions, in a carrier phrase. Results of the auditory and acoustic analyses showed that the two rhotics differed mainly in their tongue configurations (laminal and advanced vs. apical and retracted), resonance characteristics (clear vs. dark) and surrounding vowel quality (advanced and closer vs. retracted and open). F2 was found to be the most robust distinguishing acoustic cue. Manner of articulation varied for the apical rhotic from trill to tap to approximant across speakers and depending on word-position while the laminal rhotic was always realised as a tap. Duration was not found to be a robust cue in distinguishing between the two rhotics. The fifth liquid appears to be a clear post-alveolar approximant phonetically while functioning as a retroflex approximant from a phonological point of view. The lack of traditional phonetic cues separating the tap and trill segments in Malayalam highlights the importance of looking at non-segmental long-domain effects for the realisation of their clear (tap) and dark (trill) resonance, which was found to be more important than the actual manner of articulation and temporal cues. This, together with the discrepancy in the phonetic and phonological behaviour of the fifth liquid, suggests that phonetics and phonology share a 'partly absolute-partly relative relationship' and supports the notion of an Extrinsic Phonetic Interpretation (EPI), which seems to better account for the paradox surrounding the phonologically unified yet phonetically asymmetric class of rhotics.

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TRANSLITERATION SYMBOLS

A table showing the IPA symbol of the consonants in Malayalam and their corresponding transliteration symbols is given below. It is followed by a similar representation of the vowels in Malayalam.

Consonants

In each cell, the IPA symbol of the consonant is given on the left and its respective transliteration symbol on the right.

Place of articulation: **Manner of articulation:**	***Labial***	***Dental***	***Alveolar***	***Retroflex***	***Palatal***	***Velar***	***Glottal***
Plosive: voiceless	p p	t̪ t	t t̠	ʈ T	c c	k k	
Voiceless aspirated	pʰ ph	t̪ʰ th		ʈʰ TH	cʰ ch	kʰ kh	
Voiced	b b	d̪ d		ɖ D	ɟ j	g g	
Voiced aspirated	bʰ bh	d̪ʰ dh		ɖʰ DH	ɟʰ jh	gʰ gh	
Fricative	(f) (f)		s s ʃ sh	ʂ SH			h h
Nasal	m m	n̪ n	n n̠	ɳ N	ɲ nj	ŋ ng	
Liquid: ***Tap/trill***			ɾ r r R				
Liquid: ***lateral***			l l	ɭ L			
Liquid: ***approximant***					ɻ zh		
Glide	v v				j y		

1) /ʐ/ is used as the symbol for the fifth liquid following Asher and Kumari (1997) It is not based on the roman letter ‘r’ or ‘l’ the use of which might have implied the assumption of its rhoticity or laterality from the beginning. So /ʐ/ is used since it is a neutral symbol. The findings of the present study showed that the phonetic value of /ʐ/ = [ɻ̟ʲ] i.e. a clear post-alveolar approximant (symbol for retroflex approximant with a plus diacritic underneath to suggest slightly fronter place of articulation than retroflex and a ‘j’ superscript to depict palatalised quality of the fifth liquid). /ʐ/ is orthographically represented as ‘zh’ following Kumari (1972).

2) For the trill, alveolar lateral and retroflex lateral fragments, the symbols for the trill, alveolar lateral and retroflex lateral respectively are used but highlighted in bold so an example of word medial trill fragment is as follows ‘ka**R**ttaaveh’ /kar̪t̪aːvə/ (*Lord)*.

Vowels

/ə/- eh

/i/- i, /iː/ - ii

/e/- e, /eː/- ee

/a/- a, /aː/- aa

/ɔ/- o, / ɔː/ − oo

/u/- u, /uː/ − uu

/ai/- ai

/au/- au

INTRODUCTION

This thesis describes the auditory and acoustic characteristics of rhotics in Malayalam, a language that has not been the subject of much research in the phonetics-phonology literature. One of the main motivations behind this thesis is the desire to showcase, albeit in a small way, the enormous potential that Malayalam offers to research in phonetics and phonology and as yet remains untapped.

The phonetics and phonology of rhotics have fascinated linguists in recent times, whether it is the paradox surrounding the phonologically similar yet phonetically diverse rhotics (e.g. Lindau, 1985; Barry, 1997; Catford, 2001; Wiese, 2001), the persistent pursuit of identifying a common phonetic property pervading all rhotics and the importance of a lowered F3 in this regard (Heselwood, 2009; Ladefoged, 1971; Fujimura and Erickson, 1997; Espy-Wilson et al. 2000; Johnson, 2003 etc.) or the sociolinguistic factors conditioning rhotic productions in different languages (Foulkes and Docherty, 2000; 2001; Sankoff, Blondeau and Charity, 2001 etc.). Such studies have predominantly focussed on various dialects of either American English or British English, both of which have one rhotic phoneme in their inventories (Delattre and Freeman, 1968; Espy-Wilson, 1992; Hagiwara, 1994; 1995). Relatively fewer studies exist in the literature on multiple rhotic languages and part of the reason for this may be that only few of the world's languages contrast between two or more rhotics (Ladefoged and Maddieson, 1996). A large majority of such studies have focussed on different varieties of Spanish and its tap-trill contrast (Recasens, 1991; Hualde, 2005; Willis and Bradley, 2008; Henrikson and Willis, 2010 etc.) or variability in trill production (Hammond, 1999; Diaz-Campos, 2008 etc.). Also, not many studies have dealt with the phonetic and phonological relationship that rhotics share with laterals, with which it forms the category of 'liquids' (e.g. Kelly and Local, 1986; Dickey, 1997; Carter, 1999; Narayanan et al, 1999, Proctor, 2009 etc.). Not much is known about how rhotics and laterals interact with each other phonetically and phonologically within a particular language and cross-linguistically.

Liquids are a super-class that comprise the rhotics and laterals of a language and the number and type of individual members that constitute this group are language specific, typically including one or more of the following: Taps, flaps, trills, fricatives, approximants and lateral approximants. Unlike other consonant groups like stops, nasals and vowels, liquids are not characterised by a shared phonetic property and instead evidence justifying their separate classification comes from their similar phonological behaviour mainly in the form of phonotactic patterning (Ladefoged and Maddieson, 1996; Ballard and Starks, 2004; Proctor 2009 etc.).

Malayalam is one of the few languages of the world that have a large liquid inventory comprising five members: two rhotics, two laterals and a fifth liquid which has been referred to by some as being a rhotic (Asher & Kumari, 1997: 419, Krishnamurti, 2003 etc.) and others as being a lateral (Kumari, 1972:27-28) while some have refrained from commenting on its exact nature and have referred to it simply as a continuant (Namboothiri, 2002).

The liquids in Malayalam are interesting for mainly two reasons: Firstly, the two rhotics are contrastive and so are the two laterals forming several minimal pairs in the lexicon, e.g. /kaɾi/-/kari/, /paːɾa–/paːra/; /kali/-/kaɭi/, /mula/-/muɭa/ (see Appendix A, pgs. 292-301) for details of these and other minimal pairs used in the thesis). There is also disagreement in the literature regarding the nature of the two rhotics in Malayalam. While some claim both rhotics in Malayalam are trills (Ladefoged and Maddieson, 1996: 222; Srikumar and Reddy, 1988), others describe one rhotic as a tap and the other as a trill (Kumari, 1972). Since the two rhotics are lexically contrastive as mentioned above, this raises some questions regarding how the contrast between them is maintained by native speakers. What are the various cues that speakers use to distinguish between the two rhotics? What are their auditory and acoustic characteristics in general?

Secondly, to the best of the author’s knowledge, the phonetic characteristics of the fifth liquid in Malayalam have not been the subject of experimental research before. Tamil and Malayalam allegedly have a similar fifth liquid (Zvelebil, 1970). In fact, the origin of this fifth liquid can be traced all the way back to Proto-Dravidian and modern Malayalam and certain dialects of modern Tamil are the only Dravidian languages to have retained the sound in their inventories (Krishnamurti, 2003). Previous descriptions of this sound are far from consistent ranging from a ‘continuant’ (Namboothiri, 2002), to a ‘voiced retroflexed palatal fricativised lateral’ (Kumari, 1972:27-28) and to ‘a voiced sublamino palatal approximant’ (Asher & Kumari, 1997: 419). Recent studies on Tamil liquids (McDonough and Johnson, 1997; Narayanan et al, 1999) have described the fifth liquid in Tamil as a retroflex central approximant. This has important implications for the identity of the fifth liquid in Malayalam. Is it also realised as a ‘retroflex central approximant’ as in Tamil and therefore a potential third rhotic in consonant inventory of

Malayalam or is realised differently in Malayalam than it is in Tamil? In what ways does it pattern with other consonants or the other liquids in the language?

The liquids in Malayalam will therefore provide a rich, untapped source of information for researchers interested in exploring the complex phonetics-phonology relationship that characterises the class of rhotics and also the phonetic and phonological relationship between rhotics and laterals within a language and contrast maintenance strategies used to distinguish among several subtly different sounds.

The present study has mainly two objectives:

- To describe the auditory and acoustic characteristics of the two rhotics and the two laterals in Malayalam and identify the various cues used by speakers to maintain the contrasts between them.

- To define the phonetic characteristics and the phonological status of the fifth liquid in Malayalam, specifically to examine whether it could be a third rhotic in the language as has been found in Tamil.

Although the present study will discuss the phonetic and phonological aspects of all five liquids in Malayalam, the main focus is on the rhotics in the language, on the nature of contrast maintenance between the two uncontested rhotics and the possibility of a third rhotic in the consonant inventory of the language. It is mainly for the latter purpose that the laterals have been included in the study, i.e., to compare the fifth liquid's patterns with both the rhotics and the laterals and to also explore the phonetic and phonological relationship that rhotics share with laterals in order to answer the second objective of this thesis as described above.

The thesis is organised as follows:

Chapter 1 will review the literature on the phonetics and phonology of rhotics and the relationship between rhotics and laterals. Chapter 2 will briefly describe the origin of Malayalam, including its vowel and consonant inventory, and focus on previous studies on rhotics and laterals in Malayalam and Tamil and the phonotactic distribution of liquids in Malayalam.

In chapter 3, the methodology of the present study will be laid out in terms of participants involved, data elicited, methods used and types of analyses conducted. Details of a pilot study that was used to inform the methodology of the main study will also be included and, based on the results of the pilot study, hypotheses regarding rhotic identity and patterning will be set for investigation in the main study.

Chapter 4, 5 and 6 will describe the findings of the main study regarding productions of the rhotics, laterals and the fifth liquid in Malayalam respectively and discuss individual findings in the context of findings of similar studies in the literature. Each chapter will present results of the auditory analysis followed by those of the acoustic analysis and these results will then be discussed in the same format.

Chapter 7 will interpret all the results of the previous three chapters in the context of broader themes emerging from them and the research questions addressed in this thesis. It will also propose a phonological analysis to account for the results obtained.

The next chapter will review relevant literature on rhotics, addressing issues like their phonetic asymmetry, their phonological structure, and the nature of their relationship with laterals cross-linguistically. It will also examine the characteristics of particular types of rhotics, like trills and taps, in detail since these members occur in Malayalam, which is the language being researched in this thesis.

CHAPTER 1

PHONOLOGY AND PHONETICS OF RHOTICS

The term 'rhotics' seems to cover a wide range of sounds differing in both manner and place of articulation: from trills, taps and flaps to fricatives, approximants and vocalic realizations with respect to manner of articulation; from labial to uvular with respect to the place of articulation (Van Hout and Van de Velde, 2001:1, Ladefoged and Maddieson, 1996 etc.). Contrasts based on voicing, length and nasality are also known to occur among /r/ sounds in the languages of the world. (Wiese, 2001b:11). Maddieson (1984) calculated the number and percentage of /r/ phonemes in the world's languages and found a preference for the world's languages to have at least one /r/ phoneme in their inventories. Languages which have more than one /r/ phoneme are found to typically differentiate between them more by manner than by place of articulation (also Ladefoged and Maddieson, 1996, Ch. 7).

This chapter will review the literature on the phonetics and phonology of rhotics dealing with the ambiguity of membership to this class of sounds, the phonetic asymmetry of rhotics, and their phonological unity. The phonetic and phonological relationship between rhotics and laterals (which together form the class of 'liquids') will also be examined based on previous studies. The literature on particular types of rhotics like trills, taps and flaps will be reviewed in detail since Malayalam has some of these members in its inventory. The chapter will explore the potential of a non-segmental approach to account for the cross-linguistic phonetic and phonological patterns observed for rhotics and describe the basic tenets of the Firthian Prosodic Approach, a relatively lesser known theory, in this regard.

1.1 The Rhotic paradox: Phonological unity and Phonetic Asymmetry

The fascination of linguists with rhotics lies in the paradox they pose: they vary greatly and in several dimensions and yet possess a unity not completely understood that justifies classifying all the variants into one group called 'rhotics' (Wiese, 2001b:11). In this regard, Ladefoged and Maddieson (1996:245) conclude that "the overall unity of the group seems to rest mostly on the historical connections between these sub-groups; and on the choice of the letter 'r' to represent them all." The paradox then is: how can such a phonetically diverse group, with no apparent common property, function as a single unit in the languages of the world? Further still, how does one define a 'rhotic'?

1.1.1 Ambiguity in Rhotic membership

Using previous descriptions of what an r-sound constitutes would lead us to all the sounds that are denoted by symbols based on the roman letter 'r', thus deriving the following table, a subset of the IPA chart (1996 version) (Wiese, 2001):

	Dental/Alveolar/Post-alveolar	Retroflex	Uvular
Trill	r		ʀ
Tap/Flap	ɾ	ɽ	
Fricative			ʁ
Lateral Flap	ɺ		
Approximant	ɹ	ɻ	

Table 1: Subset of the IPA chart showing all the symbols based on the roman letter 'r' adapted from Wiese (2001:336)

Apart from these 8 symbols, the IPA also recognizes a diacritic for rhoticity to be added to vowel symbols such as ə˞, e˞, a˞ etc. However, the list of rhotics provided by Ladefoged and Maddieson (1996:216) does not include the rhotic vowel and uses [ʁ] for uvular approximant rather than fricative and so does Dickey's (1997:14) list. To add to the confusion, the list of sounds that may or may not be treated as potential 'rhotics' is extensive, unless one follows Ladefoged and Maddieson's suggestion to only look at the orthographic and historical relations of the symbols in question. Because it is not yet clear what a 'rhotic' is , the complete list of rhotics has not been arrived at yet and a considerable number of sounds are treated ambiguously in terms of whether or not to include them under the category 'rhotics'. For example, [χ] is described as a voiceless fricative or as a rhotic like in Dutch, which has this fricative /χ/ (Booij 1995: Ch2, 3). Interestingly Wiese points out that while [ʁ] is included in the IPA's list of rhotics, its voiceless counterpart [χ] is not, although there are other voiceless rhotics that have been identified in languages like Sedang, Irish, Ingush (Ladefoged and Maddieson, 1996: 237-238) where it contrasts with a voiced /r/. Therefore to consider rhotics as voiced consonants would only be partially correct since voiceless rhotics exist either through assimilation or in contrast with a voiced counterpart. Other examples of ambiguous rhotics include the bilabial trill [ʙ] and the labiodental approximant [ʋ], the latter being an increasingly frequent /r/ variant in present British English which has not traditionally been considered as a 'rhotic' (Foulkes and Docherty, 2001). Wiese points out that these and other questionable rhotics are "often simply positional variants of the phoneme /r/ in the respective language whatever the features of this phoneme are" (2001:13).

1.1.2 Phonetic Asymmetry among rhotics

Phonetically, rhotics encompass a wide variety of places and manners of articulation and phoneticians have in previous years tried to find phonetic correlate(s) that unite the varied members of this group of sounds. Initially, a lowered third formant was thought to be the pervading acoustic property of all rhotics but later this was found to be true only of certain languages like English and Spanish and not of certain others like Swedish and Degema (Lindau, 1985:116). A lowered third formant, Lindau points out, can be reflective of retroflexion and a postalveolar-palatal constriction or some mid-palatal or lower pharyngeal constriction. She points out that there is no one physical property characteristic of all the rhotics. Instead, two or more members of the family may resemble each other more or less strongly than each of them do with some of the other members. For instance, taps and trills share a relationship that is quite different from the one shared by taps and approximants. Lindau argues that the former pair shares a stronger resemblance than the latter pair: Taps are similar to a single pulse in a trill and have about the same duration as a single pulse (though see discussion on this later on pgs. 23, 25-26). A tap is a common allophone of the trill in at least 45 of the 85 of the world's languages known to have trills. On the other hand, taps and approximants do not in principle share many acoustic characteristics and are more similar with respect to their production in that the former involves complete or sometimes partial closure while the latter involves no closure so their productions can be seen as a change in position on a single articulatory parameter of stricture (Lindau: 118). Thus Lindau concludes that the relationship between the phonological and phonetic classes can be more complex than merely involving a one-to-one mapping as is often assumed and the relationship between the phonetically diverse rhotics is best dealt with in terms of family resemblance.

The acoustic correlate of rhoticity most commonly referred to in the literature is a lowered F3 (Fujimora and Erikson, 1997; Espy-Wilson et al, 2000; Johnson, 2003 etc.). Ladefoged (2003:149) comments on the same as follows: "the lower the F3, the greater the degree of rhoticity." However, a large majority of the research dominating the literature on /r/ is based on British and American English /r/ (e.g. Delattre & Freeman, 1968; Espy-Wilson, 1992 etc.), both of which are typically approximants. Lindau (1985) has argued that not all rhotics are characterised by a low F3, since rhotics constitute a rather varied class of sounds, both with respect to place and manner of articulation which exhibit their own inherent acoustic characteristics. She points out that a low F3 may be true of the American English /r/ which is an approximant, but cannot be generalised as a 'pervading property of rhotics'**.** For British English, Heselwood (2009) has recently argued that it is lower F3 amplitude, not frequency, and the subsequent presence of an F2 auditory peak at around 9.5-11dB that is unintegrated with either F1 or F4 that actually cues rhoticity the most. In a series of perception experiments Heselwood and Plug, (2010a;b), found that reduction in F3 amplitude or even the complete removal of F3 in postvocalic contexts actually enhances the perception of a rhotic as it paves the way for F2 prominence.

1.1.3 Phonological Patterning of /r/'s

Regardless of their phonetic asymmetry, all r-sounds tend to behave in the same way phonologically: they occupy the same place in consonant systems and in syllable structures and they tend to be vowel adherent in consonant clusters. Also, rhotics tend to follow the same rules: for instance, rhotics often alternate with other rhotics. In many languages, trills often have a tap allophone particularly in the intervocalic position, e.g. Persian, and less often an approximant variant when it occurs before a consonant in languages like Fulfulde (Lindau, 1985: 114). Rhotics have similar effects on their environments, for example, vowels before rhotics tend to be of a longer duration than those before non-rhotics and vowels preceding and following rhotics tend to be articulated lower than those in non-rhotic environments.

Wiese (2001b:12) summarizes some of the known phonological and phonotactic similarities of the various /r/ members in part also recognized by previous researchers like Ladefoged and Maddieson (1996), Dickey (1997) and Hall (1997):

- R-sounds tend to be vowel-adjacent. In languages that permit consonant clusters with /r/, they tend to occur between vowels and other consonants (with which they form a cluster) in the same syllable e.g. CrVrC.
- Although they tend to be non-syllabic in general, they often have a syllabic variant in languages that allow for syllabic consonants.
- While rhotics alternate with other segments often, their alternation with each other is even more frequent both synchronically and diachronically.
- Evidence from languages like French and German show that if a rhotic alternates with another rhotic in terms of stricture, then the phonotactics of these r-sounds do not change. In French, a subset of obstruent-sonorant clusters are allowed in onset positions while obstruent-obstruent clusters are not permitted. Interestingly, irrespective of its voicing or stricture properties, obstruent-r sequences freely occur in both Standard and regional accents of French. In other words, devoiced or fricative /r/ occurs in positions where other sonorants are restricted in French (e.g. [pXɑ̃] for /pʀɑ̃/ 'take'; [tʀ̥ɛ̃] for /tʀɛ̃/ 'train').
- The above-mentioned phonological generalizations and constraints refer to any and all types of /r/. Wiese exemplifies this by referring to the /rVr/ constraint in Dutch for instance. The phonology and morphophonology of Dutch prevent a sequence of the type of /rVr/, a constraint which is called the OCP-effect which avoids identical elements within the same domain. The relevance of this constraint in this context lies in the fact that it holds true irrespective of whether the two /r/'s in /rVr/ are of the same type or are different realizations of /r/. This shows, firstly, the unity of /r/ and secondly, the irrelevance of segmental features of /r/.

While this section focussed on the general phonological patterning of rhotics, the next section will explore the similarities in phonological patterning that rhotics share with laterals with which it together forms a class of sounds call 'liquids'. The relationship that rhotics have with laterals and the phonological and phonetic nature of their interaction with each other will also be discussed.

1.1.4 Rhotics and Laterals: Interaction between the 'liquid' consonants

Rhotics and laterals together form part of a super-class called 'Liquids'. Liquids are 'non-nasal sonorant consonants'. They are 'consonants' because their articulation involves some degree of constriction in the oral cavity, 'sonorants' because their production involves a stricture-type that is open enough to allow air to pass through without friction and because liquids are produced with air expelled through the oral cavity, they are also 'non-nasal' (Ballard and Starks, 2004). Depending on one's theoretical perspective, non-nasal sonorant consonants could either involve two sub-classes: liquids and glides or just liquids. For those who view glides as vocoids (e.g. Halle, 1992; Kenstowicz 1994 etc.) 'liquids' are the only non-nasal sonorant 'consonants' and for those who view glides as consonants (e.g. Clements and Hume 1995 as reported in Ballard & Starks, 2004), glides and liquids together form a group of sounds called 'approximants' but the two can still be differentiated from each other in that the former involves a non-turbulent air-stream. (Laver, 1994; Ladefoged and Maddieson, 1996: 322-326)

Ballard and Starks rightly point out that there is no phonetic similarity between the two groups, rhotics and laterals, on the basis of which they have been put together under this category. The production of laterals involve air passing through the sides of the tongue while the rhotics as a group share no 'one' phonetic property in common (Ladefoged and Maddieson, 1996: 245). The latter's phonetic realizations vary from approximants and sometimes even fricatives to stop-like taps and flaps. Phonetically, liquids seem to be defined based on the articulatory features that they lack rather than share and their phonological patterning, that is, the way they pattern with other segments, is the main if not only reason for their classification as 'liquids'(Ballard and Starks, 2004: 2). Some researchers (e.g. Bhat, 1974) have suggested that the distinction between laterals and non-laterals has distributional correlations with other phonetic contrasts like high-low and front-back that characterise surrounding vowels. Note, however, that in Bhat's sample of data from other studies, non-lateral members only included trills, taps and flaps which is only a minimal subset of the phonetic diversity that characterise the rhotics or non-laterals. He claims firstly that non-laterals tend to lower a preceding vowel while laterals may either raise a front vowel or lower a back vowel and when velarized lower all vowels. He gives examples from Old High German, Norwegian, Spanish, Old Icelandic, 'Scots English' etc. (1974: 76-77). Secondly, in terms of effects on vowel position, non-laterals, Bhat suggests, have a centralizing or backing effect on a neighbouring vowel (e.g. Kodagu, Rumanian, Kabardian, and Chipewyan). The non-laterals also tend to have a lateral quality to them when they occur in the neighbourhood of (particularly before) front vowels (e.g. Bariba, Papago, Chadic, Ganda, Central Bontoc, etc.). The above two correlations are interconnected, i.e., the property of vowel lowering tends to go with the property of centralization. The backing effect of non-laterals also has an acoustic explanation: both have relatively lower second and third formants. However, these differences could be a result of the place of articulation differences between rhotics and laterals in those particular inventories mentioned rather than due to a difference in their liquid identity. Place of articulation for the sounds in the samples have not been explicitly mentioned in the article. Also the backing effect that Bhat claims characterise non-laterals could also characterise a retroflex lateral since all retroflex consonants would have some amount of backing effect on surrounding vowels by virtue of their own retraction (for more details on Bhat's proposed phonetic distinction between laterals and non-laterals, see Bhat, 1974). Therefore many of these observed effects cannot be solely attributed to a difference in the manner of articulation or specifically the liquid identity. Also, in languages that have larger liquid inventories like Tamil and Malayalam, studies have shown that the differentiation between rhotics and laterals is only one dimension of contrast in their liquid system and that there are several other dimensions independent of the identity of the liquid like static/dynamic, retroflex-non retroflex or apical/laminal etc. (McDonough & Johnson, 1997 for Tamil; see general discussion in Chapter 7 of present study for Malayalam).

Therefore since the phonetic basis of liquids appears to be weak and less compelling and has a limited role to play in identifying a segment as a liquid, it seems more likely that a more useful indicator for membership into the class of liquids is the phonological patterning of segments in contrast to other perhaps more clearly defined sound groups such as nasals or glides (Ballard and Starks 2004, Proctor, 2009 etc.).

The strongest evidence in favour of laterals and rhotics forming a natural class comes from their phonological patterning and phonotactic restrictions in several segmental phenomena, e.g.

1) In English, /l/ and /r/ can occur as the second consonant of an onset cluster whereas a nasal or obstruent is not permitted to.

2) In Korean, / r / and /l/ are in allophonic variation, [r] occurs in the onset as in *muri* 'of the water' and [l] occurs in coda position *mul* 'water' (Demers and Farmer, 1991 as reported in Ballard and Starks, 2004: 3).

More examples of cross-linguistic evidence that justifies a class of 'liquids' are given in Proctor (2009: chapter 2).

The fact that rhotics and laterals have been grouped together into a single group of consonants called 'liquids' in the phonological literature, itself implies the possibility of interaction between the two sub-groups (rhotics and laterals) in the sound inventories of languages that have these members. Therefore a closer look at the nature of phonological and phonetic interaction between rhotics and laterals within a language is imperative for a better understanding of each of their individual characteristics.

Laterals and rhotics are often considered in the literature to bear a fixed relationship to one another, the rhotic being the more sonorant of the two. The /l/-/r/ relationship is expressed as one of markedness (Rice, 2005). Marked features within a feature class are often characterized as less natural, less common and less stable, more complex, more specific whereas unmarked features are characterized as more natural, stable and simpler, more general and basic in comparison. Also, the presence of marked features in an inventory is often said to imply the presence of their unmarked counterparts. In other words, if a marked feature is present in a particular sound inventory, then it is a necessary requirement that the system also have its unmarked counterpart.

The phonological diagnostics for determining the markedness relationship between features within a class are considered to be neutralization, epenthesis and target patterning (Rice, 2005:32). Assuming this to be true and that there is a universal markedness relationship between /l/ and /r/, Rice makes three predictions. Firstly, in languages with a single liquid in its inventory, it should be the unmarked one that is present and this should be common cross-linguistically. Secondly, in contexts where there is an emergence of the unmarked feature, one liquid should occur to the exclusion of the other cross-linguistically. Thus neutralization contexts would favour one over the other as would epenthesis. Thirdly, in contexts where there is a submergence of the unmarked feature, one would expect consistent asymmetrical patterning between the liquids cross-linguistically. Examples of the different contexts described in Rice's study are dealt with in the paragraphs below.

In examining inventories with a single liquid cross-linguistically, Rice found some cases where the liquid phonemicized as a lateral, e.g. Hawaiian Plynesian and Dani Eastern New Guinea, and in some as a rhotic, e.g. Maori Polynesian and Chauve Central New Guinea, etc. This shows that inventories on their own cannot provide enough evidence for a fixed markedness relationship between /l/ and /r/. Also, in languages with a single liquid in their inventories, there tends to be a great deal of variation in the phonetic realization of that one liquid and in many of such languages, free variation between the two has been reported, e.g. Sentani (Cowan 1965) where the single liquid phonemicized as /l/ varies freely between [l] and [r], and Japanese (Vance, 1987) where the /r/ has both rhotic and lateral pronunciations. Other languages of this kind include Maori, Hua, Chamorro and Yimas etc. (Maddieson, 1984).

Rice further examined languages with positional neutralization of liquids, that is, languages that have both a lateral and a rhotic but in which the contrast between the two is suspended in certain positions. One particular neutralization position of liquids is immediately following an obstruent, that is, in obstruent-liquid clusters. Given the consonantal strength hierarchy as proposed by Vennemann (1988:9) (given below), one would expect a preference for the obstruent-rhotic clusters over those of the obstruent-lateral clusters since the former cluster exhibits a steeper sonority cline than the latter kind of cluster. In other words, the frequent interpretation in the literature is that obstruent-lateral clusters are more marked than obstruent-rhotic clusters (e.g. van der Torre, 2003).

Consonantal Strength Hierarchy

Voiceless plosives > voiced plosives > voiceless fricatives > voiced fricatives > nasals > lateral liquids (l-sounds) > central liquids (r-sounds) > high vowels > mid vowels > low vowels

However, in surveying languages with obstruent-liquid clusters where no liquid contrast is found, Rice found both obstruent-lateral and obstruent-rhotic clusters to occur, e.g. Malayu Ambong (Indonesia; ref to van Minde, 1997) in which in the neutralized context a lateral rather a rhotic is found, the Sao Tomense Portuguese-based Creole, in which the standard Portuguese rhotic is replaced by the lateral (‘blaza’-‘brasa’-*ember*) etc. Therefore, the preference for one of the two kinds of obstruent-liquid clusters seems language-specific rather than universally marked.

Along with neutralization, epenthesis, as mentioned earlier, is also considered a phonological diagnostic for determining markedness relationships. The phonological process of epenthesis is not common in the case of liquids but is found in some languages, English being one of them. Liquid epenthesis has been studied in the following two English dialects: Boston English (which has intrusive *r*), and Bristol English and some American English dialects (which has intrusive *l*). Previous work on liquid epenthesis (e.g. Gick's 2002:167) suggests that intrusive r and l parallel each other in many respects. Although there may exist different synchronic environments for different epenthetic liquids, it appears that there is no fixed choice of epenthetic liquid universally.

Rice concludes that the general claim that laterals and rhotics bear a fixed relationship with each other does not appear to hold true when liquids are studied cross-linguistically since the predictions that such a claim would entail have not borne out as described above. It therefore seems that laterals and rhotics bear "an equipollent relationship" (pg. 42) to each other, and the different choices made between these two things that are "essentially, equal for phonological purposes" appear to be language-specific. In other words, the /l/-/r/ relationship does not seem be universally similar but varies from language to language.

In languages like Tamil that have larger liquid inventories constituting five members, two rhotics, two laterals and a fifth liquid, studies (e.g. McDonough & Johnson, 1997) have shown that the dimensions of contrast (for intervocalic liquids) are not merely lateral-*non lateral* but *rhotic*-lateral (rhotics having property of lowered F3 in common in Tamil), retroflex-non retroflex and static-dynamic. These latter two dimensions are independent of the identity of the liquid, i.e., laterals and rhotics each have a retroflex and non-retroflex member and features of rhotics are not defined by the absence of features present in laterals. In fact, some of the dimensions of contrast present between the two laterals exist also between the two rhotics (in the dialects that contrast between the two rhotics). Results of the present study on Malayalam will also show that the /l/-/r/ relationship varies from language to language and that there are dimensions of contrast among the five liquids of the language that do not always divide them along the categories of rhotic versus lateral.

This section described the relationship between rhotics and laterals based on certain shared phonological features with respect to patterning despite the lack of a common phonetic basis that justifies their joint membership to the class of 'liquids'. The nature of /l/-/r/ relationship also appears to be language-specific with related languages exhibiting different dimensions of contrast between rhotics and laterals and among liquids in general. So far in this thesis, the phonetic asymmetry of rhotics has been examined alongside their phonological unity as a class. The phonological similarities that rhotics share with laterals and the nature of their relationship with each other have also been described. The next section will discuss the potential of a non-segmental approach in accounting for the rhotic paradox: their phonological unity despite their phonetic diversity.

1.1.5 Looking beyond 'segments'

Wiese (2001b:12) advocates looking beyond a merely segmental solution to explain the paradox surrounding the phonetically diverse yet phonologically similar rhotics since the possible generalizations circumscribing rhotics mentioned in the above subsections are not segmental ones but instead focus on their phonotactic unity.

Wiese claims /r/ is a prosody. According to him, "/r/ is the point on the sonority scale between laterals and vowels" (Wiese, 2001a:350). Original descriptions of the sonority hierarchy (by Sievers, 1901 and Jesperson, 1904) and research based on them since, involve defining the concept as an ordered scale of sound classes. The relative order of sounds in a syllable is such that high-sonority sounds always occur closer to the peak of the syllable (or nucleus) than the lower sonority sounds. Wiese therefore makes two claims initially: firstly that /r/ is a constant point on the sonority scale and secondly that this is a plausible, if not the only solution to the paradox surrounding rhotics. He substantiates the first claim with evidence from French where although obstruent-obstruent clusters are generally not permitted, obstruent-r sequences freely occur even where /r/ is a fricative. He observes, however, that the quality (or the sonority) of /r/ ranges from fricative to vocalic and that the sonority hierarchy as is generally understood relates exactly to these properties. In that case then, /r/ cannot be a single point on such a sonority scale since it varies so widely in the very properties that define the different points on the scale. Therefore, Wiese suggests a revision of the sonority hierarchy so that previous definitions of it as relating to fixed segmental features are done away with and are instead looked at purely as an abstract ordering of points on a scale. Each position on the scale is defined not by its inherent segmental features which is not even possible in the case of /r/ anyway but by its relative position on the scale. How many points the scale can have may or may not be language-specific. Wiese gives the example of German and proposes a scale with six points based on his own extended version of the previous sonority hierarchy that grouped together laterals and rhotics as ‘liquids’ and together assigned them one point on the scale:

Obstruent < nasal < liquids < glide <vowel (Clements 1990)

Obstruent< nasal<lateral </r/ < glide <vowel (Wiese, 1988:91; Hall, 1992.)

P1 <P2 <P3 <**P4** <P5 <P6 (Wiese, 2001a:355)

/r/ is a position on an abstract sonority scale, namely the one between laterals and glides, highlighted in bold (P4). Therefore the class of rhotics is one such relative position on the scale, ordered with respect to other neighbouring positions

Wiese points out two limitations of this proposal. Firstly, in languages like Polish and Russian, word-initially, /r/ forms r-obstruent clusters which clearly go against the revised concept of sonority hierarchy but perhaps one can still argue in favour of it by applying the extrasyllabicity rule (the notion that at word-edges some segments may not form part of the syllable but are extra syllables and hence the sonority hierarchy does not apply) to such sequences since they occur word-initially. But, if /r/ is a point on the sonority scale, what is ‘extrasyllabic /r/’? Secondly, how does one accommodate rhotacized vowels into this revised concept? If rhotics are defined as a point in between laterals and glides and at the same time distinct from them and ‘vowels’, where will vowels that are ‘r-coloured’ be placed? Should they be placed nearer to the vowels or the rhotics on the sonority scale?

Wiese’s proposal appears to be quite confusing: on the one hand he argues that /r/ is a prosody, a point on the sonority scale (which is to be seen as an abstract ordering of points on a scale, each position defined relative to that of others on the scale), “namely the one between that for /l/ and glides”(2001:357). On the other hand, he claims that all major classes “can/must be defined in prosodic terms”. If /r/ is a point on the sonority scale between /l/ and glides, both of which have not been defined in prosodic terms as classes, then by Wiese’s own definition of /r/ (based on its relative position to that of other neighbouring points on the scale) and the sonority hierarchy, how do we understand and describe /r/ in detail? More importantly, Wiese does not offer any clear explanation of what an ‘abstract’ sonority scale could look like and how the phonological representation of rhotics should be characterised based on this approach. Although, no doubt, Wiese shows the importance of treating rhotics not merely as a class of sounds characterized by segmental features, but more by their prosody, his proposal still leaves many questions unanswered regarding the complex relationship between the phonology and the phonetics of rhotics.

Recent work on post-vocalic Dutch /r/ by Plug and Ogden (2003) also used a non-segmental parametric approach to explain the complex phonetic aspects of rhotics. In their study, they describe the phonetic exponents of rhoticity in postvocalic position in 4 adult speakers of Standard Dutch. The authors report that the general literature on Dutch rhotics claims that it is very common to have cases of /r/ deletion or zero realisations in post-vocalic contexts. They present both impressionistic evidence and instrumental measurements to show the parametric differences between the rhymes with and without postvocalic /r/ in the data under consideration. The materials investigated include a corpus of 22 pairs of Dutch words, each pair distinguished by the presence versus absence of a postvocalic /r/ and also containing a monophthong and ending in a coronal plosive, for example, ‘giet’- *pours*, ‘giert’- *shrieks*; ‘buut’- *home*, ‘buurt’- *area*, etc. The rhotic-constituting tokens were referred to as +r while the non-rhotic tokens were referred to as -r tokens. The auditory, impressionistic analysis involved two stages: Paradigmatic analysis focusing on the segmental realization of /r/ and syntagmatic analysis focusing on parametric differences between +r and -r tokens by holistic analysis of the whole word. This was followed by an instrumental analysis which focused on two main aspects: vowel duration and quality, and the place and manner of articulation of the final coronal plosive.

Both sets of analyses were consistent with the fact that apart from the possible segmental realisation of /r/, +r tokens differ from –r tokens in Dutch in the following aspects: 1) the vocalic portion of +r tokens tend to be longer than those of the corresponding –r token; 2) the quality of the steady state of the vocalic portion of a +r token is different from that of the corresponding –r token; 3) the vocalic portion of a +r token tends to contain an off-glide towards a mid-central vowel quality; 4) the burst of a final coronal plosive in a +r token tends to be shorter and have lower concentration energy than that of in a corresponding –r token; 5) A final coronal plosive in a +r token tends to have an abrupt release as compared to that of a final coronal plosive in a –r token. Auditory analysis revealed that the exponents of /r/ in Dutch include retroflexion of the tongue tip or blade, and probably also a tongue body gesture. Plug and Ogden

(2003) conclude that the phonetic exponents of postvocalic /r/ in Dutch are variable in degree and in temporal alignment. Their results show that the exponents of /r/ are often distributed over the nucleus and coda of the syllable without /r/ in the rhyme having any obvious segmental realization: "..although +r form lacks any clear 'rhotic', it is distinct from the –r form" (pg. 184) and this clearly reflects the significance of using a parametric approach to the study of rhotics.

Plug and Ogden (2003:160) interpret their findings using a model of phonetic exponency associated with Declarative Phonology (Scobbie et al., 1996; Coleman, 1998). A similar model of phonetic exponency associated with Declarative phonology is the Firthian Prosodic Analysis (FPA). Since FPA is a relatively lesser known theory, some of its key aspects will be presented below briefly.

Firthian Prosodic Analysis is essentially based on ideas put forward by J.R. Firth, his colleagues and his students, also often called the prosodic phonologists. The key aspects of the approach were set out in Firth's *Sounds and Prosodies* (1948). Some recent phonetic work that applied this approach to liquids include Carter (1999) and Simpson (1996).

According to FPA, in order to account for the phonological systems of a language, it is imperative that both the paradigmatic and syntagmatic aspects are integrated into a single unified description unlike purely segmental linear approaches to phonology that tend to focus only on the paradigmatic aspect. In such an analysis, the basic unit is not a segment but a structural unit which can be a syllable, word, a part of a syllable or, part of a word etc. (Ogden & Local, 1994; Robins, 1957 etc.). Along the lines of the distinction between syntagmatic and paradigmatic aspects, FPA also differentiates between 'structure' and 'system' respectively (Robins, 1957: 188-189). While structure refers to syntagmatic relations corresponding to stretches of utterance in a language like syllable, word, sentences etc., system refers mainly to paradigmatic relations involving consonants, vowels, consonant clusters relevant to various places in structure.

In Firthian Prosodic Analysis, phonological features are not assigned to segments but to 'prosodies' which are non-segmental entities, not tied to any particular aspect or level of phonology-spread over for example a syllable, part of a syllable, syntactic unit, word, root of a word etc. A feature that extends over more than one segment is abstracted from the phonology of the language and defined as a prosody.

Firth's analysis suggests there are two kinds of phonological units:

1) Phonematic units (consonants and vowels)

2) Prosodic units (frontness, backness, roundness, length, voicing, emphasis etc.)

Both types of phonological units, i.e., prosodies and phonematic units must be stated in terms of both ‘structure’ and ‘system’ since both are relevant to statements of phonetic exponency. Both have syntagmatic and paradigmatic relations with each other. Syntagmatic relations are expressed in prosodies but prosodies may also be associated with paradigmatic relations. Therefore it is possible to refer to a ‘prosodic system’ and a ‘phonematic system’ (e.g. see results of Simpson’s study below, pg. 21-22). For example, CVC could be a structure where C and V are elements of structure constituting two C systems and one V system (Ogden & Local, 1994:483). Prosodies must be in ‘system’ and are elements of structure. They do not ‘spread’ over units. They occur at places in ‘structure’ and may have exponents of varying extents (Ogden & Local, 1994: 484). Long-domain phonetic features are not necessarily ‘prosodic’. If a syntagmatic relation at the phonological level can be expressed as phonetic exponency statements, then that relation can be treated as ‘prosodic’. Different phonetic features can expone a single ‘prosodic’ unit. A single prosodic unit may have discontinuous phonetic exponents. ‘Prosodies’, like all other phonological terms, require an explicit phonetic interpretation since units of description are not seen as universally valid (pg. 483-484).

In FPA, no assumptions are made about linguistic universals. FPA views phonology and phonetics as entirely separate from each other but the relationship between the two separate entities, phonetics and phonology, need to be stated in terms of phonetic exponency statements: “The phonetic interpretation of each term in each system at all linguistically relevant places in structure must be stated explicitly in order to ‘renew the connection between phonological and phonetic levels” (Ogden & Local, 1994: 486).

FPA, as mentioned earlier, is a declarative phonology and not a derivational phonology. This is based on “its search for a single invariable phonological description of any given item” (Ogden & Local, 1994:481). Its invariability underlies the static nature of phonological descriptions produced by prosodic analysis. FPA is static and descriptive rather than process-driven or derivational. Phonetics is not treated as the output of operating rules on phonological structures. Under this approach, there are no rules, and hence no ordering of things; there are also no replacements or alterations. Phonological units are abstract which means that they are not pronounceable and are purely relational forms having an explicit phonetic interpretation. Temporal relations are treated as part of the phonetic exponency statements and not as part of phonological descriptions. The name of a phonological category in FPA is irrelevant and ad hoc since its phonetic interpretation is stated explicitly in terms of exponency statements.

The notion of an explicit phonetic interpretation of phonological units has been briefly addressed in Carter's (1999) study of British English liquids. It is referred to as 'Extrinsic Phonetic Interpretation' (EPI) whereby phonetic features relate to phonological categories in a 'partly absolute-partly relative' manner. He found, like an earlier study by Kelly and Local (1986) that the interaction between rhotics and laterals in British English is dialect-specific and structure dependent and have consequences for secondary and resonance qualities, i.e. clearness and darkness in languages like English (e.g. Kelly and Local, 1986; Carter, 1999).

Carter's study focussed on rhotic-lateral interaction in two rhotic dialects and two non-rhotic dialects of British English. With regard to the non-rhotic varieties, no comparisons could be made in the syllable-final position since these varieties have no contrast in the liquid system at that syllable position. The clear initial lateral variety has a relatively clear lateral (higher F2) and a relatively dark rhotic whereas the dark initial lateral variety has the opposite pattern, relatively dark lateral and clear rhotic. Carter's results are consistent with those of Kelly and Local (1986) in that vocoids in the clear initial lateral variety have a higher F2 after the lateral than after the rhotic and vice versa in the dark initial lateral variety: lower F2 after laterals than after rhotics (called the longer-domain effect).

With respect to the rhotic varieties, syllable position (initial vs. final) was also an important factor in determining the resonance patterns of the liquids. Results of Carter's study showed that in the same syllable position, the lateral and rhotic had opposing resonance qualities and in opposing syllable-positions, the same liquid had opposing resonance qualities. The patterns in the syllable final position applied only to the rhotic dialects in the study since /r/ is realised syllable-finally only in these dialects. As for the vocoids following liquids in both the rhotic varieties, F2 is higher when following a lateral than when following a rhotic which is similar to the pattern found in the non-rhotic clear initial lateral variety. Speakers of rhotic varieties have darker initial rhotics than initial laterals and clearer final rhotics than final laterals. Also, their initial rhotics are darker than their final rhotics. In a rhotic dark initial lateral variety, a syllable-initial lateral counts as phonologically 'clear' because it contrasts with a dark rhotic in the same system and yet its phonetic realization is 'dark'. This opposition of a phonologically 'clear' yet phonetically dark lateral was explained using the notion of extrinsic phonetic interpretation (EPI) which forms part of the FPA framework and suggests that phonetic features relate to phonological categories in a ‘partly absolute-partly relative’ fashion.

Plug and Ogden (2003) in their study on Dutch post-vocalic /r/ (see pg. 17-18 above for more details) also found some evidence that “may support theories which treat phonetic exponents as arbitrarily but consistently related to phonological categories” which includes theories like the EPI described above and in fact Plug and Ogden also refer to Carter’s article in this regard.

Apart from the notion of EPI, another key concept of FPA includes Polysystemacity. According to FPA, a language is a set of interacting systems, each of which may be stated independently of the other and this concept is called Polysystemacity in this approach. The characteristics of one system may not be the same as that of the other(s). This way the irregularities in a language can be treated as separate systems. Firth himself is reported to have used the term to mean that different consonant and vowel systems should be set out for different syllable positions and word structure (e.g. different consonant or vowel systems for word-initial and word-final positions) , and, for different grammatical structures (Palmer, 1970: xi).

Simpson’s study of Albanian liquids uses the principles of FPA to explain the interaction between rhotics and laterals with respect to their resonance characteristics to form part of a single liquid system. Albanian has four liquids: alveolar tap, alveolar trill, clear alveolar lateral, and dark dental lateral. The tap sounds clear and the trill sounds dark in resonance. The tap and clear alveolar lateral and their surrounding vowels sound fronted and some of them closer while the trill and dark dental lateral and their surrounding vowels sound retracted and more open. These impressionistic observations by Simpson are largely confirmed in the acoustic results: higher F2 values for taps, alveolar laterals and their surrounding sounds compared with lower F2 for trills, dental laterals and their surrounding sounds (cf. section 1.2.3 pgs. 29-30). Using FPA, Simpson suggests that there are two (abstract) phonological systems, R/L and $^{y}/^{w}$ and their phonetic exponency statements are described as follows:

“R intermittent coronal contact

L laterality and coronality

^{y} clear secondary cavity resonance and convex front of the tongue; laminal articulation

^{w} dark secondary cavity resonance and concave front of the tongue; apical articulation: dental in association with L, trill posture with R” (pg. 14).

In the above study, 'R' and 'L' appear to be phonematic systems whereas ^{y} and ^{w} appear to be prosodic systems. Note that an interaction between the two phonological systems (R and ^{y} or R and ^{w}) and similarly between (L and ^{y} or L and ^{w}), which is referred to in FPA as polysystemacity as described earlier, allows for the phonetic reality of the liquid realisations in Albanian to be related to the abstract phonological forms R and L by means of the different phonetic exponency statements. This appears to be simpler representation of the phonology of the liquids rather than devising a single abstract representation that captures within it all the phonetic complexities associated with their realisations.

Simpson does not mention the temporal extent of the different tongue configurations in his exponency statements described above although he suggests based on preliminary observations that it may be bound up with a rhythmic unit such as the foot. Simpson also suggests a non-segmental alternative to the notion of Coarticulation to address the long domain aspects of tongue configuration. Based on FPA, such an alternative would treat phonetic exponents of different phonological items as occurring at the same point in time. Therefore the different aspects of tongue configuration resulting in differences in surrounding vowels and consonants are not viewed as a result of 'Coarticulation' with a particular consonant, say for instance the trill or the dark lateral in the above case, but rather as a phonetic exponency of the phonological unit ^{w} which has greater temporal extent than the exponent laterality or intermittent contact (pgs. 14-15).

Since Malayalam, like Albanian, has a relatively large liquid system, it will be interesting to explore how a non-segmental approach like FPA could account for the results obtained and patterns observed for the present study on Malayalam.

1.2 Trills, taps and flaps

1.2.1 Production of trills and trill variability

According to Barry (1997) the phonetically diverse members of the phonological class of sounds often referred to as 'rhotics' have to have a focal point that directly or indirectly relates all the various R variants and this focal point is the trilled R. In his review of trills of 19 languages, Jones (forthcoming) also found some support for the view of 'trill primacy' according to which trills are seen as "the archetypal rhotics and the diachronic source of most other rhotics" (pg. 18). Nevertheless he points out that the fault with the notion of trill primacy and its interpretation in the literature is that a language with a trilled /r/ is assumed to always realise /r/ as a trill. The cross-linguistic variability trill productions as shown by Jones' review is dealt with in this subsection.

The physical basis of a trill is the presence of a sufficient airstream to make a flexible articulator like the tongue-tip or the uvula to vibrate against the surface of the vocal tract it is in close proximity with. The processes involved in the production of a trill are similar to vocal fold vibration in that both are the products of aerodynamic-myoelastic processes. The Bernoulli effect caused by the approximation of the articulator and the point of articulation can result in vibration only if the form of the articulator and the tissue elasticity, i.e., muscular tension are correctly adjusted (pg. 36). With respect to the form of the articulator, a funnel shaped constriction with the articulator opening in the opposite direction of the airstream is the most conducive for vibration. As for the ideal degree of elasticity most conducive for trills, the positioning of the tongue body and blade or tongue dorsum and sides are required to be tensed but without stiffening the tip for a lingual trill and keeping the central part of tongue low to allow the uvula to vibrate for a uvular trill(pgs. 36-37).

Since the production of trills requires stringent complex articulatory demands to be met by the speaker, it seems natural that there is a great deal of variety in the realisation of trills across speakers and languages. Jones (forthcoming) reviewed data from 19 languages that have a single rhotic contrast. There were two kinds of data sets: word list and narrative data. With respect to the incidence of trill and non-trilled realisations across languages, there were three main trends that emerged. Firstly, that like Lindau (1985) suggests, trills are realised as such only around one third of all /r/ instances. Most of the trill realisations in the data set Jones examined was found to be minimal trills with only two contacts. Secondly, trill realisations were found to be rarer in the narrative data than in the word-list data. Typically, trill realisations tend to be less prevalent in connected speech than in citation forms due to the stringent articulatory requirements for trill production. Jones points out however that both data sets involved non-spontaneous speech elicited under formal laboratory conditions and despite that there was this difference in incidence of trill realisations. Lastly, the data examined also suggested that trills may be more prevalent in consonantal contexts than in intervocalic position with some amount of preference for post-vocalic pre-consonantal contexts where trills were realised as trills relatively more frequently across speech styles. The author also acknowledges that trends observed on the incidence of trills in particular contexts must be interpreted with caution due to the uncontrolled and imbalanced nature of the data sample.

Jones observed in the cross-linguistic data sample that there were examples of canonical trills involving rapid alternation between the low amplitude contact phases and higher amplitude open phases but these also involved a weakening of contacts over time. Based on waveform amplitude and spectrograms, the initial contact was found to be one with a greater degree of occlusion than successive contacts. Acoustic effects of ‘trill weakening’ were also observed in all cases in the data set examined. In two-contact trills, it was observed that a very weak second contact may not be picked up by instrumental techniques like EPG and may also be missed by acoustic analysis and it is pointed out in the study that such trills could be cause for a perceptual reanalysis that leads to sound change to a tap realisation. Some cases of trill failure or where acoustic evidence for trilling was doubtful or did not exist were also examined. Most of the tap and approximant realisations in the sample showed no indication that suggested that they were a result of trill weakening or failure. According to Jones, it seems that such realisations of non-trilled variants could be attributed to allophonic variation due to qualitatively different production targets being selected by speakers. The study suggests that there must be differences between the taps that alternate with trills in languages that do not contrast taps and trills and the taps which are not allowed to alternate in languages like Spanish that contrast taps and trills. However the author points out that it is difficult to conclude whether such taps are ‘one-contact trills’, i.e. those that involve an initial contact but trill initiation fails thereafter, or whether these taps are qualitatively different /r/ implementations.

F3 lowering was found to be a common characteristic of trills and other manner of rhotic variants, the latter primarily in the context of labial consonants and rounded vowels. This finding of Jones (forthcoming) regarding the widespread presence of low F3 in all manner of rhotics in the sample is different from Lindau’s (1985) observations that F3 cannot be seen as an essential component of apical rhotics. Jones agrees with Lindau in that not all rhotics are characterised by a low F3 all the time but suggests that it can be ‘something of a rhotic indicator’ (pg. 19) for apical rhotic realisations in all languages some of the time (cf. Heselwood, 2009; Heselwood & Plug, 2010ab). A fall in F4 was also found to occur in the sample. Whether or not low F3 will be ‘something of a rhotic indicator’ in languages like Malayalam that has larger liquid inventories will also contribute to the discussion in the literature regarding the importance of F3 in identifying and analysing rhotics.

Even in languages like Spanish that have more than one rhotic in its inventory, trill variation is widely documented in the literature (Colantoni, 2006 a,b; Willis, 2006,2007; Bradley and Willis, 2008,etc.). The most common realisations of the Spanish trill include an apico-alveolar trill, assibilated trill, a uvular trill, a pre-aspirated trill, a pre-breathy-voiced trill and an approximant (Henrikson & Willis, 2010).Willis (2007) reports that the most common allophonic realisation of the trill in Dominican Spanish is a pre-breathy voiced tap and that the pre-breathy voice portion accounts for more than 60% of the overall duration of the segment. The second most frequently occurring allophone involved pre-breathy voicing followed by multiple closures. Willis and Bradley (2008) suggest that the range of allophonic realisations are constrained by the need for contrast maintenance between the trill and tap. They recall an earlier work by Zlotchew (1974) that showed that pre-breathy voicing is used as a compensatory durational cue so that even if the trilling gesture is lenited to a pre-breathy voiced one-tap trill, the rhotic contrast is not neutralised. Willis and Bradley argue that the innovation of breathy voice as part of the trill realisations is also motivated by articulatory and perceptual factors and that it "can be seen as a compromise between modally voiced and voiceless trills, combining the perceptual distinctiveness of the former and the aerodynamic stability of the latter" (pg.96). Therefore even in languages that contrast between two or more rhotics, their lack of total phonetic adherence to the phonological 'target' does not lead to a neutralisation of contrasts since speakers may use other strategies to create articulatory and/or perceptually appreciable differences between the sounds to maintain the contrast between them.

1.2.2 Taps and flaps

With regard to the nature of the non-trilled variants, the literature has over the years juggled between the two views of whether to consider a tap and a flap as essentially the same sound or whether to treat them as two different sounds (Jones, 1969:195 and Mangold, 1973:5 versus Ladefoged and Maddieson, 1996:230-1 etc.). Pike in the early 1940's distinguished only between a flap and a trill and considered tap and flap to be the same but preferred to use the term 'flap'. According to Pike (1943:124-125), a 'flap' involves a brief and rapid 'tap' of the articulators against each other followed by an immediate release; “approach and release are together formed by a single ballistic movement”. He describes a trill as repetitive flaps but involving complete closure of the air passage whereas his use of ‘approach’ for the movement involved in a flap suggests a partial closure for the latter. Abercrombie (1967:49) defines a ‘flap’ as being a consonant produced during a ballistic movement of the active articulator striking the passive one in passing. Meanwhile, Uldall (1958) (as reported in Thelwall, 1980) describes a flap articulation as the tongue tip being flung against the teeth ridge and bouncing off , not always involving a complete closure, often having some amount of friction during its release.

Ladefoged & Maddieson (1996) and in an earlier work, Ladefoged (1971:50) distinguish clearly between a trill, tap and a flap: A trill is an aerodynamically induced movement involving the flexible part of the active articulator vibrating against the passive articulator. Taps and Flaps are on the other hand purely muscular gestures, differing from each other in that the former involves the articulators making a brief and rapid contact and moving apart while the latter involves the active articulator striking the passive articulator in passing while on its way back to its rest position. Catford (1977:129) used only the term flap and not ‘tap’ but suggested that there are two kinds of flaps: a ‘flick’ and ‘transient’ flap. The former involves the active articulator moving from its rest position to strike or flick lightly against the passive articulator and receding again to its original position whereas the latter involves a rapid movement from a particular starting point to a different end point, momentarily striking the passive articulator on the way. Some researchers have also argued in favour of getting rid of the term ‘tap’ altogether and use ‘flap’ for both (Spajic et al. 1996: 2-3) based on the fact that both involve a single muscular contraction. Barry (1997: 38), however, argues that the tap according to the above definition involves an up and back movement, i.e., the tongue-tip raising muscular contraction has to continuously work against a muscular state which pulls the tip back down whereas by definition a flap does not involve any such antagonistic force. Barry also notes that even the gestural difference between a to-and-fro movement and movement involving ‘passing’ from one position to another is obvious.

As for the debate in the literature about whether a ‘tap’ should be seen a single-strike trill, Barry insists on the outset that a tap is not merely a temporal reduction in the gestures involved in the production of a multi-strike trill. Nevertheless he adopts two different perspectives to answer the question: In synchronic terms, purely reducing the time available for a trill will not result in a tap. However, diachronically, i.e., where articulatory reinterpretation due to perceptual similarities occur, it does seem plausible that the tapped /r/ is derived from a trilled /r/ just as tapped /d/ and /t/ are seen as cross-dialectal articulatory reinterpretations of reduced normal /d/ and /t/ (pg. 41).

Using the example of language like Toda, where a retroflex flap transitioning into a regular alveolar trill seems to be a distinctive sound, Barry suggests that it may be drawn from this that a flap may be the consequence of an established retroflex series in the consonantal system, and represents a transition to the trill position in a system which also has trills, as in the case of Toda. In this regard, the flap appears to be indirectly relatable to the trill, though not derived from it (pg. 39).

In relation to the trill variability discussed in the previous sub-section, Willis and Bradley (2008) found that speakers of Dominican Spanish not only produced various allophonic realisations of the trill but also the tap. They broadly identified four main variants: "a noncontinuant tap, an approximant tap, a perceptual tap without salient acoustic cues and complete reduction or elision" (pg. 92). A non-continuant tap is characterised by a clear break in the spectrogram accompanied by reduced waveform amplitude. An approximant tap involves a lesser reduction in waveform amplitude compared to the non-continuant tap but is characterised by fairly continuous formant structure unlike the former. The third variant involves one that sounds like a tap but has a formant structure of decreased amplitude as a result of the two articulators in approximation with each other and also has a considerably reduced waveform. Nevertheless even in this variant the formant structure is continuous throughout the tap gesture. The fourth variant is a zero variant involving the complete elision of the tap characterised by the maintenance of an uninterrupted and continuous formant structure of the surrounding vowels and involving no reduction in waveform amplitude unlike the other variants (pgs. 92-94).

The term 'tap' in the literature generally refers to a manner of articulation involving the active articulator making a very brief contact with the passive articulator. It is also frequently referred to in the phonetic literature as being similar to its cognate stop differing only in duration, i.e., it is shorter than its cognate stop. However, there is no total consensus on this issue among phoneticians, some of whom insist that the nature of the gesture involved as well as its duration, are its characteristic features (Connell, 1995: 39).

Connell shows through data from Electropalatography that taps differ from their cognate stops primarily with regard to their spatial characteristics than their temporal characteristics. The data involves the speech of one young, male adult speaker of Ibibio, one of the Lower Cross languages of south-eastern Nigeria. The speech materials consisted of wordlists combining all possible vowels [i, u, a] and all stem-initial consonants of the language (with the focus on [d] and [r] in this study) in both high and low tone environments in VCV sequences. Nonsense VCVs were used where certain VCV combinations did not give rise to any natural word. Counter to what has been established previously in the literature, durational measurements of the onset, medial and offset phases of the tap and its cognate stop revealed that apart from the onset phase where the tap had a shorter duration than the stop, the tap had a slightly longer duration in the medial phase and a substantially longer duration than its cognate stop in the offset phase. The spatial characteristics of the tap and the stop were investigated by comparing their linguo-palatal contact patterns using EPG and this was done by counting the number of electrodes activated during their medial phases. The EPG charts revealed a striking difference in linguo-palatal contact between the two, with the tap involving much less contact and never showing complete closure. The charts also show that it is primarily the contact in the alveolar-post-alveolar region that characterizes the articulation of both these consonants. Apart from the difference in the degree of closure between the two sounds, there also seems to be a difference in the direction of the tongue movement. In the case of the stop, the artificial palate revealed evidence of a 'rolling' or a forward movement of the tongue which seemed to absent in the case of the tap but the author points out that this could be because the absence of sufficient contact in the case of the tap has resulted in the palate failing to reflect any such forward movement even if it had existed for the tap. Connell concludes from the results obtained in his study that for Ibibio [d] and [r], the main difference lies in the nature of their linguo-palatal contact rather than their durations with some evidence, although inconclusive, pointing towards a secondary difference in the direction of tongue movement involved in the two sounds. He describes the tapped articulation as a weaker gesture than a stop articulation, i.e., involving less muscular activity as a result of lesser degree of contact in the case of the former. With respect to the primacy of the spatial characteristics over the temporal ones in differentiating between a tap and its cognate stop, Connell reports similar results having been obtained for at least one other language-Japanese (Sawashima and Kiritani, 1985 as reported in Connell, 1995: 46).

Therefore there is disagreement in the literature over the exact phonological and phonetic nature of even the few uncontroversial members of the rhotic family. In order to address some of the issues regarding the phonological approach that best captures the unity in diversity of the rhotics and the complex relationship between the phonology and phonetics of rhotics in general and cross-linguistically, languages like Dutch that have more than one rhotic has often been the subject of a lot of the research in this area since almost all known /r/ variants occur in Dutch (Van de Velde and De Hout, 2001; Plug and Ogden, 2003 etc.). Plug and Ogden (2003) showed in their study of Dutch post-vocalic /r/ the significance of adopting a parametric approach (cf. section 1.1.4, pgs. 17-18 above), the premise of which is based on Firthian Prosodic Analysis. Studies on other languages based on a similar approach (Albanian: Simpson, 1996;1998) and the key aspects of the Firthian approach will be dealt with in more detail in section below.

While the previous sub-section looked at the production of trills and their variability cross-linguistically in single rhotic languages, this sub-section looked at taps and flaps and how they are different from trills not just with respect to duration as is often cited in the literature but also in that they involve two different gestures. The next sub-section will examine a few languages that have more than one rhotic in their inventories that contrast with each other and the phonetic characteristics of their contrast maintenance will be addressed.

1.2.3 Rhotic contrasts in multiple-rhotic languages

Languages that have more than one rhotic are few and those that contrasts between them are still fewer (Ladefoged and Maddieson, 1996: Ch. 7). Malayalam, which is the language under study in this thesis, is one of the few languages that contrast between two rhotics. Spanish and Albanian are some of the other examples. Spanish contrasts between a tap and a trill and is perhaps the most widely researched language on rhotic contrast.

Spanish contrasts between a tap and a trill only in the intervocalic position word-internally and trills occur typically in the word-initial and word-medial position (Willis and Bradley 2008 etc.). Based on earlier work by Quilis, 1993), Willis and Bradley 2008 (pg. 94) report that the average closure duration of the alveolar tap in Spanish is around 20ms which is comparable to their own findings on Dominican Spanish regarding the same: 22ms with a standard deviation of 8. However the authors also point out that 51% of the tap productions had a measurable closure while 49% did not. The average duration of trills was found to be more than thrice that of the duration of taps with no overlap between the means and standard deviations of both categories. Therefore duration appears to be a significant distinguishing cue between the tap and the trill in Spanish.

Catalan which has a similar phonological system to that of Spanish has been reported to also have a tap and a trill that contrast only in intervocalic position. Based on the differing degrees of resistance of the trill and the tap to coarticulation from adjacent vowels, Recasens (1991) found that the tongue body during trill production in Catalan is subject to a higher degree of constraint than it is during the production of a tap. This study was built on data from an earlier study on VCV sequences in Catalan and Spanish (Recasens, 1987) and concluded that the trill and the Catalan dark lateral are more resistant to coarticulation than the tap and the clear lateral due to the 'velarization gesture' involved in the former unlike the latter. This observation by Recasens seems to suggest that in Catalan difference in tongue configurations which create a difference in resonance quality between trills and taps is a significant dimension of contrast between the two rhotics.

It has been suggested that resonance quality may also be a significant aspect of contrast maintenance among liquids in Albanian (Simpson, 1996). Albanian has two rhotics and two laterals in its inventory: an alveolar tap, alveolar trill, clear alveolar lateral and a dark dental lateral. Impressionistically, the tap, like the alveolar lateral, sounded clearer in resonance while the trill, like the dental lateral, was darker in resonance. The tap also sounded laminal with the front of the tongue having a convex tongue configuration while the trill sounded apical with the front of the tongue having a concave configuration (pg. 8). Apart from the consonants, the vocalic portions surrounding the clear tap sounded fronted than those surrounding the dark trill. Acoustically, most of the differences observed in the impressionistic analysis by Simpson were borne out. The vocalic portions surrounding the clear tap were characterised by rising F2 values whereas those surrounding the dark trill were characterised by low F2 values. Duration differences between the tap and the trill were not measured in this study.

While duration was found to be a main distinguishing cue between taps and trills in many varieties of Spanish (Quilis, 1993; Willis and Bradley, 2008 etc.), work on other languages like Albanian (Simpson, 1996) and a pilot study conducted by the present author on Malayalam (see chapter 3, pgs. 60-66 for details of pilot study) showed that other dimensions of contrast such as resonance quality which maybe a by-product of the differences in tongue configuration also appear to characterise the tap-trill contrast in languages that have both. Alternatively differences in tongue configuration may be used to create a difference in resonance quality between the rhotics in such languages as a contrast maintenance strategy.

Malayalam, a Dravidian language, is one among these few languages that contrast between the two rhotics in its inventory. The next chapter will therefore look at the rhotics in Malayalam in more detail and lay out the implications that approaches adopted in the literature towards the study of rhotics have for Malayalam. First, however, an overview of the origin of the language and a description of its phonological system will be presented in the first part of the next chapter.

Summary

This chapter reviewed the general literature on varied phonetic characteristics of rhotics and their phonological behaviour. Firstly, the criteria for membership to the rhotic family appear to be ambiguous and secondly, even though the rhotics are phonetically diverse, they exhibit similar phonological patterning and phonotactics. Thirdly, the relationship that rhotics and laterals share was explored and the two groups appear to exhibit several phonotactic similarities which justify their classification as ‘liquids’ for which however the phonetic basis is weak. Contrary to general assumptions in the literature that laterals and rhotics share a ‘fixed’ relationship with each other, Rice (2005:42) suggests that they share “an equipollent relationship” to each other, the exact nature of which may be language-specific. Next, the paradox surrounding rhotics with respect to its phonological unity despite its phonetic asymmetry was examined and some approaches addressing this paradox surrounding rhotics (e.g. Wiese, 2001a,b; Plug and Ogden, 2003) were reviewed emphasizing the need to look beyond ‘segments’. In this regard, a relatively lesser known theory, Firthian Prosodic Analysis, was examined and relevant work that used its principles was presented. Lastly, the phonetic and phonological characteristics of particular types of rhotics, namely trills, taps and flaps, were described based on previous work in the area since Malayalam, the language which is the topic of research in this thesis, has these members in its inventory. Researchers like Ladefoged and Maddieson differentiate among trills, taps and flaps based on the different articulatory gestures involved in their productions. Trills, due to their highly stringent production requirements, appear to be highly variable sounds with respect to their actual realisations across languages (Jones, forthcoming). Since Malayalam has two uncontested rhotics that are lexically contrastive, previous work on rhotic contrasts and different strategies used in their maintenance were presented which suggest that different languages appear to use different contrast maintenance strategies. It will be interesting to find out the strategies used by speakers of Malayalam in the present study. The next chapter, chapter 2, will focus on the phonological and phonetic characteristics of the liquids in Malayalam and review the limited literature on Malayalam and also other Dravidian languages like Tamil and Toda.

CHAPTER 2

LIQUIDS IN MALAYALAM

2.1Origin of Malayalam

Malayalam is one of India's twenty two official languages, spoken by approximately 32 million people in the southern state of Kerala. It belongs to the Dravidian family of languages, more precisely, the 'South Dravidian sub-family' (Zvelebil, 1970: 15). Zvelebil identifies twenty-two Dravidian languages, which include mainly four literary languages: Tamil, Malayalam, Kannada and Telugu and possibly eighteen or more non-literary languages like Toda, Kota, Irula, Kodagu etc. spoken by tribes and other minority groups. Of the four main languages in the family, Tamil is considered the oldest with a rich literature second only to Sanskrit among all the other Indian languages. Malayalam is said to have its origins in a "Western dialect of the Middle Tamil period" (Zvelebil, 1970: 16) and therefore shares close relations with Tamil. The earliest written form of Malayalam dates back to the 10th century and its independent literary life began approximately in the 13th or 14th century.

Lilatilakam, is the earliest available work on Malayalam grammar which studied the language and literature of 'Manipravalam', the literary Malayalam of the middle ages (Pillai, 1996, also Asher and Kumari, 1997: XXV), a mixture of Sanskrit and Malayalam. Keralapaniniyam, by A.R. Rajaraja Varma, first published in 1896 is perhaps the most monumental work on Malayalam and according to K.Raghavan Pillai (1996: 9) these two early works on the language show that in terms of technique there are two main influences on the history of Malayalam grammar: firstly, a traditional one from a dual source, Sanskrit and Dravidian. While in basic syntax and much of morphology Malayalam is strictly Dravidian, the Sanskrit influence is seen mostly in the vocabulary and compound structures. The Sanskritization of Malayalam began with the advent of Sanskrit in Kerala sometime in the 6th century A.D. (1996:5). The second of two influences is a consequence of the contact that Malayalam had with English since the arrival of Europeans in India. Nevertheless a large part of the language and its syntactic structure remain unchanged and is strictly Dravidian.

Even a brief survey of major linguistic and literary contributions to Malayalam would not be complete without the mention of Ezhuthachan. He was a great poet who wrote at a crucial period in the history of the Malayalam language, at a time when the language was increasingly being influenced by Sanskrit and consequently its Dravidian roots threatened. As Rajaraja Varma pointed out in his work (reported in Pillai, 1996:30), Ezhuthachan not only reformed Malayalam poetry in terms of its outlook and themes but also increasingly used Dravidian metres in his poems. Even though the Sanskrit alphabet was adopted, the addition of Sanskrit case suffixes to Malayalam bases was discouraged. Other major works that appeared in the last two centuries include George Matthan's *Malayalmayute Vyakaranam* and T.M Kovunni Nedungadi's *Kerala Kaumudi* (1878). One European scholar who made a significant contribution to Malayalam, to whom even Rajaraja Varma acknowledged his debt, is Hermann Gundert through his work, *Malayala Bhasha Vyakaranam* (first published in 1851, the complete work came out in 1868) which is still regularly reprinted. Another prolific linguist was L.V. Ramaswami Ayyar (Asher and Kumari, 1997: XXV).

Regarding the origin of Malayalam, the position taken in Keralapaniniyam is that Malayalam is a product of one of the 'Kotum Tamir' dialects (Pillai, 1996:12), the spoken form of early Tamil which is different from 'Cen-tamir', the refined literary language. "The spoken 'Tamir' prevailed in different areas of ancient 'Tamizhagam', including the area west of the Western Ghats. This area was called Cera land and the form of Tamir spoken in this area later developed into Malayalam" (Pillai, 1996: 12).

Malayalam, as it is spoken today, has three distinct regional dialects: South Kerala, Central Kerala and North Kerala. There also exists clearly marked linguistic differences based on caste and religion e.g. Namboodiri dialect, Nayar dialect, Moplah dialect, Nasrani dialect etc. and a four-way difference in language among Brahmin, Nayars, other touchables and the untouchable castes (Zvelebil, 1970). Like Tamil, the written form and the vernacular are quite different in Malayalam but the differences are not as sharp as they are in Tamil (Britto, 1986 as reported in Asher and Kumari, 1997:XXV).

2.2The phonological system of Malayalam

Many a time, Malayalam has been referred to as being ‘a Phonologist’s paradise’ due to its intriguing complexities and symmetries (Asher & Kumari, 1997: 405, Mohanan, 1986) and not to mention its rich consonantal system. Malayalam has 38 consonants and 11 vowels in its phonological system. The consonant inventory of Malayalam has been given below:

Place of articulation: **Manner of articulation:**	***Labial***	***Dental***	***Alveolar***	***Retroflex***	***Palatal***	***Velar***	***Glottal***
Plosive: voiceless	p	t̪	t	ʈ	c	k	
Voiceless aspirated	pʰ	t̪ʰ		ʈʰ	cʰ	kʰ	
Voiced	b	d̪		ɖ	ɟ	g	
Voiced aspirated	bʰ	d̪ʰ		ɖʰ	ɟʰ	gʰ	
Fricative	(f)		S, ʃ	ʂ			h
Nasal	m	n̪	n	ɳ	ɲ	ŋ	
Liquid: ***Tap/trill***			ɾ,r				
Liquid: ***lateral***			l	ɭ			
Liquid: ***approximant***					ɻ		
Glide	v				j		

Table 2. Consonant inventory of Malayalam based on Asher and Kumari, (1997: 406).

<u>Plosives</u>

Malayalam has plosives at five places of articulation and at all these places they occur as voiceless and voiced. All of them, except the alveolar plosive occur as unaspirated and aspirated. The alveolar plosive occurs only as unaspirated. Aspiration, however, is not a distinct feature of Dravidian languages and its presence in Malayalam is due to the large number of loan words from Sanskrit. Nevertheless, the extent to which the four way distinction between voiceless-unaspirated, voiceless-aspirated, voiced-unaspirated and voiced-aspirated is maintained varies between speaker to speaker (Asher and Kumari, 1997:407).

Among the plosives, the alveolar pair (/t/, /d/) stands apart from the rest in their resistance to any influence from Sanskrit which is the source of voiced and aspirated plosives in Malayalam. /t/ and /d/ differ from plosives at other places of articulation also in that they have a more restricted distribution occurring only word-medially either as voiceless geminates or as a voiced singleton following a homorganic nasal. For example,

1)'paatta' /pa:tta/ *cockroach*

2) 'ninde'/n̪ɪnde/ *yours*

Fricatives

Four out of five fricatives in the language / s,ʃ,ʂ, h/ occur only in Sanskrit loan words and the fifth one /f/ in English loan words. Also, not all dialects of the language differentiate among /s,ʃ,ʂ /. For example, the Ernad dialect reportedly lists only /s/ (Panikkar, 1973: 2 as reported in Asher & Kumari, 1997: 414).

Nasals

Malayalam has a six way nasal contrast underlyingly /m, n̪, n, ɳ, ɲ, ŋ/ but some linguists have identified a seven-way phonetic contrast namely bilabial, lamino-dental, apico-alveolar, sublamino-palatal, lamino-palatal, dorso-palatal and dorso-velar (Asher & Kumari, 1997: 415). All six nasals occur as geminates. Apart from the geminates which occur only word-medially in Malayalam, the dental and the alveolar singleton nasals are in complementary distribution and even the orthography does not distinguish between these two places of articulation. Their distribution is as follows: 1) the dental nasal occurs word-initially and in medial homorganic nasal-plosive sequences, 2) the alveolar nasal occurs word-medially and medially in homorganic nasal-plosive sequences and 3) both occur as geminates where they contrast in lexical items although the functional load of this contrast is very small, e.g. kanni 'name of a month'- kan̪n̪u↔ 'calf', tinnum 'eat-FUT' – tin̪n̪u 'eat-PAST' (Asher & Kumari, 1997:416)

Vowels

Accounts of the phonology of Malayalam vowels are few and varied. In the traditional classification, Malayalam is said to have five short and five long vowels (Velayudhan, 1971:3).

	Front	Central	Back
Close	i		u
Mid	e		o
Open		a	

Fig:1 Vowel phonemes in Malayalam based on Velayudhan (1971:3)

Velayudhan (1971) cites examples of vowel contrast in the language (4):

/iʈukkuka/ *to hold something, as between the body and arm*

/eʈukkuka/ *to take*

/aʈukkuka/ *to put in order*

/oʈukkuka/ *to put an end to*

/uʈukkuka/ *to wear*

Vowel length is phonemic in Malayalam. Velayudhan identifies two degrees of phonemic length and three (or more) degrees of subphonemic length. The two phonemic degrees are short and long vowels as is characterized by the orthography which is largely phonemic. For short vowels, he further identifies three degrees of phonemic duration: extra-short, short and half-long and for long vowels, two degrees of phonemic duration: long and extra-long. Apart from short /o/ which does not occur word-finally, there is no distributional restriction on the occurrence of short or long vowels. Velayudhan also lays out in his pioneering work on Malayalam vowels, the general features of the allophonic system of Malayalam vowels (5) some of which have been summarized below:

1) Both short and long vowels are monophthongs
2) Although there are some qualitative differences between the short and long vowels, the primary and most significant cue in perceptually distinguishing between short and long vowels in Malayalam is the quantitative difference, or the difference in 'duration'.
3) Vowels have a reduced duration preceding long consonants and consonant clusters.
4) All short vowels in utterance medial position tend to usually get centralized.
5) The high back, rounded, short vowel /u/ often has an unrounded allophone [ɯ].

Traditional Malayalam orthography lists two diphthongal structures /ai/ and /au/. Apart from these two, there are two others, /ei/ and /oi/, the status of which are problematic according to Velayudhan. Some analyses treat these latter two as a sequence of vowel + semivowel /y/ phonemically.

Asher and Kumari (1997: 420), unlike Velayudhan (1971), lists 12 vowel phonemes for Malayalam

/a, aː , i, iː , u, uː , o, oː , e, eː , ə, æ/

Of these, /æ/ occurs only in loan words from English and the status of ə is controversial in the literature on the phonology of Malayalam. It occurs only word-finally and has a range of realizations: [ə], [ɨ], [ɯ]. Valentine (1976a and 1976b as reported in Asher and Kumari, 1997: 420-421) argues that / ə/ is an 'enunciative vowel' whose occurrence can always be predicted. Many traditional grammarians on the other hand point to the contrast between past tense forms in (consonant +) –u and the corresponding adverbial participle forms in - ə; e.g., /koʈut̪t̪u/ *give*-PAST and /koʈut̪t̪ə/ *give*-PP. Valentine, however, considers it as a contextual variant of /u/.

In Malayalam, the vowel /ə/ has no word-initial form since its occurrence is restricted to the word-final position and it is represented in the orthography of the language using the diacritic (˘) and is often transliterated with the symbol for /u/[1]in the literature (e.g. Kumari, 1972; Asher and Kumari, 1997 etc.). The use of the diacritic (˘) indicates a consonant not followed by a vowel, the vowel / a / being inherent in a consonant symbol.

Depending on the stance taken with respect to the phonological analysis of / ə/ in Malayalam, the number of consonants that occur word-finally will vary. If it is taken to be an 'enunciative vowel', then a wide range of consonants can be seen as occurring in word-final position. Asher and Kumari's own stance in the matter is as follows:
"…in cases where a consonant occurring as the last consonant segment in a word must be followed by [ə] if it is not followed by another vowel, that consonant does not occur in word-final position" (423). Nevertheless they acknowledge that taking this perspective does not provide a straightforward solution to the problem of deciding which consonants in Malayalam occur word-finally: i) some consonants do not attract a following [ə] whereas some require it in both prepausal and preconsonantal position and some others obligatorily in preconsonantal position but optionally in prepausal position; ii) there is also considerable dialectal variation; and iii) Style-dependent variations, e.g., the likelihood of final [ə] increases along with an increase in degree of informality. The authors then conclude the following:

Consonants that do not occur finally: all stops; the nasals /ɳ, ɲ/; all fricatives;

Consonants that occur finally: /m, n/

Consonants for which the occurrence of following [ə] is optional to a certain degree: /ŋ,l,ɭ,ɾ,r,j/

[1] In this study the transliteration symbol used to represent // is /eh/ and not /u/ as is followed generally. This is to avoid any confusion with the actual high back vowel /u/.

Asher and Kumari do not include in this categorization the dental and alveolar nasals since they are in complementary distribution except when geminated (intervocalically). Although the distinction between /ɾ/ and /r/ is neutralized in word-final position, they are included above because their underlying nature becomes apparent when a vowel is added.

Velayudhan’s (1971) acoustic phonetic study on vowel duration in Malayalam is perhaps one of the few considerably detailed works on Malayalam vowels so far. More recently Radhakrishnan (2009) conducted a perception study of isolated synthetic vowels by monolingual and bilingual Malayalam speakers. While a detailed appraisal of Radhakrishnan’s study is irrelevant to the objectives of the present study, the vowel space map of the native Malayali speakers in her study, based on the perceptual labelling of the synthetic vowels to the vowels in Malayalam they most resembled, has been given below:

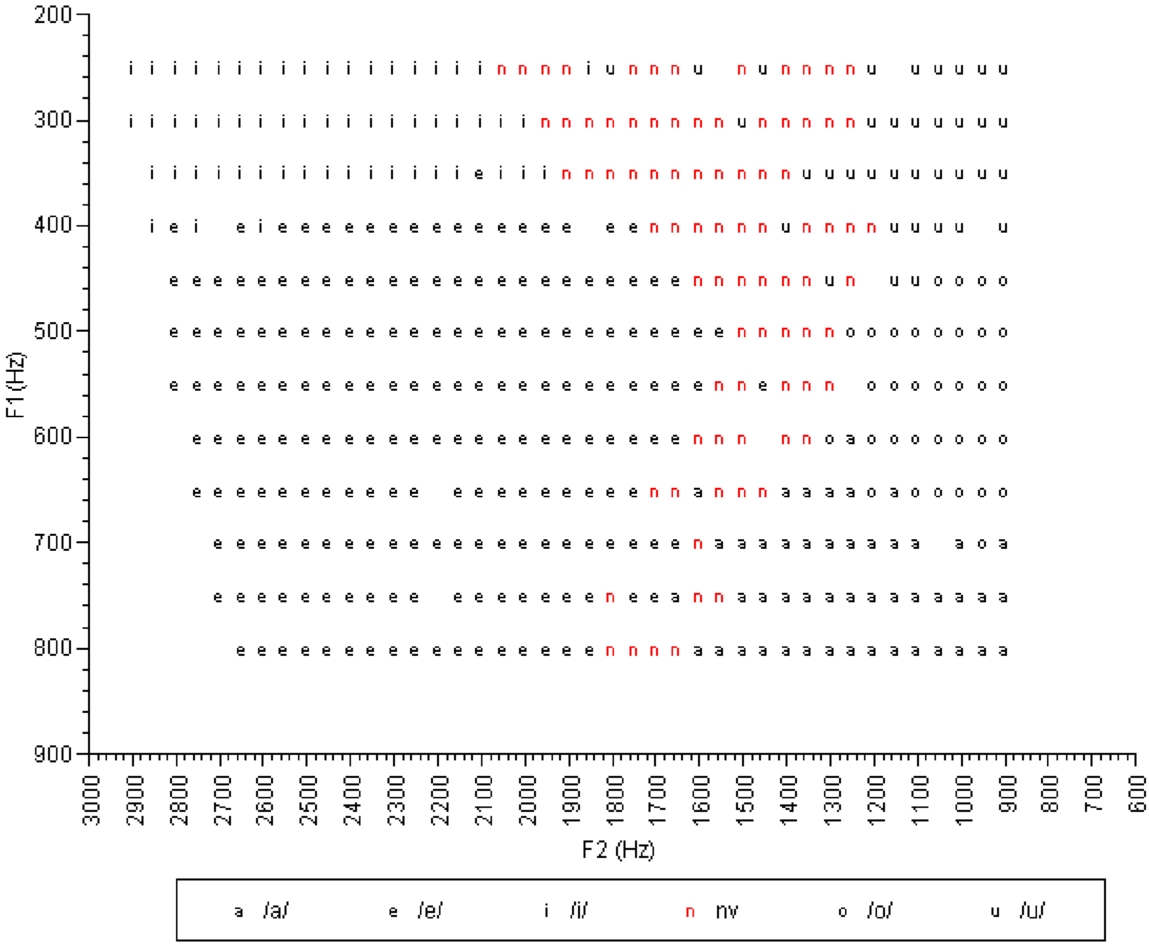


Fig.2. Vowel space map of isolated synthetic vowels as perceived by native Malayali speakers in Radhakrishnan’s study (2009:64).

The native speakers in Radhakrishnan's study were allowed to listen to the synthetic vowel tokens any number of times before making the decision regarding its labelling and apart from the list of Malayalam vowel phonemes (only short vowels were included so there were five vowel categories given), they also had the option of choosing the 'not a vowel in my language' category if they thought what they heard did not resemble any of the vowels in Malayalam. The author comments that unlike other languages like Greek that also have five vowels in its inventory, Malayalam vowels tend to be "spread out in the F1/F2 space with very little unclaimed space" (2009:80). Radhakrishnan's prediction for Malayalam vowels, based on Greek, that the vowels would be organised perceptually in a maximally contrastive manner was not found to be true. The above figure of the vowel space in Malayalam based on Radhakrishnan's study has been included to provide the reader with some kind of a reference point in terms of the neutral vowel space in Malayalam to be able to compare and contrast it with the Malayalam vowel space in a liquid environment later on in the present study.

Consonantal fragments ('chillukaL')

Yet another distinct feature of Malayalam is the presence of what are called Consonantal fragments or 'chillukal'. It is the name given to /r,l,ɭ,n,ɳ / when they occur in the syllable-final position (Pillai, 1996:35). They tend to be preceded by vowels and followed by consonant clusters or a single consonant, e.g.

aa**R**bhaaDam /aːrbʰaːɖam/ *pomp*

ka**R**ttaaveh /kartta:və/ *Messiah*

Rajaraja Varma points out some of the properties of fragment consonants:

1) The fragment consonant is claimed to have a different phonetic realization as compared to the same consonant in its full form or when used in a combination,

e.g. ava**L** yachichu (*she begged*) dhaavaLyam (*whiteness*)

vi**l**vali (*tightening a bow string*) vilvam *('a particular plant*)

ka**NN**vilaasam *(the grace of the glance*) KaNvan *(the sage Kanva*)

nee**R**maratu (*name of a plant*) naRmada (*name of a river*)

The words on the left are the so called ‘fragments’ whereas those on the right are not and are all compound words The claim is that there is a difference in the phonetic realisation of /r,l,ɭ, n,ɳ/ depending on whether they occur in compound words or as ‘fragments’ but no further explanation is offered in this regard. Note that most of these lexical items are no longer in regular use.

2) Fragments have the characteristics of a vowel which is why they can be produced as isolated entities. They are described as being “consonants with the qualities of vowels” (Pillai, 1996: 36).
3) Fragments are sometimes replaced by the corresponding vowels in writing and in spoken idiom e.g. etirvasam- etrivasam-‘the opposite side’ but Pillai (1996) points out that many of the examples that Rajaraja Varma gives in this regard are no longer in regular use.
4) The length of the fragment is calculated as follows and Malayali linguists have termed the unit of time taken to utter a short syllable as a ‘maatra’: If the vowel preceding the fragment is short, then the fragment and the vowel will together have one maatra. If it is long, then the two together will have two maatras. For example,

A**R**tham /art̪ʰam/ *meaning*- aaRtti /aːrt̪t̪ɪ/ *greed*

u**L**patti /ʊɭpat̪t̪ɪ/ *birth/ creation*- aa**L**kuuTTam /aːɭkuːʈʈam/ *crowd*

ku**R**bana /kʊrbaːna/ *holy communion*- kuu**R**mma /kuːrmma/ *sharpness*

5) When these fragments occur word-finally, adding a ‘ə’ (or ‘eh’ in orthography) after it makes no difference to the meaning of the word, for example,

naa**l** – naaleh- *blue*
paa**l**-paaleh- *milk*
kaa**l**-kaaleh-*leg*
mo**L**-moLeh-*daughter*
waya**R**-wayaReh-*waist*
paya**R**-payaReh-*beans*

Since both the laterals and one rhotic are claimed to have ‘fragment’ variants in word-final and post-vocalic, pre-consonantal contexts, the rhotic and lateral fragments will also be examined in the present study in order to assess whether there is any phonetic justification in classifying such cases as a separate category.

Liquids

Malayalam has a rather large liquid system comprising two rhotics, two laterals and a fifth liquid the nature of which is uncertain in the literature. Certain dialects of Tamil also have a five member liquid inventory with two rhotics, two laterals and the fifth liquid being an allegedly similar sound in both languages (Zvelebil, 1970). Since the liquids in Malayalam are focus of the present thesis, a more detailed review of the phonology and phonetics of these are given in the sections below.

2.3 Liquids in Malayalam

2.3.1 Rhotics

The rhotics in Malayalam are particularly interesting because Malayalam is one of the handful of the world's languages that has been reported to have trills at more than one place of articulation which are also contrastive in nature. There is, however, a lack of consensus in the literature over whether both the rhotics in Malayalam are trills (Ladefoged, Cochran & Disner, 1977; Srikumar and Reddy, 1988; Ladefoged and Maddieson, 1996) or whether one is a tap and the other a trill (Kumari, 1972; Yamuna, 1986). This discrepancy in results could either be due to the fact that most of these studies were based on individual speakers and in some cases one of the authors themselves (Srikumar and Reddy, 1988) and/or because the criteria used for judging whether a sound is a tap or trill were different. Or else, these differences could be reflecting the possibility that one of the rhotics is underlyingly a trill but varies phonetically from being a trill on some occasions and in some speakers to being a tap on other occasions or in certain other speakers.

Phonological patterning

The two rhotics in Malayalam contrast mainly in the intervocalic position which is where there are several examples of minimal pairs in the lexicon, e.g. 'kari' /kaɾi/ *soot* and ' kaRi' /karɪ/ *curry*. Both rhotics also occur word-initially but do not form minimal pairs in this word-position, e.g. /ɾa:t̪ri/ *night* and /ra:ɳʧuka/ *seize suddenly*. In the word-final position, however, the contrast is neutralized since only the retracted rhotic (what the present study is referring to as the trill) occurs in that position, e.g. /avar/ *them*. Trills word-finally are referred to as 'fragments' by Dravidianists (cf. pgs. 41-42 above). The same words can be produced with an epenthetic schwa in which case the word-final trill converts into a tap followed by a schwa, e.g. /avar/→/avaɾə/ *them*. This is often the case in casual speech and faster speech.

The trill forms the second element of word-initial double clusters, e.g. /t̪rikoɳam/ *triangle* and the third element in triple clusters, e.g. /st̪ri:/ *woman* . It also occurs in post-vocalic, pre-consonantal contexts where it is referred to as a 'fragment' like it is in word-final position post-vocalically by traditional grammarians. The tap, on the other hand, does not form clusters or fragments.

One of the most prominent and unique phonological characteristics of the rhotics in Malayalam as opposed to the laterals is that the rhotics in Malayalam do not geminate unlike the laterals and the other consonants in Malayalam (Sadanandan, 1999; Asher and Kumari, 1997).

'Sandhi' is used to describe a wide variety of phonological processes that occur at morpheme or word-boundaries. Sandhi rules form an integral part of the traditional descriptions of the grammar of Indian languages. In Malayalam there are two sets of Sandhi rules, one for the Dravidian part of the language and the other that applies to the Sanskrit-influenced part. Within the first set that applies to the Dravidian-influenced part of Malayalam, there are mainly four types of Sandhi rules: Lopasandhi (which further divides into swaralopam for vowels and vyanjanalopam for consonants), Aagamasandhi (involves insertion of a new sound in the formation of a compound word), Dwithasandhi (doubling of the first consonant of the second word in compound word formation) and Aadeshasandhi (assimilation). The Sandhi rules that apply to the Sanskrit vocabulary of Malayalam is further divided into two rule types: those that apply to vowels, i.e. Swarasandhi (Deerghasandhi, Gunasandhi, Vridhisandhi, YaNsandhi) and those that apply to consonants, i.e. Vyanjanasandhi (Thomas, 1990). The Sanskrit Sandhis will not be addressed in further detail since there are no specific rules among them that apply to the liquids in Malayalam (For more details on the Sandhi rules that apply to the Sanskrit-influenced vocabulary of Malayalam, see Thomas, 1990).

Among the different Sandhi rule types that apply to the Dravidian vocabulary of Malayalam, there is one that applies specifically to the liquids and glides. For instance, given below in (1-3) are examples of Lopasandhi where words ending in a final liquid or glide when in combination with words beginning with /k,ʧ,t̪,p/ results in the deletion of the final liquid or glide of the first word. Here the same rule applies to both the lateral and rhotic (based on examples from Gopinathapillai, 2006).

1) /ʃiʃjar + /kaɭ/= /ʃiʃjakaɭ/
2) /kaʈal + /puram/ = /kaʈappuram/
3) /makkaɭ/ + /t̪a:jam/= /makkat̪t̪aajam/

There appear to be no specific Sandhi rules that apply exclusively to both the rhotics and not the laterals in Malayalam. There are however rules that apply only to the laterals and nasals but not the rhotics or the fifth liquid in Malayalam which will be described in the next section on laterals.

<u>Phonetic characteristics</u>

Ladefoged and Maddieson (1996:223, 237) based on earlier work by Ladefoged, Cochran and Disner (1977: 49-50) claim that some speakers of Malayalam contrast the /r/ in ‘kari’ /kari/ *soot* and /r̠/ in ‘ kaRi’ /kar̠ɪ/ *curry* by producing the former as a more advanced alveolar trill and the latter as a more retracted alveolar trill. According to the authors, both these trills are apical and the more advanced of them, /r/, has fewer trills, or in other words, fewer number of periods and in rapid speech may be produced as a ‘rhotacized dental fricative’ while the retracted trill is almost a retroflex sound. Spectrograms of words containing these two trills (‘pura’ /pʊra/ *roo*t, ‘pur̠a’/pʊr̠a/ *outer*) showed a higher locus for the second formant in the case of the more advanced trill /r/ and a lower third formant for the more retracted one /r̠/.

Srikumar and Reddy (1988) following a brief account of the discrepancy in the description of the Malayalam trills in the literature, takes on Ladefoged’s classification of both these rhotics as being trills. The former’s study involved conducting an articulatory and acoustic analysis of the two trills in Malayalam as spoken by one speaker, Srikumar himself. Articulatory analysis was based on the results obtained from using Palatography and X-ray photography. They found that both the rhotics are produced in the alveolar zone, one, /r̲/, slightly further back than the other, /r/, but more importantly, one was an apical trill (the more retracted one) and more velarized while the other was a laminal trill (the more advanced of the two trills) and more palatalized. This difference between the rhotics based on resonance quality has also been observed in Albanian by Simpson (1996) where the alveolar tap is produced clearer and the alveolar trill is produced darker. Recasens (1991) also reports a similar difference between the two rhotics in Catalan: clear tap versus dark trill (cf. Chapter 1, pgs. 29-30).

As for the acoustic analysis, spectrograms of the tokens produced by the speaker showed that /r/ exhibited no formants indicating a complete closure without any interruption whereas the position of the formants representing /r̲/ varies depending on the surrounding vowel context. /r̲/ becomes slightly fronter and opener before front vowels indicated by the two or three low frequency formants below 2100 Hz while /r/ shows a brief but marked interruption in its formant structure. The quality of the following and preceding vowels was also found to change depending on which of the two trills they were surrounded by. /a/ and /u/ preceding /r/ had higher F2 values than /a/ and /u/ preceding /r̲/ whereas /i/ did not have different F2 values depending on whether it preceded /r/ or /r̲/. Srikumar and Reddy (1988) suggest that /a/ and /u/ are therefore fronter before /r/ than /r̲/. Both /a/ and /i/ following /r/ had higher F2 values than /a/ and /i/ following /r̲/ suggesting that they were fronter following /r/ than /r̲/. The authors rightly attribute the vowels being fronter before /r/ than /r̲/ to be the consequence of “place of consonantal production” (pg. 48). Open vowels like /a/ before /r̲/ (F1=740Hz) was claimed to be more open than before /r/ (F1=700Hz) while close vowels like /u/ and /i/ showed the opposite pattern, i.e. more open before /r/ (F1=500Hz for /u/ and 560Hz for /i/) than /r̲/ (F1=400Hz for /u/ and 520 Hz for /i/). Both /a/ and /i/ when following the rhotics were found to show the same pattern, i.e., both were more open after /r/ than /r̲/. However the authors report no measures of statistical significance for any of the differences in values which makes it difficult to assess the significance of the differences, for instance, the 40Hz difference in F1 between /a/ before /r/ and /r/ may or may not be a significant difference. Nevertheless despite the lack of statistical tests to verify the strength of significance, the F2 differences between the vowels surrounding the two trills appear to be robust leading to Srikumar and Reddy’s conclusion that the differences in surrounding vowel quality may be a distinguishing factor between the two rhotics in Malayalam.

Important durational differences were also observed both in the preceding vowels and the trills themselves. Preceding vowels before /r̠/ were found to be shorter than those before /r/. /r̠/ shows shorter duration before front vowels than before back vowels while the duration of /r/ was not found to significantly differ depending on the frontness/backness of its preceding vowel. The duration of /r/ and /r̠/ was not found to differ significantly. The authors justify their classification of the two rhotics in Malayalam as being trills based on a definition by Abercrombie which identifies some trill realizations as being one-tap trills without using any of their own results to support the claim and without elaborating the theoretical framework which would help differentiate between a one-tap trill and a regular tap. Besides, their results cannot be generalized considering the study involved only one informant who was also one of the authors. Nevertheless Srikumar and Reddy's study highlights certain important dimensions of contrast between the two rhotics in Malayalam: Firstly, that the trills differ slightly in place of articulation, /r/ being laminal and advanced and /r̠/ being apical and retracted. Secondly, /r/ was found to be palatalized and /r̠/ was found to be velarized. This is similar to findings on Catalan rhotics by Recasens (1991) where one rhotic (tap) was found to be palatalized and the other (trill) velarized. Thirdly, there appear to be some systematic differences in vowel quality depending on whether they surround /r/ or /r̠/ which may be yet another distinguishing cue between the two rhotics. Lastly, duration was not found to be a significant distinguishing cue between /r/ and /r̠/.

Toda, another Dravidian language, spoken by around a thousand speakers in the Nilgiris, is a rich source for any study on trills. Toda has been reported to have six trills i.e., three plain rhotics and three palatalized rhotics (Spajic et al, 1996:1). Spajic et al describe the rhotics in Toda based on data from six male speakers mainly although data from six female speakers were also collected but not fully analysed at the time of this report. Acoustic analysis and articulatory analysis of the data using video palatography (for three speakers) and linguograms were carried out. The number of contacts in each trill produced by each speaker was counted. The dental 'trill' was found to be produced primarily with a single contact while the retroflex one was often a two or three contact trill with the alveolar one exhibiting the most variation in the number of contacts. Although this could suggest that the dental rhotic is a flap or a tap as Emeneau described them, Spajic et al (1996) argue that there were cases in their data where all the speakers produced the dental rhotic with more than one contact in both environments tested (in citation form and in sentences/phrases where they occur intervocalically).

Based on spectrograms, the authors show that in the production of the words **kar** *border* (fronted alveolar) and **kar̲** *juice*, *sap* (alveolar) in the frame **(kad _)**, the two white spaces in the spectrograms, which represent the periods of contact of the tongue against the roof of the mouth, were about 15 ms apart, too short a time to have produced two flaps. This does not necessarily imply that all dental rhotics, including those that have single contacts are all trills but if the dental rhotic were a flap or a tap underlyingly then the results obtained would suggest that this underlying 'flap' or 'tap' has a trill variant in intervocalic contexts. The problem with this notion, according to Spajic et al (1996:8-9), is that although it is not uncommon to find underlying trills having single contact allophones, an underlying flap or tap having a trill variant has never been reported anywhere yet and therefore is a highly unlikely possibility.

Apart from preferring to classify all the three plain rhotics in Toda as trills and not one tap and two trills like the Dravidianists, Spajic et al also highlighted that more than the role of place of articulation in distinguishing among these rhotics, what is more important is that they differ phonologically and acoustically. The Dravidianists' approach of using place of articulation to distinguish among the rhotics is mainly due to historical works which have found rhotics often but not always adhering to rules that apply to their respective natural classes. In other words, the dental rhotic follows rules which affect other dentals, alveolar rhotic with other alveolars and so on. Spajic et al found from their data that the so-called 'dental' and 'alveolar' rhotics are both produced in about the same place and can both be called apical alveolar trills (9-13) (see also Ladefoged and Maddieson, pgs. 223-225). Also, the 'dental' rhotic in Toda seems to involve a secondary articulation involving parts of the tongue not involved in the contact itself, "some kind of tongue body raising and/or tongue body fronting" (11). Acoustically, the retroflex rhotic differed from the other two in that it had a lowered third formant while the dental rhotic had a lower F1 and raised F2 compared to the alveolar rhotic. The plain rhotics differed from their palatalized counterparts mainly in an increase in F2, which steadily rises from the onset of the preceding vowel through to the offset of the rhotic. Therefore there appear to be two main sets of dimensions of contrast maintenance among the six rhotics in Toda that are evident from the results of Spajic et al's study: Firstly there is the plain (non-palatalized) versus palatalized dimension. Secondly, each of these two groups, i.e.

the plain rhotics and the palatalized rhotics, contain three trills differing in place of articulation and/or tongue body configuration. Resonance quality and tongue body configuration therefore appear to be two of the important dimensions of contrast maintenance among the rhotics in Toda as was found to be the case for Malayalam by Srikumar and Reddy (1988) and Albanian by Simpson (1996).

Tamil, considered to be the parent language of Malayalam, also has two rhotics in its inventory. However there have been reports of a neutralization of the rhotic contrast in some dialects of Tamil (Schiffman, 1980). The two rhotics in Tamil are dental/pre-alveolar /r/ and post-alveolar /r̲/ (Narayanan et al, 1999). In recent articulatory studies both have been found to be apical, the latter having a slightly more posterior and lower tongue body position than the former resulting in a slightly lower F3 for the /r̲/ than /r/. Their other acoustic characteristics were found to be the same. Narayanan et al (1999) do not refer to the manner of articulation of the rhotics in their study and use the /r/ symbol as a more general symbol of r-sounds and marking the posteriority of one with a diacritic (hyphen underneath) whereas Ladefoged (1971) refers to /r/ as a flap and /r̲/ as a trill (a claim also supported by Schiffman, 1980). Therefore the main dimensions of contrast between the two rhotics in dialects of Tamil that have not lost the contrast appear to be a slight place of articulation difference (pre-alveolar versus post-alveolar) combined with tongue body height and position (tongue body slightly lower and more posterior in post-alveolar rhotic than the pre-alveolar rhotic) and possibly also manner of articulation (tap versus trill).

Taking into account these results for the rhotics in Toda (Ladefoged et al, 1996), Tamil (Ladefoged, 1971; Schiffman, 1980; Narayanan et al, 1999) and Malayalam (Srikumar and Reddy, 1988), resonance quality and tongue body configuration may be important dimensions of contrast maintenance among rhotics in Toda and Malayalam while place of articulation may be a dimension of contrast maintenance among rhotics in Tamil and to some extent in Toda. It will be interesting to examine whether the results of the present study based on a larger group of speakers will support the findings of Srikumar and Reddy (1988) and reaffirm the significance of some of the dimensions of contrast highlighted by their paper.

2.3.2 Laterals

Malayalam has two laterals, a voiced alveolar lateral and a voiced retroflex lateral. The former is often produced as apico-alveolar and the latter as 'sublamino-palatal' laterals (Asher and Kumari, 1997: 418-419). The two laterals are contrastive and there are several minimal pairs in the lexicon, e.g.:

'vala' /vala/ *net*- 'vaLa' /vaɭa/ *bangle*

'mula' /mula/ *breast*- 'muLa' /muɭa/ *sprout/seedling/bamboo*

Phonological patterning

The voiced alveolar lateral occurs word-initially, e.g. /lo:lam/ *gentle* , in some word-initial clusters as the second element, e.g. /pla:və/ *jackfruit*, intervocalically, e.g. /mula/ *breast*, medially as a geminate consonant, e.g. /mulla/ *jasmine*, in several medial consonant clusters, e.g. /ka:lpa:ɖə/ *footstep*, and word-finally (where in informal speech it is often characterized by a vocalic release) e.g./pa:l/-/pa:lə/ *milk*.

The voiced retroflex lateral occurs in some word-initial consonant clusters as the second element in loan words from English, e.g. /gɭa:sə/ *glass*, intervocalically, e.g. /muɭa/ *thorn*, medially as a geminate consonant, e.g. /kaɭɭi/ *liar (female)*, word-finally (where in informal speech it is often characterized by a vocalic release), e.g. /avaɭ/-/avaɭə/ *her*.

A Sandhi rule which forms part of 'Aadeshasandhi'(Sandhi involving assimilation) applies to only the laterals and nasals as shown below. The word-final lateral is deleted and the /t/ of the following word assimilates to the place of articulation of the deleted lateral ((based on examples in Gopinathapillai, 2006).).

1) /akal/ + / t̪i:/= /akatti/
2) /vil/ + /t̪u/ = /vittu/

3) /ve:ɭ / + / t̪u / = /ve:ʈʈu /

4) /ke: ɭ/ + /t̪u/ = /ke:ʈʈu/

Another type of Aadeshasandhi involves assimilation of the word-final alveolar lateral fragment into an alveolar nasal fragment when combining with a word beginning with a nasal. /l/ →/n/ / _/m/ (based on examples in Gopinathapillai, 2006).

1) /kal/ + /mad̪am/= /kanmad̪am/

2) /nel/ + /muɭa/ = /nenmuɭa/

3) /kal/+ /mat̪il/ = /kanmat̪il/

4) /nel/+ /maɳi/= /nenmaɳi/

Therefore it appears that there is some evidence of phonological alternation between laterals and nasals in Malayalam and also certain rules that apply to only laterals and nasals but no other consonant groups.

<u>Phonetic characteristics</u>

There have been mainly two phonetic studies that have examined the laterals in Malayalam: Menon (1973) and Local & Simpson (1996). In the latter study, the focus was not so much on laterals as they were on the phonetic implementation of gemination in the laterals and nasals in Malayalam. The authors found that apart from duration differences, there were other significant correlates that distinguished the singleton and geminate laterals, namely surrounding vowel quality and consonantal resonance. The geminate laterals were found to have a clearer resonance than their singleton congeners and the vowels surrounding the former were more raised than those surrounding the latter. Menon (1973) acoustically analysed the two laterals in Malayalam in VCV sequences. Five short vowels /i,e,a,o,u/ and the alveolar and retroflex laterals were combined in all possible ways and were read in an appropriate sentence frame in order to keep prosodic pattern of the utterances consistent. These sentences were read by 5 adult native speakers of Malayalam and were tape-recorded. Another group of 10 Malayalam speakers took part in a perception experiment involving the tape-recorded data of the first group. A total of 250 utterances were analysed. F1, F2, F3 and the terminal frequencies of the initial and final vowels were measured. F1, F2, F3 of the laterals were also measured. Formant frequencies of the vowels were measured at the points where the formants showed the least fluctuation. Terminal frequencies of the vowel formants were calculated at the points where the boundary lines between the vowels and laterals intersected. Formant frequencies of the laterals were measured at the approximate mid-point of the lateral segment. To determine the segmental boundaries between the laterals and vowels on the spectrogram, the abrupt downward shift of F1 of the laterals was taken to be the cue for marking the beginning and end of the lateral segment. In cases where this cue was ambiguous, the sudden decrease in the amplitude of higher formants, usually found in the laterals was taken to be the cue for marking the lateral-vowel boundary.

Although the retroflex lateral was found to have an effect on the preceding front vowels, in general, the magnitude of the influence of the retroflex lateral on vowels was small. A significant finding, however, was that F2 frequencies of back vowels were found to increase when following both the laterals. This is characteristic of such vowels adjoining consonants produced with a relatively wider pharyngeal cavity (Menon, 1973: 101-102). F2 values of vowels preceding and following the retroflex lateral were only found to be slightly lower than those surrounding the alveolar lateral and Menon suggests that the variations are "rather small" (pg.101). He points to a more significant finding in that the F2 values of /a,o,u/ following both the laterals were higher than the F2 values of the same vowels preceding both the laterals. This variation was found to be larger in /o/ and /u/ than in /a/.

The retroflex lateral was found to have a higher F1 than the alveolar lateral and following Fant's (1960) investigation of Russian laterals, this is perhaps because of the relatively narrow tongue blade and the consequent increase in the width of the lateral passages associated with the production of the retroflex lateral. However, despite this difference between the retroflex and alveolar lateral, both were found to have a lower F1 compared to that of the adjoining vowels. The phonetic quality of the laterals seems to be dependent on the frequency positions of the higher formants. The higher F2 and the wide gap between F2 and F1 that Menon found for the two laterals in Malayalam seem to suggest that both are produced with a relatively wide pharyngeal cavity in the language, which also explains why the following back vowels have increasing F2 frequencies. The F2 values of the two laterals were strongly influenced by the F2 values of the preceding and following vowels. In a homogenous vowel context, F2 and F3 values of the retroflex lateral were found to be lower than those of the alveolar lateral. Depending on the surrounding vowel quality, F2 values for the alveolar lateral varied between 1570-2010 Hz and F3 between 2415-2720Hz while F2 values for the retroflex lateral varied between 1120-1795Hz and F3 between 1500-2480Hz. Menon rightly attributes the lower F3 of the retroflex lateral to its larger front cavity as compared to that of the alveolar lateral. He points out that the lower F2 of the retroflex lateral compared to the alveolar lateral may be either due to the additional narrowing of the pharyngeal 'pass' of the former or due to the retroflexion of the tongue.

The F2, F3 transitions in vowels associated with the laterals strengthened the auditory impressions of the distinction between the alveolar and retroflex laterals. For instance, F2 and F3 terminal frequencies of vowels preceding the retroflex lateral (F2 ranged between 1160 and 1580Hz and F3 between 1350 and 2355Hz) were found to be lower than those of vowels preceding alveolar laterals (F2 ranged between 1500 and 2100 Hz and F3 between 2400 and 2800 Hz). The same was true of the vowels following the alveolar versus retroflex lateral (F2: following retroflex laterals ranged between 1150 and 1650Hz and F3 between 2300 and 2550Hz; F2 of vowels following alveolar laterals ranged between 1600 and 2100Hz and F3 between 2400 and 2750Hz)

Tamil also has two laterals in its inventory, a dental lateral and a retroflex lateral. Narayanan et al (1999) in their study of Tamil liquids found that the dental lateral is characterised by a lower F2 (1200 Hz) and higher F3 (2400Hz) than the retroflex lateral (F2=1460Hz and F3=1800Hz). Articulatorily, they found that the two laterals differed in their constriction locations: the medial oral constriction for /ɭ/ occurs in the palatal region while that for /l/ occurs in the alveolar region. The larger front cavity of /ɭ/ compared to that of /l/ results in the lower F3 in the case of the former. The acoustic analysis in their study involved the first author producing /paC/ utterances and therefore a direct comparison with Menon (1973) is not possible since the latter's study involved VCV sequences. Nevertheless in contexts where the preceding vowel was /a/, the retroflex lateral in Malayalam showed F3 values ranging from 2000-2450Hz depending on the following vowel context (1973:110). This appears to be higher than the F3 values of the retroflex lateral in Tamil in the preceding /a/ context (1800Hz) (1996:2000). The difference in results may be a consequence of the different word-positions of the liquid in both studies or maybe suggests that retroflexion is stronger in the Tami lateral? Menon's study suggests that the dimensions of contrast between the laterals in Malayalam are place of articulation, formant transitions in surrounding vowels and relative positions of F2-F3. The dimensions of contrast between the Tamil laterals appear be place of articulation/tongue blade constrictions, constriction formation, release durations, pathlengths and velocity, and low versus high F3 (i.e. retroflex versus non-retroflex) (Narayanan et al, 1999; McDonough & Johnson, 1997). The present study will be based on a larger number of speakers and examine different word-positions and therefore results of this will enable a more direct comparison of the Tamil and Malayalam retroflex laterals and more importantly aim to identify the dimensions of contrast between the two laterals in Malayalam and compare them to patterns observed in Menon's results.

2.3.3 Fifth Liquid

Although there is disagreement in the literature regarding the manner of articulation of the two rhotics in Malayalam, the literature on the rhotics in Malayalam interestingly seems to be consistent on one aspect and that is the number of rhotics in its phonological inventory: two. A recent study on the liquids in the Brahmin Dialect of Tamil has revealed that there may be a third rhotic in this dialect which has been described as a central retroflex approximant (McDonough & Johnson, 1997) These results may be relevant to Malayalam since some of the lexical items in which this third rhotic appears are common to both languages, Tamil and Malayalam e.g. (/paʐam/ *banana*; /paʐi/ *blame*, etc.). The corresponding consonant sound in Malayalam has been variously called a continuant (Namboothiri, 2002), a 'voiced retroflexed palatal fricativised lateral' (Kumari, 1972:27-28) and 'a voiced sublamino palatal approximant' (Asher & Kumari, 1997: 419). And since Malayalam has its origins in a western dialect of the middle Tamil period (Zvelebil, 1970:16) the phonological and phonetic nature of this allegedly 'common' sound between Tamil and Malayalam, a potential third rhotic in the latter's phonological system is worth investigating.

<u>Phonological patterning</u>

The origin of the fifth liquid in Malayalam, /ʐ/, has been traced back to the Proto-Dravidian consonant inventory and out of all the descendants of Proto-Dravidian, only certain dialects of Modern Tamil and modern Malayalam have retained the sound in their systems (Krishnamurti, 2003: 52-53; Asher and Kumari, 1997: 405). Krishnamurti classifies the original proto-Dravidian sound, denoted in his book as /ẓ/, as being a "retroflex approximant (frictionless continuant)" (pg. 152) sound patterning with a series of other retroflexes: "… a separate series of phonemic retroflexes with different articulatory effort /ṭ ṇ ḷ ẓ/…"(pg. 27). There is also a reference to the proto-Dravidian ancestor of the fifth liquid as being an 'apical' consonant that is one of the most marked segments: "Among apical consonants alveolar *ṯ and the retroflex approximant *ẓ are the most marked segments" (pg. 28). The Proto-Dravidian consonant system included two laterals, one trill, one frictionless continuant (approximant) and of these the rhotic /r/ and the frictionless continuant '/ẓ/' were not geminated in Proto-Dravidian or in older descendant languages (Krishnamurti, 2003: 27,152).

Rajaraja Varma in his *Keralapaniniyam* classifies /ɾ/and /ɭ/ as being exclusively Dravidian sounds and not found in Sanskrit. He attempts a classification of these and the other liquids in Malayalam and divides them into two groups: the /r/ group (/r/, /ɾ/ and /ʐ/) and the /l/ group (/l/ and /ɭ/) (Pillai, 1996:33). Interestingly, he categorizes the fifth liquid in Malayalam, the allegedly common sound between Malayalam and Tamil, /ʐ/, as belonging to the /r/ group the reason being that they all are produced at more or less the same point of articulation.

Unlike the other four liquids, /ʐ/ occurs only intervocalically but nevertheless is quite frequent in the lexicon of the language. In the Malayalam alphabet system, / ʐ / is the 35th consonant placed between /ɭ/ and /r/, the 34th and 36th consonant of the language respectively. The patterning of this sound (which in orthography will be denoted by 'zh' following Kumari (1972)) with respect to the other rhotics and laterals in Malayalam, is shown below[2]: ('l' refers to the alveolar lateral and 'L" refers to the retroflex lateral)

[2] All these examples have been taken from Kumari (1972:41-42)

i) The fifth liquid almost forms a three-way contrast with the other two laterals as shown below:

/l/-/ɭ/-/ʐ/

1) ‘Kali’ /kali/ (anger)-‘kaLi’ /kaɭi/ (*game*)- kazhi /kaʐi/ *(eat*)
2) ‘vaalu’ /va:lə/ (*tail*)- ‘vaaLu’ /va:ɭə/ (*sword*)- ‘vaazhu’ /va:ʐə/ (*reign*)
3) ‘Talam’/t̪a:lam/ ‘taaLam’ /t̪a:ɭam/ (*beat as in music beats*)-‘tazhu’ /t̪a:ʐə/ (*lock*)

ii) It also contrasts individually with each of the two laterals

/l/ and /ʐ/

1) ‘mala’/mala/ (*mountain*)-‘mazha’/maʐa/ (*rain*)

2) ‘vali’/vali/ (*to pull*)- ‘vazhi’ /vaʐi/ (*path*)

3)’toli’ /t̪oli/ *(skin*)-‘tozhi’ /t̪oʐi/ (*kick*)

4) ‘palam’/palam/ (*a measure*)-‘pazham’ /paʐam/ (*banana*)

/ɭ/ and /ʐ/

5)’kuLi’/kʊɭi/ (*bath*)-‘kuzhi’/kʊʐi/ (*pit*)

6) ‘chuLi’/ʧʊɭi/ (*wrinkle*)-‘chuzhi’/ʧʊʐi/ (*whirlpool)*

iii) It also contrasts with the two rhotics but such cases seem to be fewer in the lexicon of the language.

/ɾ /-/r-/ʐ/

1) ‘kari’/kaɾi/ (*soot*)- ‘kaRi’ /kari/ (*curry*)-‘kazhi’ /kaʐi/ *(eat*)
2) ‘kara’/kaɾa/ (*land*)-‘kaRa’ /kara/ (*stain*)-‘kazha’/kaʐa/ (*wooden poll*)

There seems to be some evidence to suggest that the phonological behaviour of the fifth liquid is similar to that of the other retroflex consonants in the languages. Like other retroflexes in the language, it does not occur word-initially (Asher and Kumari, 1997). The fifth liquid also tends not to occur with other retroflex sounds in the same syllable or adjacent syllables which could be indicative of its own identity as a retroflex sound.

In the examples of Sandhi rules mentioned in the above section on laterals (pgs. 50-51), it seems to be that the rules of lateral-to-nasal assimilation and deletion of word-final laterals in the context of suffixes /t̪i/ or /t̪u/ applies to only to the laterals and not the rhotics and the fifth liquid. There seem to be rules associated with lateral-nasal alternation which do not apply either to the two rhotics or the fifth liquid. These cases may be indicating the fifth liquid's affinity to the rhotics rather than the laterals The strongest evidence justifying the phonological affinity of the fifth liquid with the rhotics in Malayalam is that the two uncontested rhotics and the fifth liquid are the only consonants in Malayalam to not geminate, i.e. they only occur singly while every other consonant can occur single and as geminates (Sadanandan 1999, Asher and Kumari, 1997).

Phonetic characteristics

To the best of the present author's knowledge there has been no previous phonetic study of the fifth liquid in Malayalam. However, there have been a few recent studies on what is allegedly the same sound in Tamil (McDonough & Johnson, 1997; Narayanan et al, 1999). Therefore a review of the findings of these studies is imperative in order to understand the characteristics of this sound in Tamil and consequently its implications for the present study on Malayalam.

McDonough & Johnson (1997) studied the five liquids in the Brahmin dialect of Tamil: two rhotics-a tap and a trill, two laterals-alveolar and retroflex and a fifth liquid which has been variously referred to in the literature as being a glide, a continuant, a rhotic and a lateral (Firth, 1934; Arden, 1942; Christdas, 1988 and other references cited in Narayan et al, 1999). The aim of the study was to study the articulatory, acoustic and perceptual characteristics of the five Tamil liquids, in particular the fifth one. Electropalotography and Static Palatography were used to examine the articulatory properties. Acoustic properties were also examined and as part of the perceptual experiment, the intelligibility of the EPG recordings was tested. Speech productions of one speaker were used for the articulatory part of the study while the speeches of two additional speakers were studied for the acoustic part and four listeners were used for the perception experiment.

The perception experiment of the study involved asking 4 listeners (3 male and 1 female) to identify the tokens they listened to by circling one of five possible words on an answering sheet in two contexts: 'a_am' or 'a_i'. Two of these four listeners were speakers of the Brahmin dialect (1 male and 1 female) under investigation and two were not. The material played to them consisted of edited speech signals that were recorded simultaneously with the EPG data using a digital signal analysis system. Three productions of each of the ten words in the data set, i.e. slow, normal, fast, were digitally spliced from the carrier phrases in which they were produced. All the tokens were then recorded to audio tape in four blocks of thirty with the order of the tokens randomized in each. Results revealed that the speakers of the Brahmin dialect correctly distinguished the contrasts among the five liquids most of the time while speakers of other Tamil dialects that do not have a fifth liquid confused the fifth liquid in question with the retroflex lateral and McDonough and Johnson (1997: 22) suggest that this could possibly be due to the longer duration and retroflexion that is common to the fifth liquid and /ɭ/. One of the speakers, who was a bilingual English-Tamil speaker and uses Tamil only occasionally, tended to categorize the liquid tokens based on whether or not they were retroflex irrespective of their laterality. This is consistent with the liquid contrasts in English (retroflex rhotics and plain laterals), his dominant language.

The EPG time series and palatograms showed that for the fifth liquid in Tamil, /ʐ/, there was tongue contact on the hard palate as is typical for retroflex sounds but unlike /ɽ/ and /ɭ/ there was no evidence of forward motion during the consonant closure. It was also found to be different from /ɽ/ and /ɭ/ in that the Linguogram and EPG data showed a mid-sagittal gap between the tongue and the palate. Evidence from MRI images and Linguogram data also suggested that in the production of this sound the tongue body was held low in the mouth while the tip curled towards the hard palate (McDonough & Johnson, 1997: 16). The authors therefore described this sound as being an apical retroflex central approximant.

In another study on Tamil liquids by Narayanan et al, the researchers found that the fifth liquid, for which they used the symbol [ɻ], involved an anterior tongue body with the narrowest tongue constriction at the palatal region but the exact location was inconsistent. No medial linguapalatal contact was found and central airflow occurred. Unlike the other liquids in Tamil, this was characterised by a "pitted tongue shape and a correspondingly greater back-cavity volume" (1999: 1996). Acoustically, the fifth liquid was found to be similar to /ɭ/, both of which were characterised by a low F2-low F3, i.e. with F2 and F3 close together (F2 at 1485Hz and F3 at 1800Hz). Both were characterised as being 'retroflex' and their tongue-tip constriction formation and release involves a counter-clockwise movement, i.e. from back- to-front. However, unlike /ɭ/, the spectra of /ɻ/ exhibited no zeros in the high frequency region (2.5-5kHz). This lack of significant lateral channels in /ɻ/ reflected in the lack of zeros in their spectra was the main acoustic difference between the two. Narayanan et al (1999), like McDonough and Johnson (1997), also categorise the fifth liquid in Tamil as a central retroflex approximant.

Implications for Malayalam

The similarity between the fifth liquid in Tamil and the one in Malayalam has been indirectly alluded to by Zvelebil (1970:149) – the " phonetic value of /ʐ/ in modern [Tamil] and [Malayalam] seems to range from retracted voiced fricative…to retroflex voiced vibrant.." affirming that this is a consonant common to both Tamil and Malayalam. The results of the recent studies on the Tamil fifth liquid therefore have significant implications for the present study on the fifth liquid in Malayalam and lead to the following questions:

1) Considering that early work has described the fifth liquid in Malayalam as being similar to the recently investigated one in Tamil, is it possible it could be realised as an approximant too? Is this fifth liquid in Malayalam then a lateral or a rhotic?

2) Phonotactically, there seems to be some evidence to suggest that the fifth liquid might be a retroflex rhotic, what are the phonetic characteristics of this consonant in Malayalam even if it is phonologically the same sound as in Tamil? How similar or different will its realisation be in Malayalam with respect to what has been recorded for Tamil?

Questions (1) and (2) above will form part of the research questions of the present thesis. There are broadly two main research questions addressed in this thesis:

Firstly, what are the auditory and acoustic characteristics of the two uncontested rhotics in Malayalam? How do native speakers maintain the contrasts between the two rhotics? Secondly, what are the phonetic features and what is the phonological identity of the fifth liquid in Malayalam? Could it be a third rhotic in the consonant system of the language?

This chapter reviewed some of the prominent works on the liquids in Malayalam and other Dravidian languages like Tamil and Toda while the previous chapter focussed on the general phonetic and phonological characteristics of rhotics and laterals and the nature of their relationship with each other. The next chapter will describe the methodology adopted for the present study based on the participants, method, data, and analyses conducted.

CHAPTER 3
METHODOLOGY

This chapter is a detailed description of the study design. Since the research questions addressed in the thesis are mainly phonetic, its design is predominantly experimental in nature and combines a qualitative and quantitative approach in the data analyses. This chapter is divided into broadly two parts: The first part describes an initial pilot study conducted in order to assess the validity of the research questions that the thesis addresses and also enable the author to design the main study with fewer limitations. The second part deals with the design for the main study describing participants involved, data collected from them, methods used to record speakers and modes of analyses conducted. The second part then leads to the hypotheses of this thesis and their predicted outcomes.

3.1 Pilot Study

A pilot study was conducted with two adult male native speakers of Malayalam. Both subjects were from Kottayam district in Central Kerala. They read out a word-list containing 5 ɾ−r minimal pairs and 6 tokens of the fifth liquid in Malayalam in CVC or VCVC structures. Each of these tokens was read twice. The tokens were analysed auditorily and narrow phonetic transcriptions made. Acoustic analyses were then carried out using PRAAT by visually inspecting spectrograms and the corresponding waveforms. For every token, F1, F2, and F3 of ɾ, r and the fifth liquid and the surrounding vowels were measured at the onset, middle and offset. The duration of the rhotic segments and the surrounding vowels was also measured. The onset measurements were made 10 ms after the beginning of the segment and the offset 10 ms before the end of the segment. Ten milliseconds considered enough time into the beginning and from the end of the target segment to avoid surrounding segments' coarticulatory effects.

3.1.1 Tap-trill minimal pairs

Auditory analysis

Results of the auditory analysis revealed that majority of all ɾ tokens were realized as ɾ for both speakers and the large majority of r tokens were realized as ɾ for both speakers (Table 3). For both speakers, no target taps were produced as trills and no target trills were produced as approximants.

PHONETIC REALIZATIONS								
	TAP		TRILL		APPROXIMANT		TOTAL	
SPEAKER	1	2	1	2	1	2	1	2
TARGET TAPS	7	10	0	0	3	0	10	10
TARGET TRILLS	7	6	3	4	0	0	10	10

Table 3: Phonetic realizations of target taps and target trills based on auditory analysis

Apart from differences in the realisation of the rhotics themselves, the quality of the surrounding vowels seemed to differ depending on whether the target token was ɾ or r. The vowels surrounding a target trill sounded more open and retracted than those surrounding a target tap, irrespective of whether the target taps and trills were realized as taps and trills. The trill itself seemed to sound more apical and velarized while the tap sounded more laminal and palatalized. Based on the auditory analysis, the most frequent realization of the tap and trill by both speakers were as follows: target tap [ka̝ɾʲɪ]; target trill [ka̠ɾ̠ɪ]

Acoustic Analysis

Two kinds of measurements were made: Duration and formant frequencies of the target segments and their surrounding vowels.

Duration

Duration was not found to be significantly different depending on whether the target was /ɾ/ or /r/ (Fig. 3). As can be seen from the figure below, the duration of the vowels preceding and following a trill was not found to be considerably different from that of vowels surrounding a tap and they showed no particular trends. This is an unexpected result since previous literature claims that vowels surrounding a trill tend to be shorter than those surrounding a tap. Regarding the duration of the rhotic segments, one would expect the trill segments to be longer than the taps by definition although it is not clear even from previous literature whether a one-contact trill would be longer or shorter than a regular tap. Most of the trill realizations for both speakers were produced with mostly two or three contacts on an average. The duration of the tap more often than not was longer than the trill in the corresponding minimal pair and as can be seen from Fig. 3, the range of duration measures seem to be the same for the target taps and trills. In Fig.4, duration values of the rhotics have been plotted based on the realisation of their manners of articulation. There seem to be no clear demarcation of duration values based on realisation of manner of articulation of the rhotics. Taps realised as taps range from around 30ms to nearly 100ms while taps realised as approximants range from 60ms to 100ms. Trills realised as taps and trills realised as trills range from around 45-50ms to 100ms. Duration then does not seem to be a significant distinguishing cue with respect to either the perception or production of taps versus trills in Malayalam.

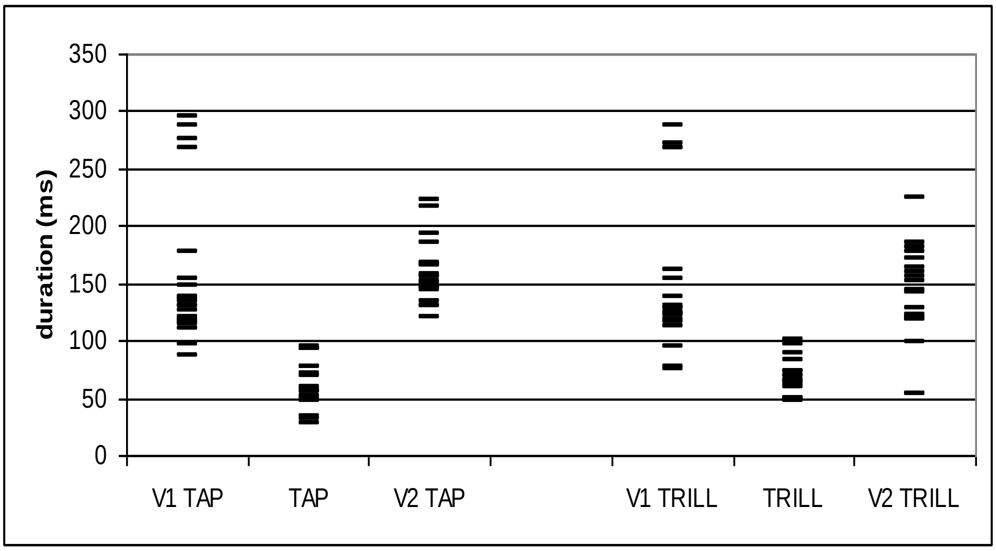


Fig. 3: duration (ms) for target /ɾ/ and /r/

Note that there is a gap in values plotted for duration of V1 before tap and before trill with a few plotted between 250-300ms range which represent the long vowels in the data set whereas the rest which fall within the 75-175ms range for vowels preceding both taps and trills represent the short vowels in the data set.

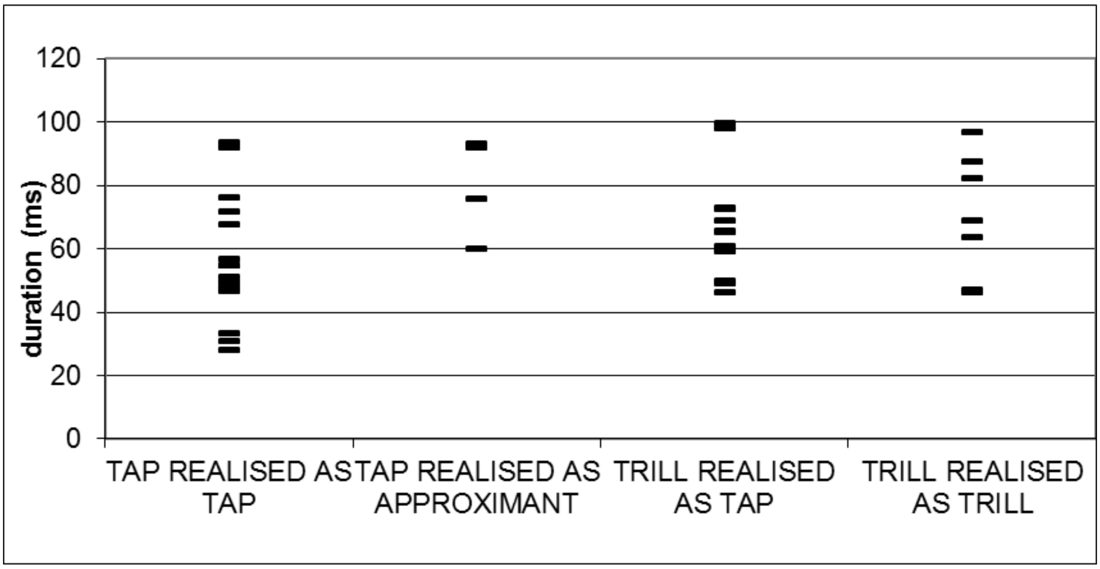


Fig. 4. Duration of target taps and trills based on their realisations

Formant patterns

Results of the acoustic analyses were consistent with those of the auditory analysis. Trill tokens were characterized by higher F1 and lower F2 while tap tokens were characterized by lower F1 and higher F2 reinforcing the auditory impression of apical-velarized trill versus laminal-palatalized tap (Figs 5,6 and 7). F2 was found to be the most robust acoustic correlate of the differences between ɾ−r minimal pairs followed by F1. F3 was found to be inconsistent between the minimal pairs.

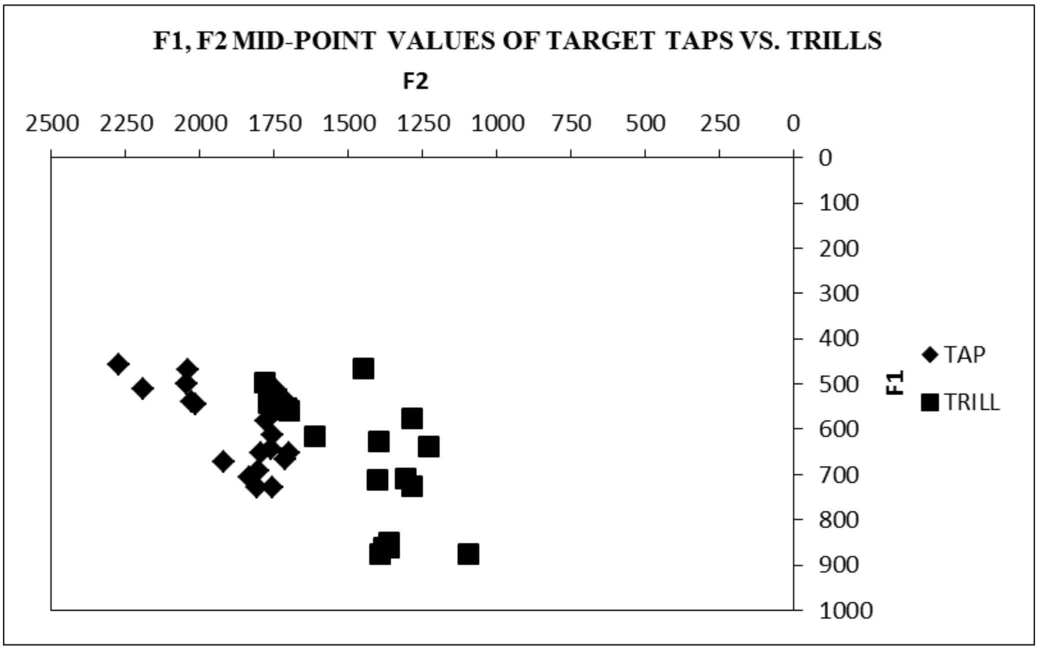


Fig 5: F1-F2 mid-point values of target taps versus target trills.

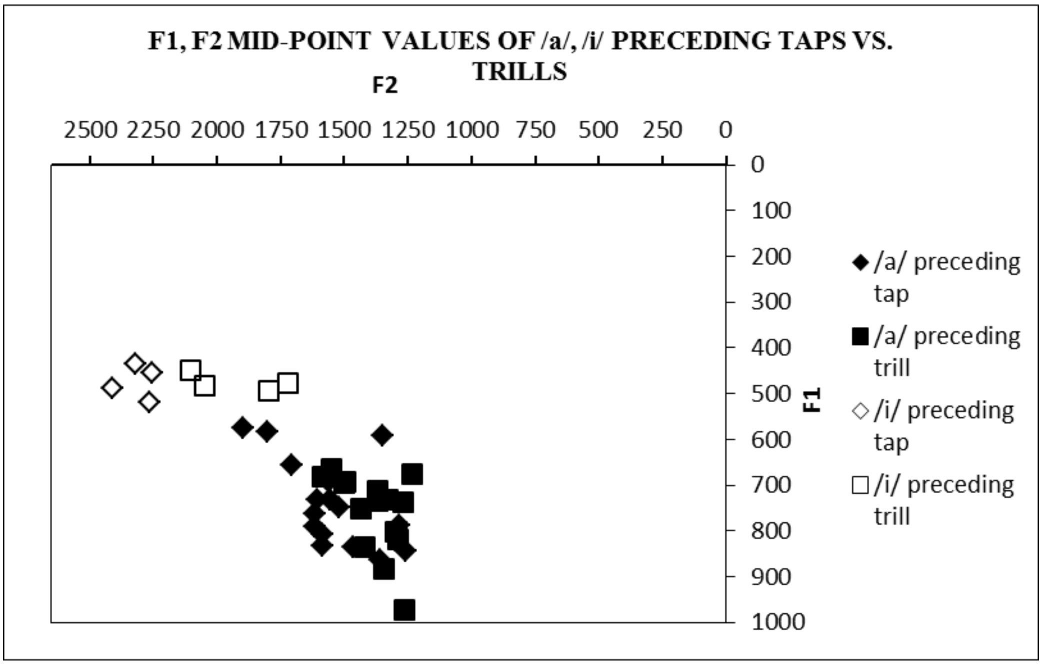


Fig 6: F1-F2 mid-point values of /a/, /i/ preceding target taps versus target trills.

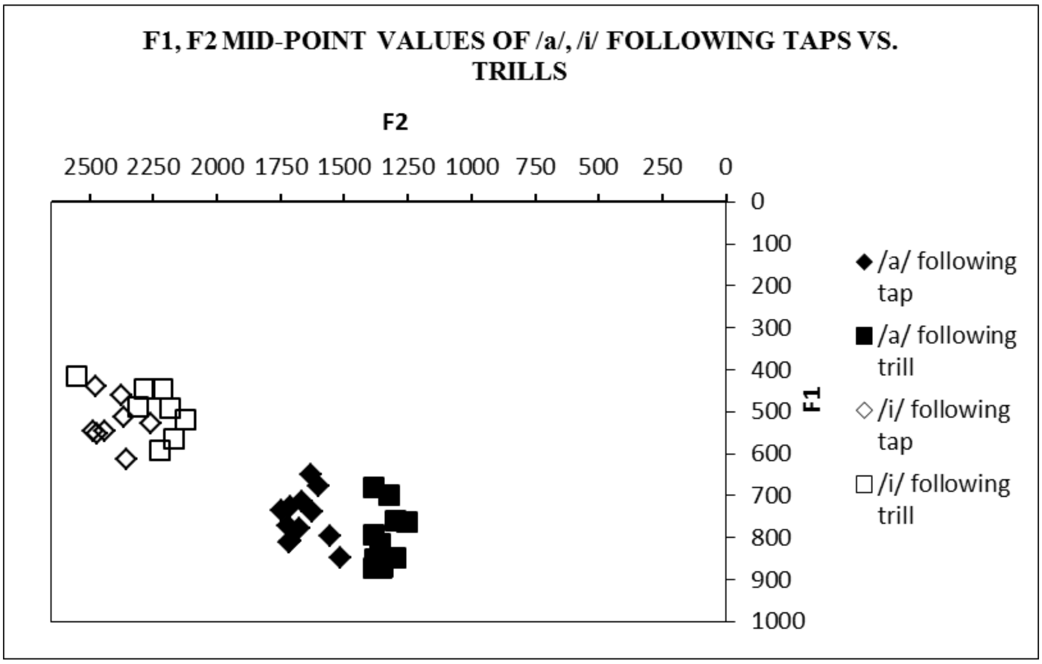


Fig 7: F1-F2 mid-point values of /a/, /i/ following target taps versus target trills.

Acoustic and auditory analyses seem to suggest that vowels tend to be closer and fronted surrounding target taps and more open and retracted surrounding target trills. The quality of the surrounding vowels may be significantly contributing to the distinction between tap-trill minimal pairs, as suggested in earlier findings (Ladefoged and Maddieson, 1996; Srikumar and Reddy, 1988). In terms of the quality of the rhotic segment itself, the target tap in Malayalam was palatalized (clearer resonance) while the target trill irrespective of its realisation was velarized (darker resonance).The clear-dark (palatalized-velarized) distinction observed between the two rhotics has previously been associated with the dental-alveolar distinction (Ladefoged and Maddieson, 1996) and the geminate-non geminate distinction in Malayalam (Local and Simpson, 1999). Local and Simpson (1999) in their paper present an acoustic and impressionistic profile of a subset of the geminate consonants in Malayalam nouns and note that there were systematic spectral and temporal differences in vowels and consonants in nouns with and without geminates. One such difference between geminate-non geminate consonants in Malayalam is that the former tend to sound clearer and the latter darker with respect to their resonance. Hence, the clear-dark feature maybe an impressionistic device used by Malayali speakers to distinguish between different groups of closely related sounds. Or perhaps the clear-dark difference could be reflecting the place of articulation difference between the two rhotics, i.e., apical vs. laminal. Also, an interesting observation is that apicality and velarization (darkness) are compatible features since tongue-tip articulations often involve a certain amount of tongue retraction and also in apical articulations the tongue body has a concave configuration which could be conducive to velarization effect whereas the opposite is true for laminal articulations (tongue-blade articulations) in which the tongue body has a convex configuration which could be more compatible with a palatalization effect.

3.1.2 Fifth Liquid

As for the fifth liquid, auditory analysis seems to suggest that it is a retroflex central approximant and acoustically its spectrogram showed a lowered F3 possibly suggesting the plausibility of a third rhotic in Malayalam, with rising F2 and lowered F1. More importantly, the spectral properties of this third rhotic were found to be similar to those of the recently identified third rhotic in the Brahmin dialect of Tamil (McDonough and Johnson, 1997). This retroflex approximant in Malayalam, however, seems to be different from that described as the common r-variant in several dialects of British English which tends to be characterized by a dipping F1 and F2 as opposed to the former's dipping F1 but rising F2. Also, if a rising F2 is said to correlate with palatalization then does that pose a problem for Malayalam in that this would then suggest that it has a palatalized retroflex rhotic? Although theoretically palatalization and retroflexion require two contradictory articulatory gestures, Toda, another Dravidian language, has been reported to have a palatalized retroflex trill in its inventory, (Ladefoged and Maddieson, 1996:225). In order to confirm whether this fifth liquid in Malayalam is a palatalized retroflex 'rhotic' articulatory work seems imperative. Moreover, it will also be interesting to find out what native speakers of Malayalam perceive the phonetic nature of this fifth liquid to be, i.e. whether it is an r-sound or an l-sound. For instance, will the rising F2 influence at least some of them to describe it as a lateral rather than a rhotic?

The pilot study looked at only 2 male speakers and no statistical measures were calculated on the data to check for significance levels and effect size etc. Also, segmental criteria used to judge boundaries may not have been consistent throughout. The main study design as will be shown in section 3.2 however took into consideration all these gaps and made the necessary changes to generate more accurate, credible and systematic results.

3.2 Present Study

The design of the main study is described below in four subsections: Subjects, data, methods and analyses. The subsection on subjects explains the number of participants, their age range, socio-economic background, educational qualifications and reasons why the particular subject group was chosen for this study. Next, the data set is looked at in detail, the kind of target words used and examples are also given, surrounding sounds' contexts etc. This is followed by a section on the methods used to record the speakers and prepare their files for analyses thereafter, i.e., placing text grids in their sound files, segmentation criteria used to isolate phrase, word and segment boundaries and details of scripts used that enabled automated measurements to be made. The analyses section follows this and is further divided into two: auditory and acoustic analyses.

3.2.1 Participants

A total of 16 adult subjects were recorded: eight males and eight females between the age group of 45-65 years, belonging to rural middle-class families, all born and settled in Kottayam district in Central Kerala. Only the recordings of the eight males were analysed due to time constraints owing to the large number of tokens per speaker and detailed measurements involved for each token. Adults living in rural neighbourhoods of the district were chosen to reduce degree of English influence on their Malayalam and because of their little use of English in day-to-day life. It was also ensured that these subjects have been educated in institutions where Malayalam is the medium of instruction (at least all through the school years) to check for minimum influence of and exposure to English. Kottayam district in Central Kerala was selected as the participant region firstly because the author is a native of the same place and is most familiar with this dialect of Malayalam. Secondly, due to the geographically almost central (south-central) position of Kottayam, the variety of Malayalam spoken here is relatively freer of influences from languages spoken in neighbouring states unlike the Northern and Southern dialects of Malayalam. Due to the geographical proximity of Northern Kerala to Karnataka and of Southern and Eastern Kerala to Tamil Nadu, they are influenced not surprisingly by Kannada and Tamil respectively. In this sense then, the variety of Malayalam spoken by educated speakers of Central Kerala is considered to be the one closest to standard Malayalam.

Some researchers on the language like Asher and Kumari (1997) have alluded to there being differences among the namboothiri, nasrani and moplah dialects (referring broadly to the Hindu, Christian and Muslim variety of Malayalam respectively) in Kerala. As a native speaker of the language who has lived there a considerable number of years, however, the present author feels that these differences are true mostly of the Northern and Southern areas and rarely apply to the Central Kerala variety. Nevertheless to allow for a more homogenous group of speakers, all participants in the present study were Christians. Although the Hindus form the majority in Kerala and therefore would form a more representative sample merely in terms of number, they were not chosen instead because they are further subdivided into castes which also often reflect their class and depending on which their vernacular may vary (e.g. namboothiri versus nayar dialect versus narayaniyer dialect etc.). Christian speakers were also chosen since the author belongs to that community and therefore it was relatively easier to obtain participants belonging to the same.

In terms of the educational qualifications the subjects had a minimum of class 12 qualification which is equivalent to A-levels in the Western system of education and a maximum of either having merely attended or completed their Bachelor's degree. Highly qualified individuals were deliberately not chosen since it would in all likelihood imply quite a good grasp and regular use of the English language, which in turn may have an effect on their Malayalam pronunciation.

3.2.2 Data

The five member liquid system of Malayalam /l/, /ɭ/, /r/ /ɾ/ and /ʐ/ are the target segments. A word-list constituting at least ten words containing each of these five sounds in all permissible word-positions were compiled (given below). The three liquid 'fragments' (as the traditional grammarians refer to these sounds in Malayalam) that occur only word-medially, preceded by a vowel and followed by a consonant, and word-finally preceded by a vowel have also been included in the data set. As mentioned in the literature review, traditionally, in Malayalam, these three liquids and two other non-liquids are classified as belonging to a separate distinct group of sounds called 'consonant fragments'. According to earlier Grammarians of the language, these are different from /r/ and / l/ and /ɭ/ occurring in other contexts with respect to their timing and length (refer Chapter 2, pgs. 41-42). In order to check if there is any phonetic basis for this classification, these have also been included and looked at specifically, as an addition to the main questions addressed in this study.

Three repetitions of each word containing the target token(s) were elicited. These words were read as part of a carrier sentence of the type, 'avaroDeh ______ parayuka' (*Say* ________ to them) .

Since /l/ and /ɭ/, /r/ and /ɾ/ are two pairs of contrastive phonemes and /ʐ/ contrasts in some instances with one or both of the laterals or in other instances with one or both of the rhotics, the data set will mainly include minimal pairs as shown below:

/ɾ/-/r/

1) 'kari / kaɾɪ/ (*soot)*, kaRi / karɪ/(*curry)*

2) Pura / pʊɾa /(*root)*, puRa / pʊra/(*oute*r)

/l/-/ɭ/-/ʐ/

4) 'Kali' / kalɪ*/ (anger)*-'kaLi' / kaɭɪ/ *(game*)- kazhi / kaʐɪ/ *(eat*)

5) 'vaalu' /vaːlə/ (*tail*)- 'vaaLu' / vaːɭə / (*sword)*- 'vaazhu' / vaː ʐə / *(reign*)

6) 'Koolu'/koːlə/ *(stick*)-'kooLu'- / koː ɭə / 'koozha' / koː ʐa/ *(bribe*)

/l/ and /ʐ/

1)'mala'/ mala / (*mountain*)-'mazha'/ maʐa / (*rain*)

2) 'vali'/valɪ/ (*to pull*)- 'vazhi' /vaʐɪ/ (*path*)

3)'toli' /tolɪ/ *(skin*)-'tozhi' / toʐɪ/ (k*ick*)

/ɾ /-/r/-/ɻ/

3) ‘kari’/ kaɾɪ/ *(soot)*- ‘kaRi’ / karɪ/ *(curry)*-‘kazhi’ / kaɻɪ/*(eat)*

4) ‘kara’/ kaɾa */ (land)*-‘kaRa’ / kara / *(stain)*-‘kazha’/kaɻa/ *(wooden poll)*

The data set included front and back vowel contexts to examine effects of surrounding vowels on the five liquids. /ɾ/ occurs word-initially and intervocalically. /r/ occurs word-initially (mainly in loan words from Sanskrit) and intervocalically. /l/ occurs word-initially, medially and finally. /ɭ/ occurs medially and finally. /ɻ/ occurs only intervocalically. In word-final positions, the /ɾ /-/r/distinction is said to be neutralized and this is better understood with examples of words without and with final schwa (Asher and Kumari, 1997: 418):

1) ‘aar(u)’ /aː ɾə/– / aː r/ *who*

2) ‘avar(u)’/ava ɾə/– /ava r/ *them/they*

The examples given below of final /r/ and final /l/ are referred to by traditional Malayali Grammarians as ‘consonantal fragments’: ‘kaya**R** /kajar/ *rope* , ‘paa**l** /paːl/ *milk ,* ‘koo**L**/koːɭ/ , etc.

The wordlist was randomized in order to prevent the speakers from recognizing any pattern to the data presented which may have then affected their productions. The data set also included random words inserted as ‘distractors’ and one of these was inserted in between every four target words in the data set. A total of 238 tokens were produced by each speaker (excluding the distractors). The wordlist which was presented to the participants has been included in Appendix A, pgs. 292-301.

3.2.3 Method

The participants were recorded using an R1 Edirol digital recorder and a SONY MS907 microphone at a sampling frequency of 22050Hz. The target tokens were presented in the carrier sentence frame mentioned in the above subsection via powerpoint slides. No more than two tokens were present on a single slide. This was done to ensure that the participants did not read through the data too quickly and also the speed with which they moved from one slide onto the next was controlled by the fieldworker (the author). Each participant read through the whole data set once and then again the whole set a second time in order that they were not reading the same token twice consecutively. The participants were only told that the fieldworker was interested in Malayalam as a language and were not aware of any details regarding the study.

Using PRAAT, the sound files were first prepared for analysis. PRAAT allows one to place tiers below the waveform and spectrogram. For each sound file, depending on the word-position of each of the targets, specific portions of the carrier phrase were isolated using boundaries. Three tiers were added for each of the target words. If the target segment was in the word-initial position, then the final segment /ə/ (always) of the preceding word, '/avaɾoɖə/' in the carrier phrase was also included along with the target word. For example, in the case of a word like /ɾaːt̪ri/ where the author is interested in the word-initial /ɾ/ and the effect of surrounding sounds, /ə/ of the preceding word '/avaɾoɖə/' serves as the preceding vowel to the /ɾ/ in /ɾaːt̪ri/ and is therefore interesting (see Fig. 8 below). If the target segment is in word-medial position then only the word containing the target segment is isolated. If the target segment is in word-final position, the first vowel of the following word in the carrier phrase /e/ (all cases) is included within the tier boundaries for the target word. For example, in the case of the word /kaal/ where the author is interested in the word-final /l/ and the effect of surrounding sounds, /e/ of the following /en̪n̪ə/ serves as the following vowel to the /l/ in the target word /kaal/ (see Fig. 9 below).

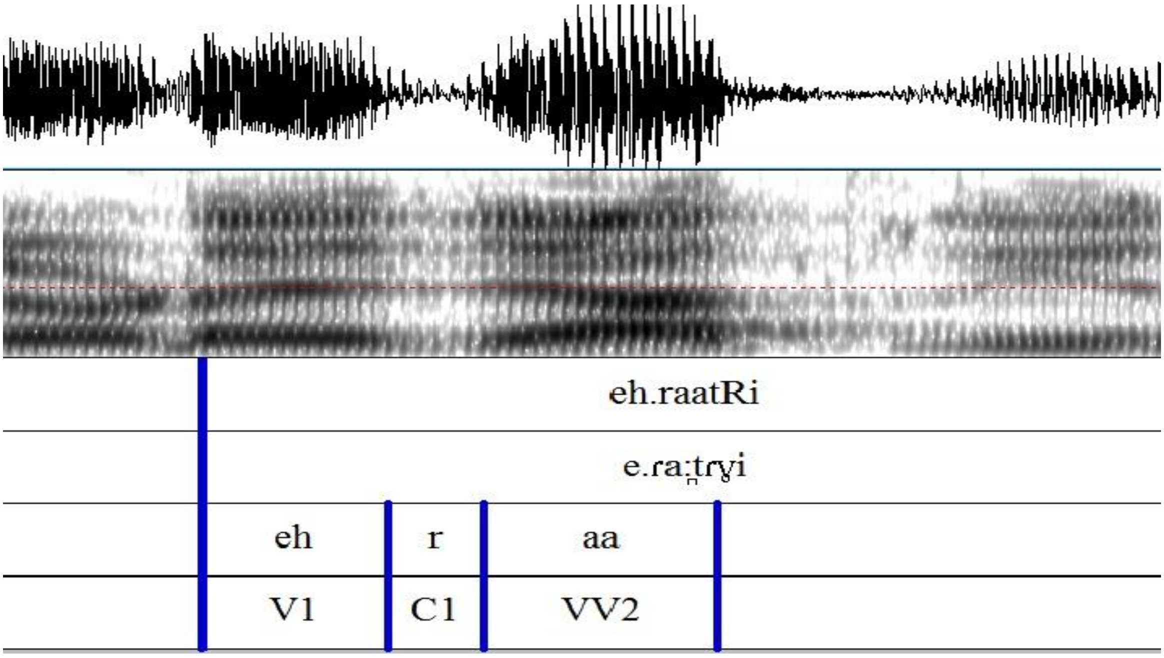


Fig 8: An example of the word ‘raatRi’ /ɾa:t̪ri/ labeled using text grids in PRAAT.

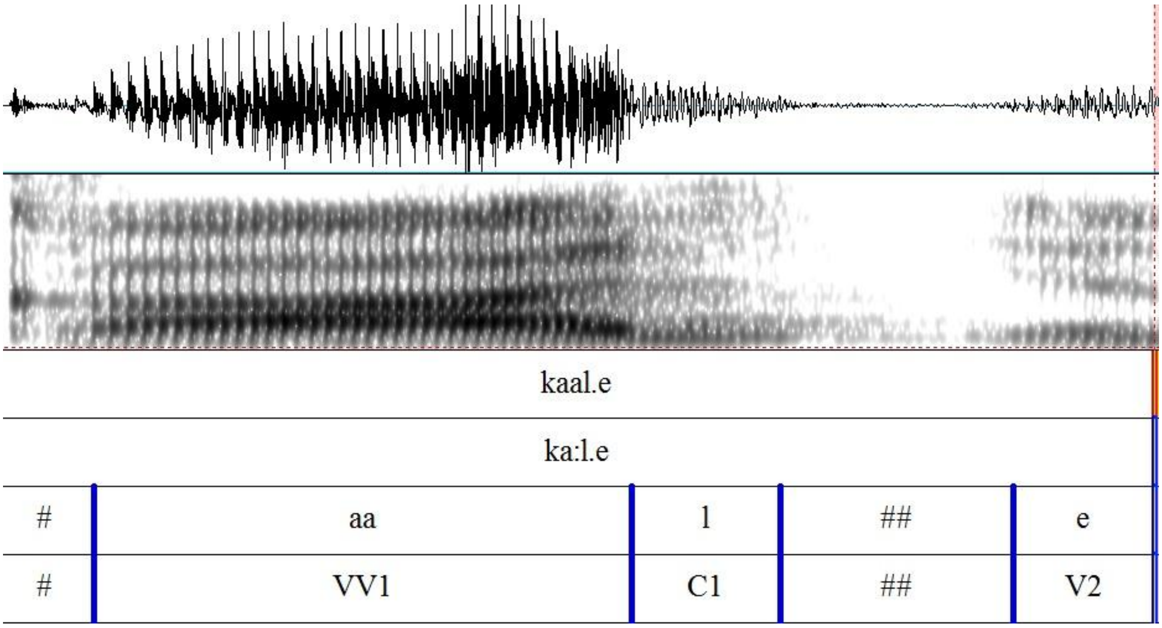


Fig 9: An example of the word ‘kaal’ /ka:l/ labeled using text grids in PRAAT

Four tiers were added for each of the target words. The first tier included the phonology or the ‘target’ written orthographically. The second tier included the actual phonetic realization of the target words and the third tier involved segmentation of individual segments in the target word/phrase. The fourth tier was a duplicate of the third tier notating whether the individual segment in tier 3 is a vowel or consonant, singleton or geminate, preceding or following sound. The main purpose of using these four levels of tiers was to aid the analyses better and enable automated scripts to run on the data and yield all the measurements needed which were then manually checked for each individual segment.

The criteria used to segment individual speech sounds within the target word are given below:

Segmentation criteria

Depending on the type of segment, the criteria to mark their boundaries varied:

Vowels: The beginning of a vowel was determined by the onset of periodicity in the waveform and corresponding onset of glottal pulses in the spectrogram. The end of the vowel was marked where intensity dropped to a near zero.

Lateral: Intensity changes and formant transitions were the major cues in identifying the onset and offset of a lateral. A drop in intensity relative to that of the neighbouring vowels was taken as indicative of the beginning/end of a lateral consonant and often but not always laterals were accompanied by patches of white space in between certain formants.

Tap: Taps were identified by a lowering of intensity relative to the nearby vowel over a small region and were characterized by one or sometimes what looked like more than one 'contact' (a contact is taken to be a spike in the waveform and an often but not always corresponding thick /dark striation). Canonical tap realisations were rarer and most of them were weaker realisations called 'tap approximants' (discussed in more detail in the next chapter, pgs. 87-88).

Trill: The criteria were similar to that for taps except trill realisations involve more than one contact. What looks like a burst was counted as a 'contact' when its frequency was in the range of >1500 Hz and reflected in dark/semi-dark distinct striations on the spectrogram and corresponding prominent spikes on the waveform. Intensity and amplitude patterns relative to that of the neighbouring sounds were once again the major cues in identifying the beginning and end of a trill. Word-initially, many speakers produced their trills preceded by a short epenthetic vowel which was then taken to be part of the trill during segmentation. In a few cases, the final /ə/ of the previous word in the carrier phrase /avaɾoɖə/ was elongated to presumably aid the initiation of voicing of the oncoming trill but in these cases a drop in pitch and intensity at the end of the elongated vowel which increased again once again at the beginning of the trill was taken to imply that it was not one long segment but two segments constituting an elongated previous vowel followed by a trill.

Approximants: Lowering of intensity or in some cases of the fifth liquid increase in amplitude relative to that of surrounding sounds were the main cues in marking approximant boundaries. Also relative changes in the waveform patterns corresponding to changes in formant patterns visible in the spectrogram compared to those of the nearby vowels and other consonants were other useful cues.

Stops: intervocalic stops: The beginning of white space after the end of glottal pulses of the preceding vowel marked the beginning of the hold phase of the stop followed by the release or burst characterized by a spike in the waveform and thick/dark distinct striation(s) in the spectrogram. The end of the stop was marked at the onset of periodicity in the following vowel's waveform.

Initial stops: the beginning was marked by the release of burst characterized by spike(s) in waveform and corresponding distinct dark lines/striation(s) and the end was marked at the onset of periodicity of the following vowel in prevocalic contexts.

Final stops: The beginning was marked similar to that for intervocalic stops and the end was marked at the end of the burst(s).

Fricatives: These were characterized mostly by dark irregular patterns on the waveform and a corresponding dark band ('cloud') in the higher frequency regions in the spectrogram. Relative difference in intensity was taken to be another cue to mark fricative boundaries.

Fig. 10 is an illustration of how the present author labeled sound files using text grids and based on the above segmentation criteria:

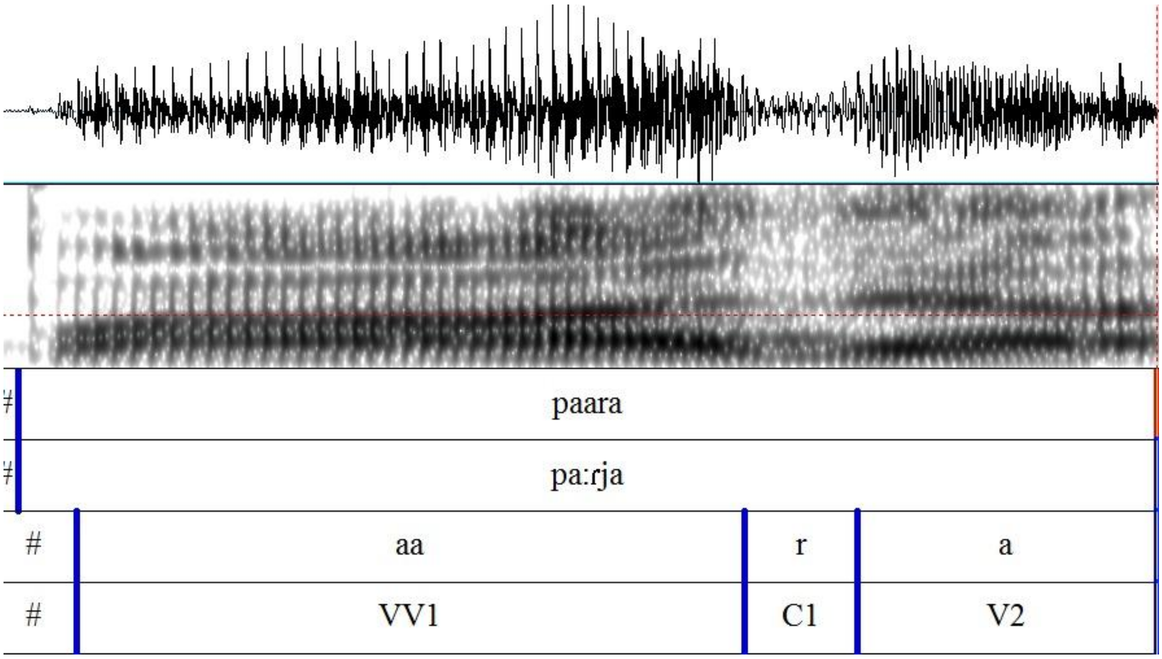


Fig 10: An example of the word ‘paara’ /paːɾa/ labeled using text grids in PRAAT

In this picture, the first tier is the phonological tier, where the target word/phrase is notated in orthography. The second one is the phonetic tier where the actual realization of the target, based on the author’s own auditory perceptions combined with a visual inspection of the waveform and spectrogram, is notated using the appropriate IPA symbols. The third tier involves segmentation of the target word based on the criteria mentioned earlier in this section. The fourth tier is essentially a duplicate of the third, only notating the same with respect to whether the segment is a vowel or consonant, singleton or geminate, preceding or following.

3.2.4 Analyses

<u>Auditory analyses</u>

Auditory analysis was conducted in two stages: The first part included only listening to the sound files and making narrow phonetic transcriptions using the IPA and describing them as they were perceived by the author. Each token and its surrounding sounds were listened to several times before transcribing them. Apart from transcribing the target tokens and the words containing them, a count was also taken of the different realizations a target token had per speaker in order to be able to compare and /or contrast the consistencies or variations amongst the speakers' production patterns. The second part included opening the sound files in PRAAT and involved both listening to the tokens and also observing their spectrograms and waveforms. This proved to be particularly useful in understanding that sound tokens that may perceptibly belong to the same category may reflect more subtle differences in their waveforms and spectrograms. This was mainly applicable in the case of the two uncontested rhotics: target taps and target trills. For example, the waveforms and spectrograms of all tokens categorised perceptually as taps did not appear the same. While some appeared to have one release burst depicting a single contact, others had a reduced waveform but an approximant-like formant structure perhaps depicting a weaker incomplete closure (for more details of the results of the spectrographic analysis, see Chapter 4, section 4.1.1, and Chapter 6, section 6.1.2.1). The second part involving a combination of the auditory judgements and visual inspection of the spectrogram and waveforms was also useful in making preliminary observations with respect to the fifth liquid in comparison to the rhotics and the laterals. There were a few tokens for which there was inconsistency between the judgements made in the first and the second part of the auditory analysis. In such cases, the results of the first part of the auditory analysis, which relied purely on auditory judgements and no visual aid in the form of waveforms or spectrograms, were used. The preference for the results of the purely auditory analysis was made keeping in mind that the present author was mainly interested in what native listeners would perceive these sounds to be and not what the sounds looked like visually. Despite the occasional differences between auditory impression and acoustic profile, acoustic patterns confirmed the author's auditory impression for the majority of the data.

Acoustic Analyses

Two main measurements were made: duration (ms) and formant frequencies (F1, F2 and F3) (Hz). Measurements were made using automated scripts (Al-Tamimi and Khattab forthcoming[3]). The details of how the scripts calculated the two measurements are given below along with the rationale behind calculating these measures.

[3] The scripts used in the present study were adapted by Al-Tamimi from scripts used in his research (Al-Tamimi and Khattab, forthcoming).

Duration

In the literature on tap-trill productions across the world's languages, duration is often mentioned as one of the cues to distinguish between tap-trill minimal pairs. A tap by definition is a brief, *rapid* gesture of the active articulator against the passive whereas a trill involves aerodynamically induced vibration(s) of the active articulator against the passive (Ladefoged and Maddieson, 1996:217). Based on these definitions, the literature often suggests that everything else being equal, a tap tends to have a shorter duration than a trill. In a previous work on the two uncontested rhotics in Malayalam, Srikumar & Reddy, 1988, based on results from a single speaker, found that there was no appreciable difference between the duration of the 'non-retracted trill' (which in the present study is being called a tap instead) and the 'retracted trill' (which in the present study is being called a trill). Although not significant, in general the pattern seemed to be that the duration of the 'non-retracted' trill was either equal to or longer than that of the 'retracted' trill. Also, the 'retracted' trill was found to be shorter in duration than the non-retracted trill before front vowels but no differences were found before back vowels. Duration of the vowels preceding the 'retracted trill' was found to be shorter than those preceding the 'non-retracted trill'. The strength of these differences however has not been mentioned. The present author's pilot study did not reveal any systematic durational differences between the rhotics or vowels surrounding one rhotic versus the other. Irrespective of whether the two rhotics in Malayalam are seen as being one tap and one trill (as in the present study) or one non-retracted and one retracted trill (as in Srikumar & Reddy's study), duration of the rhotic segments themselves and of the vowels surrounding them may or may not be significant cues to distinguish between the two rhotics and either way therefore worth investigating.

Duration is measured in this study for mainly two reasons: Firstly, as mentioned above, in order to check whether in Malayalam, speakers use durational differences to distinguish between tap-trill minimal pairs. Secondly, the fifth liquid in the pilot study sounds like a retroflex approximant and also has a clear resonance (palatalized). However, recent studies argue that the production of a single segment cannot involve both retroflexion and palatalization since they are opposing articulations and so it is instead suggested that languages reporting existence of such segments actually include not just the consonant but also a glide that follows it (Hamann, 2002). In other words, one explanation given is that there may be a glide like element produced after the consonant giving the effect of palatalization and 'appearing' to be 'one' segment when it could perhaps be a back (retroflex) consonant + glide sequence. Hamann claims the relatively ‘long’ duration of such segments reported is also evidence favouring her idea of the back (retroflex) consonant + glide sequence = ‘palatalized’ retroflex sounds. Therefore duration of the 5th liquid is also taken into consideration so as to shed a little light on whether it could be a combination of two sounds or just one.

With regard to duration therefore, the following measurements will be made:

a) **Duration of vowels preceding and following** the target rhotics, laterals and fifth liquid.
b) **Duration of the rhotics, laterals and 5th liquid** themselves

<u>Formant Frequencies</u>

The pilot study (section 3.1) showed that the quality of the vowels surrounding the target tap and trill tokens may be largely contributing to the distinction between them. Trill sequences (both the vowels surrounding target trills and trills themselves) were characterized by higher F1 and lower F2 while target tap tokens (both the vowels surrounding target taps and the taps themselves) were characterized by lower F1 and higher F2, reinforcing the auditory impression of apical-velarized trill versus laminal-palatalized tap (Figs. 5, 6 and 7, pgs. 65-66). F2 was found to be the most robust acoustic correlate of the differences between ɾ−r minimal pairs followed by F1. F3 was found to be inconsistent between the minimal pairs. As for the fifth liquid tokens, spectrograms showed a lowered F3, rising F2 and a lowered F1.

In a recent work on Tamil liquids (including dental & retroflex laterals, ‘pre-alveolar & post-alveolar rhotics’ and a 5th liquid further classified as a retroflex central approximant), the 5th liquid which is allegedly similar to the one in Malayalam (Zvelebil) and occurs in shared lexical items, was found to show similar acoustic characteristics as the retroflex lateral. F2 and F3 were close together around 1500 and 1850 Hz respectively. F4 of [ɻ] was however found to be higher than that of [ɭ] (around 3000 Hz for [ɻ]). The difference between them was found to be in the lack of zeroes (anti-formants) in the high frequency region (2.5-5 kHz) for [ɻ] reflecting the lack of significant lateral channels which is why the F4 values are higher for [ɻ] than [ɭ] (Narayanan et al, 1999:2002-2003). The presence of lateral channels for [ɭ] and thereby the presence of anti-formants reduces the frequencies of the nearby formants which in this case is the F4 since the lowest zero frequency for [ɭ] was around 3340 Hz between the F4 and the F5. Therefore, although it may be worthwhile to note F4 measures along with the standard first three formant measures for all the five liquids in Malayalam (since the liquid system of the two languages have been reported to be similar), the reduced frequencies of higher formants due to the presence of anti-formants may make it more difficult to view the fourth formant on the spectrogram and calculate its frequency.

There appears to be only one acoustic study of Malayalam laterals so far, Menon (1973), which showed that the retroflex lateral had a higher F1 than the alveolar lateral but in general both laterals showed lower F1 values than their surrounding vowels. F2 was found to be higher and spectrograms for both laterals showed a wide gap between F2 and F1. This wide F1-F2 gap combined with the increasing F2 frequencies of the back vowels surrounding these laterals, Menon suggests, may be because both laterals are produced with a relatively wide pharyngeal cavity in the language. F2 and F3 values of the lateral segments and terminal F2 and F3 values of the preceding vowels were found to differ based on place of articulation of the laterals: both lower in the case of the retroflex lateral than the alveolar lateral.

Although the present study does not focus especially on laterals in Malayalam, it would still be imperative to measure their formant values and those of the vowels surrounding them along with those of the two uncontested rhotics and the 5th liquid so that the values may be compared and contrasted with each other to check if the 5th liquid acoustically behaves like the rhotics or the laterals. Therefore, with regard to formant measurements, the present study will measure:

a) F1, F2 and F3 of the two rhotics, the two laterals, and the fifth liquid at onset, mid-point and offset.

b) F1, F2, and F3 of the vowels surrounding each of the five liquid tokens, calculated at mid-point and offset for preceding vowels and onset and mid-point for following vowels.

The automated script (see Appendix B, pgs.302-307) calculated the formant frequencies of each of the target segments at specific points, the location of which depends on their duration. If a segment was longer than 30ms in duration, the duration of the mean period for each speaker was calculated first, corresponding roughly to 10 ms for males and 5 ms for females. For onset and offset measurements, a window having the duration of the mean period was computed, starting from the “real” onset/or ending at the “real” offset respectively. “Real” onset /offset here mean the point where the onset and/or offset boundaries of the segments were marked on the textgrids by the author (based on segmentation criteria given above). Then, the maximum intensity of this portion was computed, and at this point of maximum intensity the onset/offset formant values were extracted. This method of measurement is said to provide an “exact” location of the frame where measurement values were computed. For mid-point values a window for the duration of the mean period was computed first that starts from the “real” mid-point – (mean period duration divided by 2) and ends at the “real” mid-point + (mean period duration divided by 2). Then the maximum intensity of this portion was computed and at this point of maximum intensity the mid-point formant values were extracted.

If a segment was shorter than 30ms, then the same procedure was applied in calculating onset and offset values but by dividing the duration of the mean period by 2 (i.e. the window was based not on the total period but on the first half of the period).

A 25ms Gaussian window with a 5ms step was applied on the waveform where the following setting was used: A maximum of 5 formants were asked for in the formant analysis and the highest ceiling was 5000Hz for males and 5500Hz for females. Once formant computation was applied on the data, onset, mid-point and offset values were extracted at the times determined according to the measurement locations described above.

Each measurement generated by the automated scripts was also manually checked by the author by visually inspecting the waveform and spectrogram to avoid any errors and correct them when present. To avoid any inconsistencies among tokens, the measurements of which, were accurately made by the scripts and those that were not, the present author made sure the points at which the manual measurements were made were the same as those the script uses. The exact locations the script used for making measurements has been described above and these points are marked for each segment in the sound file by vertical lines (function of the script itself). Therefore when the author found any errors in the scripts’ calculation during the manual check, these time lines were used as the locations at which the corrected measurements were to be then made.

This subsection of the chapter looked at the modes of analyses used in this study and the next section will briefly describe the statistics tests used to assess the significance of the results obtained.

Statistical Analysis

The original data set had 11 independent variables namely speaker, gender, consonant/vowel (i.e. segment is a consonant or vowel), singleton/geminate, word-position, consonant type, preceding vowel type, following vowel type, target manner of articulation, realization of manner of articulation and realization of place of articulation. It had 2 main dependent variables namely duration and formant frequencies. However within formant frequencies, F1, F2, F3 onset, mid-point and offset values were separate variables and so the data set had a total of 13 dependent variables.

Univariate and Multivariate ANOVA's were the two main kinds of statistical tests performed. Univariate ANOVA's were used where there was one only dependent variable and multivariate ANOVA's were used where there were more than one dependent variables to be tested at the same time. The former was used to calculate the statistical significance, effect size and other descriptive statistical measures of the effects of several independent variables on the *duration* of the target liquid segments and their surrounding vowels. Separate univariate ANOVA's were conducted on the data for consonant duration, preceding vowel duration, following vowel duration in each of the three word-positions (initial, medial and final), i.e., a total of nine separate univariate ANOVA's were conducted. The number and type of independent variables varied depending on whether selected cases were consonants, preceding vowels or following vowels. For consonants, the independent variables included realization of the manner of articulation of the target liquid, preceding and following vowel type. For preceding vowels, only realization of the manner of articulation and preceding vowel type were used and for following vowels, only the realization of manner of articulation and following vowel type were used.

Multivariate ANOVA's were conducted for each of the three word-positions separately and for each category of segment type separately, i.e., consonants, preceding vowels and following vowels. Therefore a total of nine MANOVA's were conducted on the data set. Multivariate ANOVA's were used to test the effects of several independent variables like realization of manner of articulation, preceding and/or following vowel type, on the *formant frequencies* of the target liquid segments and their surrounding vowels. As mentioned earlier, the number and type of independent variables varied depending on the kind of segment type, i.e. whether the selected cases in the data set were consonants , preceding vowels or following vowels: realization of manner of articulation of the target liquid segment, preceding and following vowel type for consonants, realization manner of articulation and preceding vowel type for preceding vowels and realization manner of articulation and following vowel type for following vowels. The test statistic reported for the MANOVA's conducted is Wilk's Lambda. The Levene's test of equality of error variances were significant in almost all cases ($p<0.001$) when ideally it should have been non-significant but since SPSS does not offer a non-parametric variety of MANOVA, the present author based on Fields (2009) has compromised for this fact by raising the significance level to the 0.001 level. Post-hoc tests, namely Bonferroni and Tukey post-hoc tests were also conducted within the univariate and the multivariate ANOVA's. Bonferroni is generally more recommended as a post-hoc test due to it being relatively simpler to compute, and can be used with several types of statistical tests (Fields, 2009: 473).

In order to report the effect size of a significant difference between groups in the data, the omega-squared values were calculated since the omega-squared values provide a relatively unbiased estimate of variances in a population and accounts for random errors more than eta-squared values (Sheskin, 2003: 284). While this section described the details of the statistical tests used in the present study, the next section will state the hypotheses of the main study based on results of the pilot study and their predicted outcomes.

3.2.5 Hypotheses

A trill and a tap differ from each other in their articulatory requirements: The former involves vibration of the active articulator against the passive while the latter is only a purely muscular gesture, a brief, rapid movement of the active articulator against the passive and involves no vibration. As mentioned in section 2.1, the pilot study conducted with two male speakers of Malayalam seems to suggest that in terms of phonetic realizations at least, both speakers tend to produce one as a tap and another as a trill, this trill more often is realized as a tap. Although these results are based on just two speakers and therefore cannot be generalized, one could suggest that if both rhotics were underlyingly trills as argued in most of the literature on the language (e.g. Ladefoged and Maddieson, 1996; Srikumar and Reddy, 1986 etc.) then it could be expected that at least few tokens of both rhotics would be realized by the speakers as trills. However, for both speakers, all the target tokens of one of the rhotics, i.e., the one occurring in 'kari' *soot* are *realized* as [ɾ] and not even one token by any of the two speakers were realized as trills whereas in the case of the second rhotic, i.e., the one occurring in 'kaRi' *curry*, 50% of the one speaker's tokens and 20% of the other speaker's tokens were realized as trills and the rest as taps.

Based on the differences between a trill and a tap stated above and the results of the pilot study together with the author's judgment of her own production of these two rhotics, the expected patterns for the two rhotics in Malayalam are as follows:

1) **One is hypothesized to be a laminal tap (palatalized), e.g. 'kari' *soot* [kaɾi] and the other an apical trill or apical tap (velarized), and e.g. 'kaRi' *curry* [kari]. The latter tends to be produced slightly further back than the former.**

2) **Vowels surrounding the target tap and the target trill are expected to vary: Those surrounding the latter may be expected to be more retracted and more open than those surrounding the former irrespective of the realization of the manner of articulation of the rhotics.**

3) **Acoustically, the target tap and surrounding vowels are expected to be characterized by a lower F1 and higher F2 (reflecting palatalization) whereas the target trill and surrounding vowels are expected to be characterized by a higher F1 and lower F2 (reflecting retraction and velarization) irrespective of the realization of the manner of articulation of the rhotics.**

Regarding the fifth liquid in Malayalam, the pilot study revealed that auditorily it sounds like a retroflex central approximant and is characterized by a lowered F3, often cited in the literature as being the acoustic correlate of rhoticity, and also a high F2, the trend expected for the fifth liquid in the main study is as follows:

4) **The fifth liquid is hypothesized to be a third rhotic in the inventory of Malayalam: Auditory impressions expected are that of a retroflex central approximant and acoustic features expected are a lowered F3 and perhaps a rising F2.**

Summary

This chapter described the thesis design in detail, first the pilot study followed by the present study. The pilot study was conducted on two male speakers reading isolated words containing at least one of the two rhotics or the fifth liquid in intervocalic position. Both auditory and acoustic analyses were carried out on the data. Results suggest that the two uncontested rhotics in Malayalam seem to vary in place and manner of articulation, i.e., laminal tap versus apical trill and this is reflected in their acoustic properties as low F1, high F2 versus high F1, low F2. Also, the vowels surrounding these rhotics seem to vary systematically: front and close versus open and retracted respectively. The fifth liquid seems to sound like a ‘retroflex’ approximant and showed low F3 and high F2.

The section on the present study was further divided into subsections looking at details of the participants who were recorded for the study, the data set compiled, methods used to record the participants and prepare their digital sound files for analyses and a subsection describing the different modes of analyses. The present study is experimental in nature and employs a combination of auditory and acoustic analyses on the data. 8 male speakers were recorded reading words containing at least one of the 5 liquid segments in Malayalam in a carrier phrase. Sound files were labelled using text grids option in PRAAT and the target segments were segmented using specific systematic criteria and automated scripts were run on the data to generate two kinds of measurements mainly: duration and formant frequencies. These measurements were then manually checked.

Based on the results of the pilot study, at the end of this chapter, four main hypotheses have been drawn out for the main study and these and their predicted outcomes have been laid out in section 3.2.5. The next three chapters will describe the results of the main study in detail.

CHAPTER 4
RESULTS AND DISCUSSION I: Rhotics

This chapter aims to report and interpret the findings from the auditory and acoustic analyses of 8 male speakers reading out randomized words containing at least one of the five liquid segments in Malayalam, in a carrier phrase. The auditory analysis results describe findings from the author's auditory impressions of the target tokens and their surrounding sounds. The acoustic analysis results describe findings based on two sets of measurements, duration and formant frequencies of the target tokens and their surrounding vowels. This section also includes results from the statistical analyses conducted on the data using SPSS with significance measured at the 0.001 level. While the first half of the chapter presents the results obtained for the auditory and acoustic analysis with respect to the rhotics, the second half will discuss these findings in the context of relevant studies in the literature.

4.1 Results I

4.1.1 Auditory Analysis

Target taps, irrespective of word position, are realised as taps by all speakers. Target trills, on the other hand, are more variable in their realisations than the taps across speakers. As shown in Table 4 below, word initially, 5 out of 8 speakers produced a higher percentage of target trills as taps or approximants. Speakers 2, 7 and 8's productions showed the opposite trend, a higher percentage of target trills being produced as trills than taps or approximants (ranging from a 78.57% trill production by speaker 7 and 64.29 % trill production by speaker 8). Apart from speaker 8 who had no approximant realisations of target trills, all the others had at least one target trill realised as approximant. Speaker 4 produced 7/14 target trill tokens as approximants, i.e. 50% of his trill tokens as approximants whereas speakers 1,3 and 5 produced nearly 30 % target trills as approximants. Interestingly no target tap tokens are realised as approximants by any of the 8 speakers.

Target	Taps					Trills				
Realization	Total	DT	Taps	Trill	Approximant	Total	DT	Taps	Trill	Approximant
	N		N	N	N	N		N	N	N
SPEAKER										
1	18	1	17	0	0	14	0	6	4	4
2	18	3	15	0	0	14	0	3	10	1
3	18	0	18	0	0	14	3	6	1	4
4	18	1	17	0	0	14	0	5	2	7
5	18	3	15	0	0	14	0	8	2	4
6	18	1	17	0	0	14	2	10	1	1
7	18	1	17	0	0	14	0	2	11	1
8	18	1	17	0	0	14	1	4	9	0

Table 4. .Phonetic realisations of taps and trills in word-initial position. DT refers to the number of discarded tokens for each speaker.

Word-medially, all speakers produced the majority of their target trills as taps (ranging from 100 % tap realisations for speakers 1, 4, 5 and 6 to 54 % tap realisations for speaker 8) and very few target trill tokens were realised as trills. In the word medial position, none of the target trill or tap tokens were realised as approximants by any of the speakers.

Target	Taps					Trills				
Realization	Total	DT	Taps	Trill	Approximant	Total	DT	Taps	Trill	Approximant
	N		N	N	N	N		N	N	N
SPEAKER										
1	24	0	24	0	0	25	2	20	3	0
2	24	1	23	0	0	25	4	20	1	0
3	24	0	24	0	0	25	0	19	6	0
4	24	0	24	0	0	25	0	25	0	0
5	24	4	20	0	0	25	5	20	0	0
6	24	3	21	0	0	25	8	17	0	0
7	24	1	23	0	0	25	2	19	4	0
8	24	5	19	0	0	25	3	13	9	0

Table 5. Phonetic realisations of taps and trills in word-medial position. DT refers to the number of discarded tokens for each speaker.

There are three main impressionistic findings with respect to the differences between a target tap and a target trill in Malayalam. Firstly, irrespective of their phonetic realisation, target trills differ from target taps in that the former are produced more open and slightly retracted than the latter. Secondly, apart from the tongue backing versus raising for a target trill versus a target tap respectively, there also appears to be a difference in the part of the tongue making contact with the alveolar ridge. The target trills irrespective of whether they are realised as trills or taps, are produced 'apical' (the tip of the tongue makes the contact with the alveolar ridge) whereas the target taps are produced as 'laminal' (the tongue blade makes the contact with the alveolar ridge). In other words, the target taps are produced as lamino-alveolar taps and the target trills are produced as either apico-alveolar taps or apico-alveolar trills. In terms of resonance, the target trill tokens are produced with a 'darker' resonance (velarized) whereas the target tap tokens are produced with a 'clearer' resonance (palatalized). Thirdly, and most importantly, the vowels surrounding a target trill versus those surrounding a target tap differ considerably in their auditory impressions. Vowels surrounding a target trill, whether front or back, sound more open and retracted whereas those surrounding a target tap sound more fronted and raised. An example of the author's phonetic transcription of a tap-trill minimal pair is as follows: 'kara' /kaʲɾʲa/ *shore* – 'kaRa' /ka̠rˠa̠/ *stain*.

The trill fragment, like the target non-fragment trill, had mainly two realisations, namely an apico-alveolar tap and an apico-alveolar trill. The trill fragments realised as taps sounded like the target non-fragment trill realised as taps. Trill fragments realised as trills sounded like regular trills but also accompanied by a short epenthetic vowel /ə/. The incidence of trill realisations was relatively higher in the post-vocalic, pre-consonantal position, i.e. in the case of word-medial trill fragments than in word-final trill fragments. The next part of this section on the analysis of spectrograms and waveforms explores with illustrations the different tap, trill and trill fragment variants produced by the speakers.
Auditory analysis only enables one to distinguish between what is perceptually a tap versus what is a trill with a certain degree of confidence but a combination of listening to speakers' productions and inspecting the waveforms and spectrograms of the productions at the same time opens up a wealth of information regarding the nature of the productions. Based on Jones's (forthcoming) review of trill variability in 19 languages, there appears to be a great diversity in the nature of 'tap' and 'trill' realisations that is often not perceptible but is observable on their waveforms and corresponding spectrograms. Willis and Bradley (2008) identify 'tap' variants such as 'tap approximants', and 'non-continuant taps'. The former includes those tap variants that sound like taps but have the continuous formant structure of approximants, indicating a 'tap' production with an incomplete closure. The latter on the other hand are the canonical taps that sound like taps

and are also characterised by an initial reduced waveform, a corresponding white patch in the spectrogram indicating the tap closure which is then followed by a short release burst (see Chapter 1, pg. 27 for more details).

Based on the main data in this study, the present author identified the following tap and trill variants:

1) Tap approximants: Sounds like a tap but has the continuous formant structure of approximants combined with a reduced waveform, i.e. decrease in waveform amplitude (see fig. 11 below).

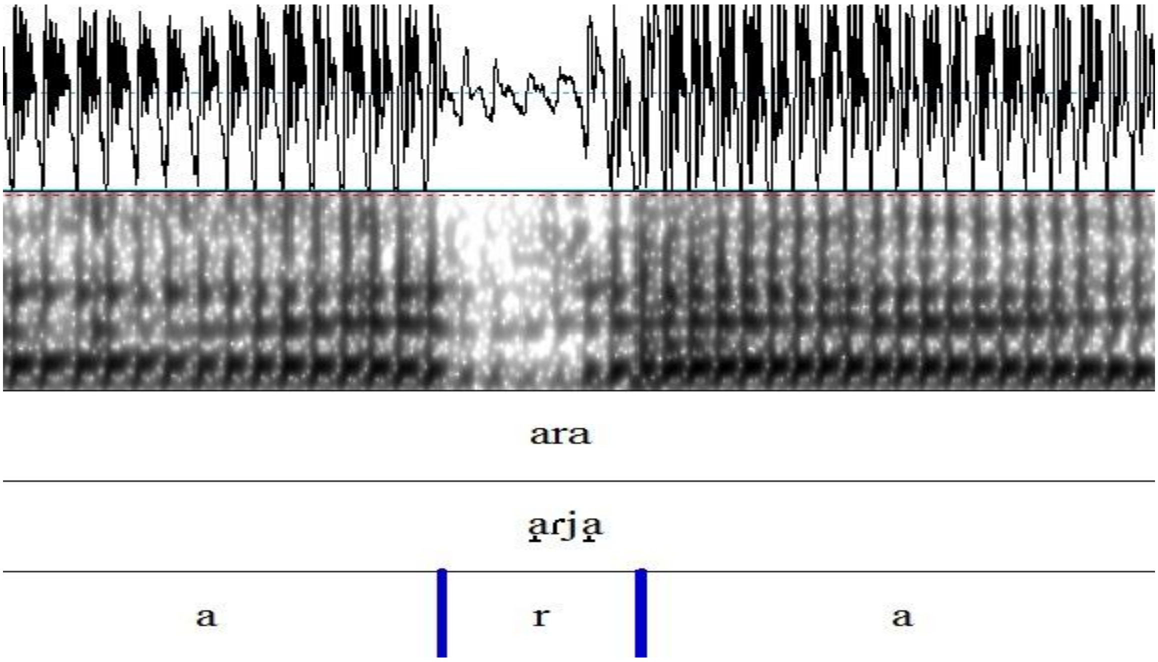


Fig. 11. Waveform, spectrogram and text grid of /ara/ showing decreased amplitude during /r/ combined with approximant-like continuous formant structure.

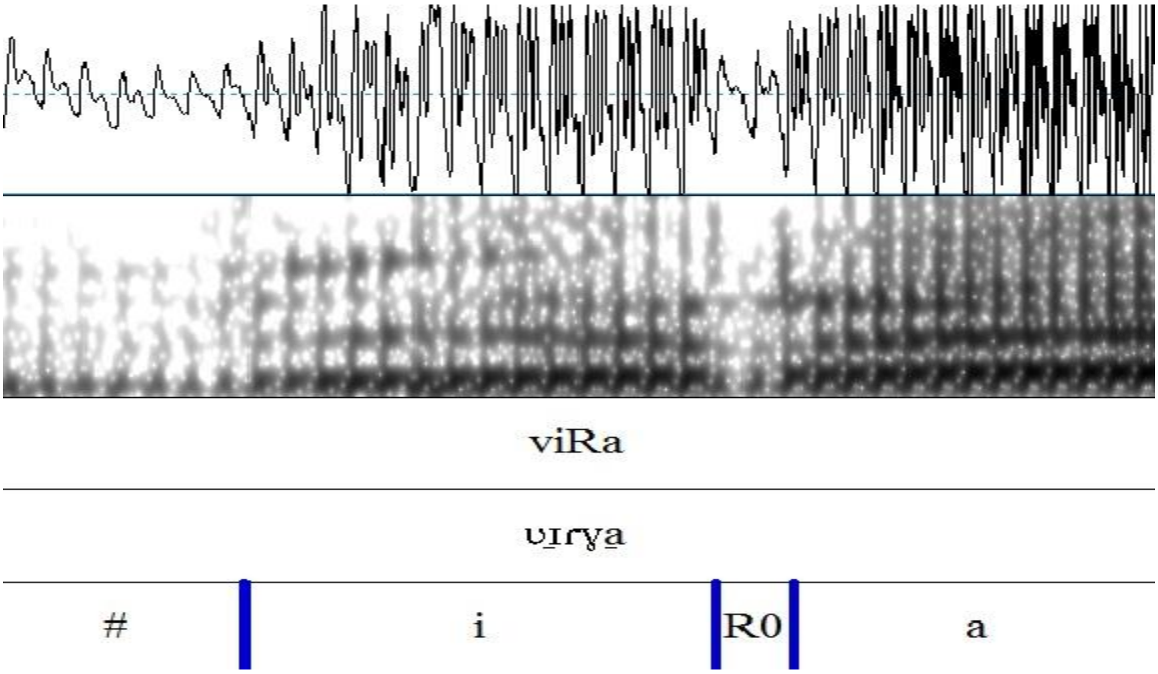


Fig. 12. Waveform, spectrogram and text grid of /viRa/ showing relatively continuous approximant-like structure but sounds like a weak trill

2) Trill approximants: Sounds like a weak trill where some form of vibration is perceptible but has a fairly continuous formant structure similar to that of approximants (see figs. 12 above and 13 below).

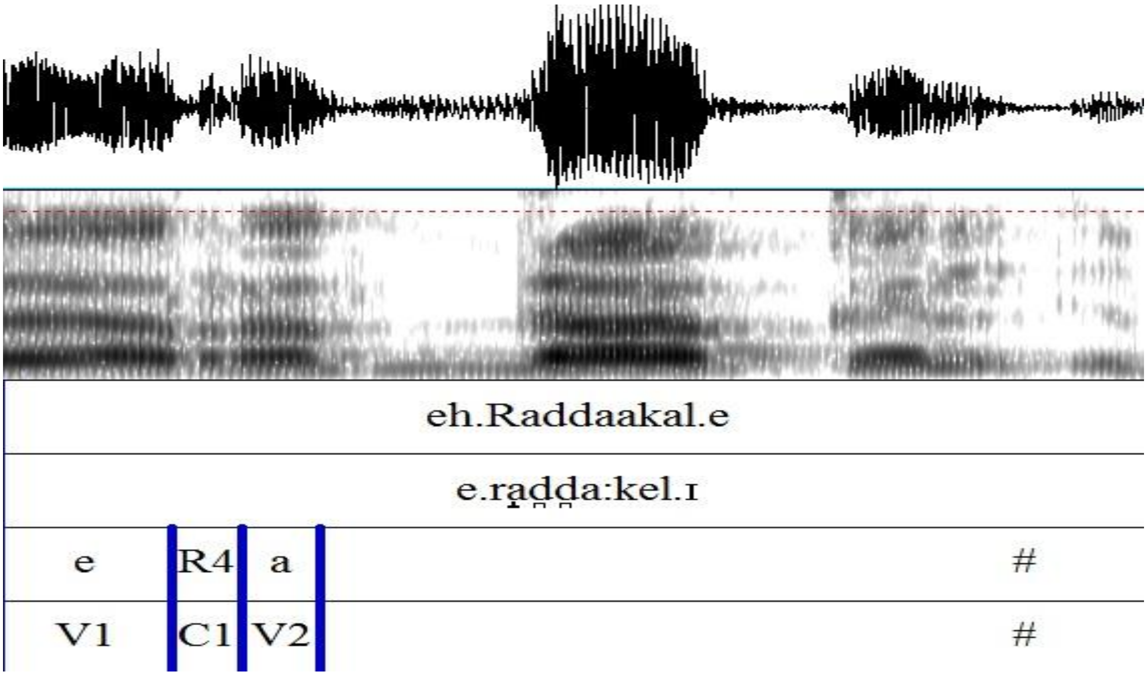


Fig. 13. Waveform, spectrogram and text grid of /radda:kal/ where /r/ is characterised by an initial drop in waveform amplitude followed by cluster of spikes corresponding to a fairly continuous approximant-like formant structure in the spectrogram

3) Canonical taps: non-continuous formant structure, closure evident in the form of white space preceding a more visible or distinct burst/release. There were hardly any cases of non-continuant taps in the data set, 2 cases of word-initial target trills produced by one of the eight speakers as a non-continuant tap (see fig. 14 below).

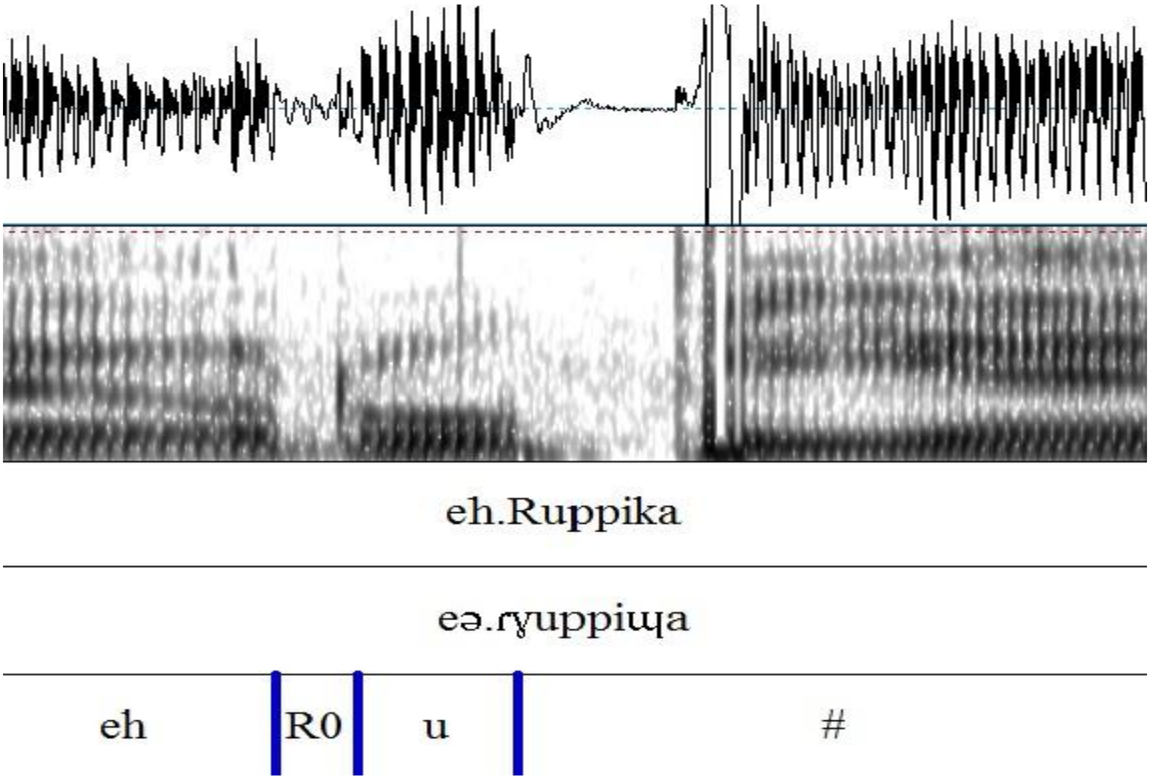


Fig. 14. Waveform, spectrogram and text grid of /ruppika/ where /r/ is characterised by a drop in waveform amplitude and a corresponding white patch in the spectrogram followed by a single release burst.

4) Trill + epenthetic vowel sequences: Sounds like a trill plus a very short epenthetic vowel, the latter often only perceptible when zooming into the trill sequence. These are not characterised by the open-close phases of a canonical trill. Instead they constitute an initial brief drop in waveform amplitude followed by a cluster of ‘spikes’ in the waveform and corresponding cluster of dark striations in the spectrogram. Such variants were produced by speakers for target trill fragments realised as trills (see fig. 15 on next page).

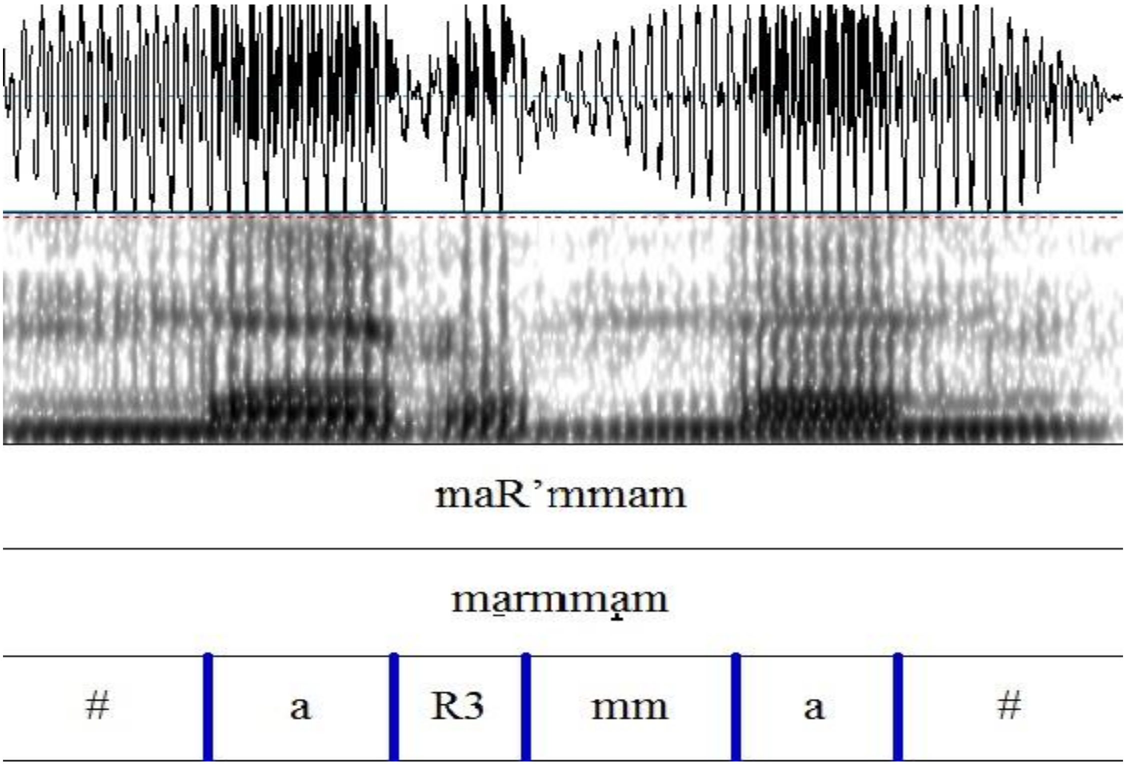


Fig.15. Waveform, spectrogram and text grid of /ma**r**mmam/ where /**r**/(‘**R**’) is characterised by an initial drop in amplitude followed by two contacts and a small vowel portion.

5) Multi-contact Trill: Sounds like a trill with one or more than one contact and the formant structure consists of an initial drop in waveform amplitude followed by a cluster of spikes in waveform corresponding to a cluster of dark striations in the spectrogram. This is the first cycle indicating the first contact followed by the same pattern repeated for every subsequent contact for multi-contact trills (see fig. 16 below).

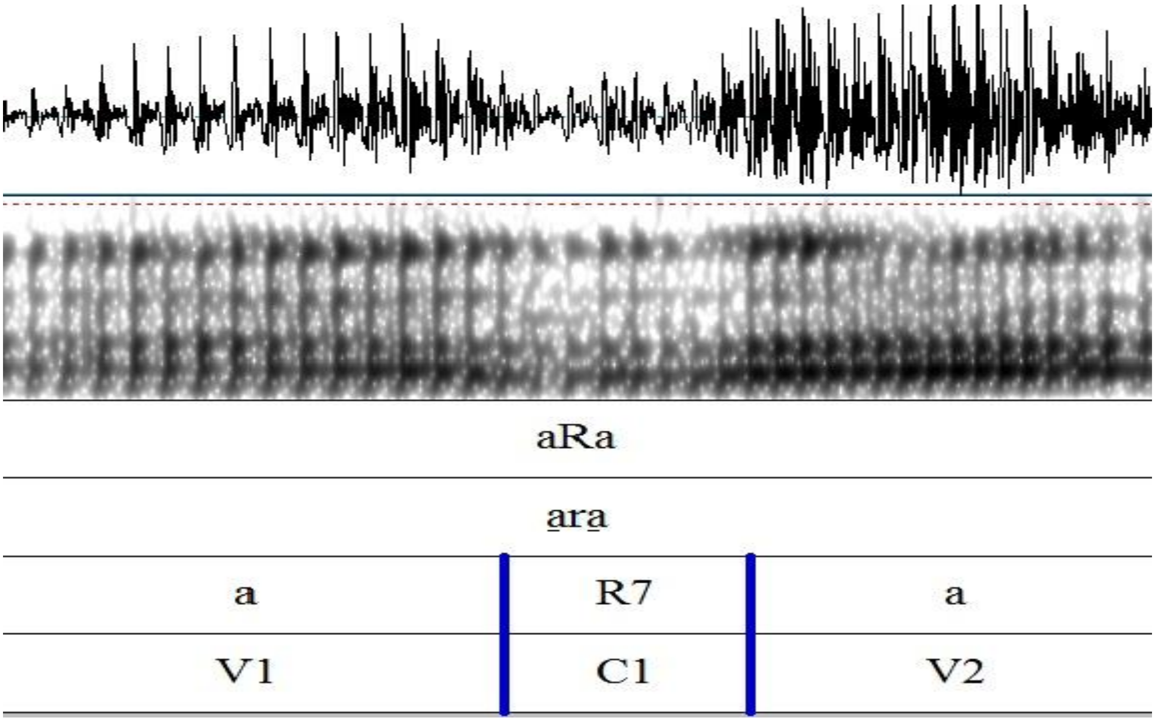


Fig. 16. Waveform, spectrogram and text grid of /aRa/ perceptually a trill, characterised by a slight drop in waveform amplitude but the spectrogram appears fairly continuous with the vertical striations possibly representing the contacts.

All target taps *realised* as taps were produced as tap approximants, i.e., with an incomplete closure exhibited in their fairly continuous formant structure similar to that of approximants but also showing a decrease in waveform amplitude characteristic of taps.
Target trill productions were more varied than target tap productions especially in the word-initial position where speakers produced trills, trill-approximants, tap-approximants and approximants. Inter-speaker and intra-speaker variation were evident. While speaker 6 realised all but 2 word-initial target trill tokens as tap-approximants, speaker 7 realised a large majority of his word-initial target trill tokens as trills. Word-medially, there was less variation in the type of trill realisations produced by the speakers. The target trills were realised either as tap-approximants or trills word-medially. A large majority of all speakers' productions of target trills were realised in this word-position as tap-approximants and very few as trills (see tables 6,7, next page).

Speaker	Target taps				Target trills						
	Total	DT	Non-cont. taps	Tap approx.	Total	DT	Non-cont. taps	tap approx.	trills	approximants	trill approx.
1	18	1	0	17	14	0	2	4	1	4	3
2	18	3	0	15	14	0	0	3	5	1	5
3	18	0	0	18	14	3	0	6	1	4	1
4	18	1	0	17	14	0	0	5	1	7	1
5	18	3	0	15	14	0	0	8	1	4	1
6	18	1	0	17	14	2	0	10	0	1	1
7	18	1	0	17	14	0	0	2	10	1	1
8	18	1	0	17	14	1	0	4	9	0	0

Table 6. Number of variants of tap realisations and trill realisations in word-initial position. DT refers to number of discarded tokens for each speaker. Note 'tap approximant' and non-continuant taps form part of the tap category and trill approximant forms part of the trill category in table 2 above.

Speaker	Target taps				Target trills						
	Total	DT	Non-cont. taps	Tap approx.	Total	DT	Non-cont. taps	tap approx.	trills	approximants	trill approx.
1	24	0	0	24	25	2	0	20	3	0	0
2	24	1	0	23	25	4	0	20	1	0	0
3	24	0	0	24	25	0	0	19	6	0	0
4	24	0	0	24	25	0	0	25	0	0	0
5	24	4	0	20	25	5	0	20	0	0	0
6	24	3	0	21	25	8	0	17	0	0	0
7	24	1	0	23	25	2	0	19	4	0	0
8	24	5	0	19	25	3	0	13	9	0	0

Table 7. Number of variants of tap realisations and trill realisations in word-medial position. DT refers to number of discarded tokens for each speaker. Note 'tap approximant' and non-continuant taps form part of the tap category and trill approximant forms part of the trill category in table 3 above.

Trill fragments occur in Malayalam word-medially in a post-vocalic and pre-consonantal context and word-finally following a vowel. In both word-positions, the two types of variants found in the speakers' production of trill fragments were tap-approximants and trills+ epenthetic vowel sequences (see fig. 15 above). Speakers 6 and 7 realised all their word-final trill fragments as trills + epenthetic vowel sequences and speaker 5 realised all his word-medial trill fragments as trills + epenthetic vowel sequences. A large majority of all speakers' productions of word-medial trill fragments were realised as trills+ epenthetic vowel sequences and very few as tap-approximants. There was much more inter-speaker variation with respect to the realisation of word-final trill fragments. While speakers 1 and 4 had fairly equal number of tap-approximant realisations and trill + epenthetic vowel sequences, speakers 3, 5, 6 realised a large majority of their word-final trill fragments as tap-approximants. Speakers 2, 7, 8 on the other hand had the opposite pattern in that they realised a large majority of their word-final trill fragments as trill + epenthetic vowel sequences (see tables 8,9 below).

Speaker	Trill Fragments		
	Total	Tap approx.	Trill + vowel
1	21	1	20
2	21	1	19
3	21	6	14
4	21	5	15
5	21	0	17
6	21	7	12
7	21	5	15
8	21	1	19

Table 8. Number of tap and trill variants of target trill fragments in word-medial position

Speaker	Trill Fragments		
	Total	Tap approx.	Trill + vowel
1	9	5	4
2	9	1	5
3	9	6	2
4	9	3	5
5	9	6	2
6	9	7	1
7	9	0	8
8	9	0	8

Table 9. Number of tap and trill variants of target trill fragments in word-final position

There were cases of trill weakening particularly among word-final trill fragments (see fig. 17 on next page) and also in some word-initial trill realisations. As shown in the figure below, there is a strong initial contact and the subsequent contacts get weaker which is characterised by the light striations and more white space in the spectrogram towards the end of the segment. Nevertheless the strong initial contact was enough to give a definite impression of a trill.

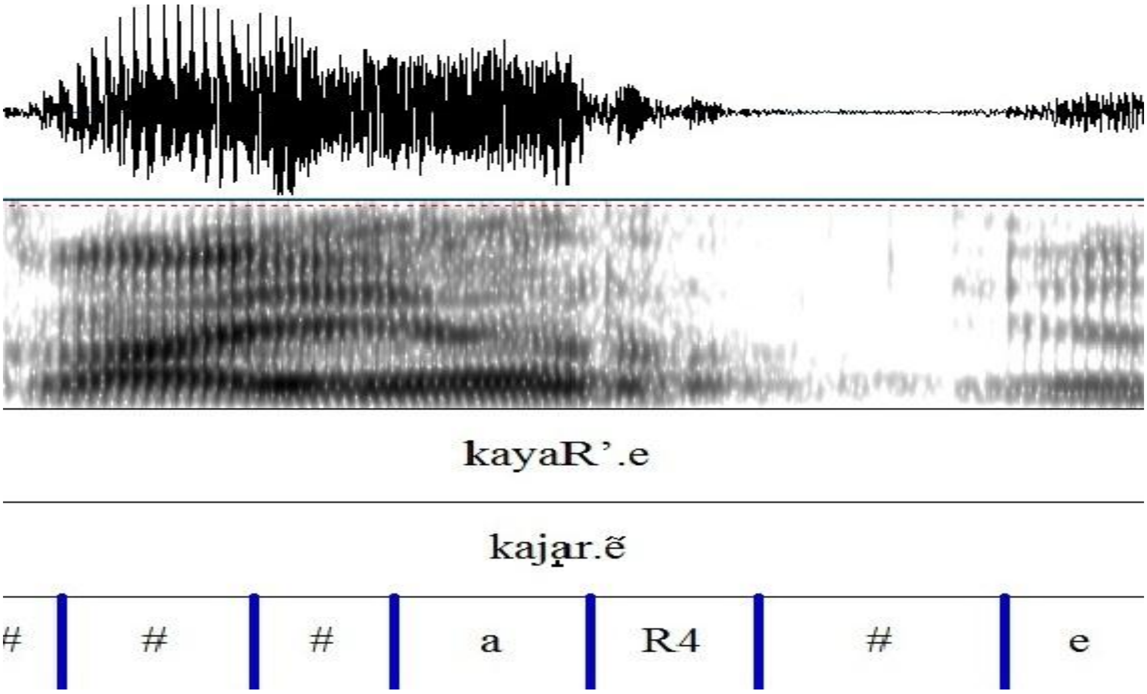


Fig. 17. Waveform, spectrogram and text grid of /kajar/

There were also a few target trill cases where some amount of vibration was perceptible but not enough to give the impression of one or more contacts. In such cases, the formant structure was fairly continuous like that of an approximant and the auditory percept was largely that of a tap. These could be cases of trill failure where an attempt was made at initiating vibration to sustain the contacts but trills were not produced and instead a tap with a weak vibratory element was perceived.

No robust evidence was found that might suggest that the vast majority of trills realised as taps, tap-approximants, or approximants etc. were the consequence of trill weakening or trill failure. It is nevertheless difficult to state with any certainty whether the trills realised as tap approximants/approximants/non-continuant tap /trill approximant could be different realisations of a one-contact trill.

This section described the results of the auditory analysis combined with observations of the waveform and spectrograms of the different tap, trill and trill fragment variants as produced by the speakers in this study. The next section will describe the results of the acoustic analysis conducted.

4.1.2 Acoustic analysis

Duration and formant frequency measurements were taken for each liquid token and their preceding and following vowels.

4.1.2.1 Duration

Separate univariate ANOVA's were conducted for consonant duration, preceding vowel duration and following vowel duration in each of the permissible word-positions. The independent variables were realisation of manner of articulation and preceding vowel type. Only word-initial and word-medial cases apply with regard to duration of taps versus trills since word-finally only trill fragments occur in Malayalam. Also, out of these two word-positions, tap-trill minimal pairs occur only in the word-medial position.

Consonant duration: Tap-trill duration

All target tap and target trill cases were selected from the original dataset and an ANOVA was run with word-position and realisation of manner of articulation as the two independent variables. In general, both factors, word-position [$F(2,722)=137.66$, $p<0.001$] and realisation of manner of articulation [$F(5,722)=32.33$, $p<0.001$] were found to have a significant individual effect on the duration of target taps and trills. Effect size measures indicate that there was a strong effect of word-position on tap-trill duration, $\omega^2 =0.210$ while realisation of manner of articulation had a medium to strong effect, $\omega^2 = 0.131$. The Bonferroni and Tukey post-hoc tests revealed the general effect of the realisation of manner of articulation of the target taps and trills on their duration does not imply that each of the different realisation types are significantly different from each other. Trills realised as taps were found to be the shortest in duration and trills realised as trills the longest in duration among all the different tap-trill realisations. Trills realised as taps (M=33.7, SD=20.2) were found to be significantly shorter than taps realised as taps (M=42.96, SD=20.86) but the strength of the differences in their duration was only medium, d=0.45. However, trills realised as taps, taps realised as taps, and trill fragments realised as taps (M=38.38, SD=15.84) were all found to be significantly shorter than trills fragments realised as trills (M=51.86, SD=19.48) and trills realised as trills (M=54.47, SD=32.38). The durational differences between taps realised as taps and trills realised as trills, and between taps realised as taps and trill fragments realised as trills were significant but only had a medium effect , d=-0.44 and d=-0.49 respectively. On the other hand, the strength of the difference between trills realised as taps and trills realised as trills , and trills realised as taps and trill fragments realised as trills were large, d=-0.86 and d=-0.91 respectively. Trill fragments realised as trills and trills realised as trills were not significantly different from each other in their duration. In all cases where significant differences were found, significance was measured at $p<0.001$. However, the standard deviation values (SD) were all relatively high values in proportion to the respective mean values implying a considerable overlap in duration among the tap-trill subsets mentioned above.

Post-hoc tests on word-position showed that the medial target tap and target trill cases (M= 35.1, SD=15.21) were significantly shorter in duration than their initial (M=58.54, SD=25.74) and final counterparts (M=51.29, SD=26.28).This result could be biased due to extremely unequal sample size (medial cases=447 versus initial cases=225 and final cases=61). The effect size measures nevertheless showed a large effect of word-position on tap-trill duration, i.e. between initial and medial position and between final and medial position, d=1.25 and d=0.98 respectively.

The effect of the interaction between word-position and realisation of manner of articulation of target taps and trills was found to be non-significant , $F(3,722)=2.6$, $p>0.01$ This non-significant effect might suggest that all realisation of manner of articulation types in all permissible word-positions do not differ in duration from each other. However, the non-significant 'p' value of this general ANOVA effect could be a consequence of even just one or few (and not all) cases of non-significant values for any of the possible /permissible combinations of word-positions and realisation of manner of articulation. Therefore individual ANOVA's were conducted narrowing down the selected cases by word-position and realisation of manner types, i.e., univariate ANOVA's were run on specific subsets of the original dataset in such a way that types of realisation of manner of articulation were selected from the dataset based on common word-positions they occur in and separate ANOVA's were run on each word-position. For instance, target taps and target trills occur in Malayalam in word-initial and word-medial positions commonly. These two categories have four realisation of manner types in the word-initial position (taps realised as taps, trills realised as taps, trills and approximants) and three realisation of manner types in the word-medial position (taps realised as taps, trills realised as taps and trills). Also as mentioned before the sample size was different for the different word-positions. Hence, due to the different number of realisation of manner types and different sample sizes between the word-positions, separate ANOVA's were run on the target tap-target trill subset in word-initial position and word-medial position with the only independent variable being realisation of manner of articulation.

Word-initially, realisation of manner of articulation was found to have a significant effect on the duration of target taps and trills, $F(3,221)=7.25$, $p<0.001$, $\omega^2=0.075$, the ω^2 value indicating that the strength of the effect was medium. The Bonferroni and Tukey post-hoc tests revealed, however, that only trills realised as taps and trills realised as trills were significantly different from each other. The former (M=51.09, SD=24.4) was significantly shorter than the latter (M=74.86, SD=35.17). In other words, target trills realised as taps were significantly shorter than target trills realised as trills in the word-initial position (see Fig.18 below). The strength of this difference was found to be large: d=0.98. Target taps realised as taps (M= 58.03, SD= 21.34) were not significantly different in duration than target trills realised as trills (M=74.86, SD= 35.17) but were 'nearly' significantly different (p=0.003). This result may not be accurate due to unequal sample size: 124 cases of taps realised as taps versus 58 trills realised as taps versus 35 trills realised as trills versus 8 trills realised as approximants. Also Cohen's d value measuring effect size showed that despite the p value being 'non-significant, the durational difference between the taps realised as taps and trills realised as trills was of medium strength: d=0.69.

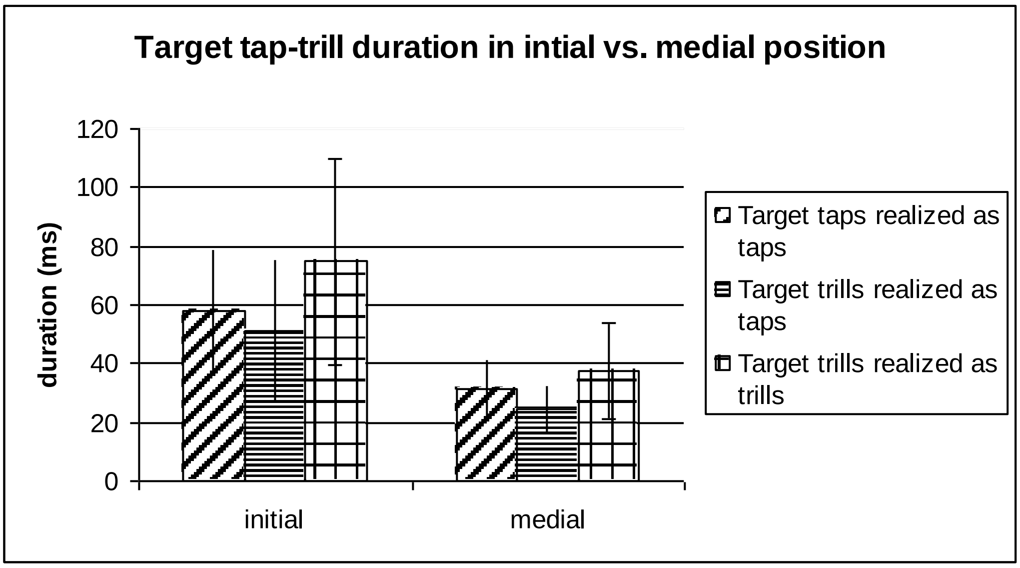


Fig.18. Average duration and SD of target taps-target trills in initial versus medial position. Error bars=±1SD.

Word-medially, realisation of manner of articulation was found to have a significant effect on target tap-trill duration, $F(2,308)=25.8$, $p<0.001$, and $\omega^2=0.129$ indicates that this effect was medium-large. The post-hoc tests showed that trills realised as taps were the shortest in duration (M=24.53, SD=8.2) and were significantly shorter in duration than taps realised as taps (M=31.21, SD=10.26) and trills realised as trills (M=37.49, SD=16.35) (see Fig.18). The strength of the durational difference between taps realised as taps and trills realised as taps was found to be medium-to-large, d=0.71 whereas the effect was large in the case of the differences between trills realised as taps and trills realised as trills, d=1.24. Taps realised as taps are nearly significantly different from trills realised as trills (p=0.002). This p value in the case of taps realised as taps and trills realised as trills could be biased due to an unequal sample size: 110 cases of the former versus 42 cases of the latter. The trills realised as taps (N=159 cases) and taps realised as taps (N=110) have unequal sample sizes but the difference is relatively much smaller than the sample size difference between the latter and trills realised as trills. Nevertheless, effect size measure, d=0.54, indicates that the durational difference between taps realised as taps and trills realised as trills although 'non-significant' by 'p-value' still had a medium effect size.
Target trills in Malayalam also occur word-finally but traditional grammarians have referred to these cases and target trills occurring in word-medial clusters preceded by a vowel and followed by a consonant as a 'fragment' (there are lateral fragments too, for details of fragments, see chapter 2, pgs. 40-41). Trill fragments have two realisations of manner types in both word-positions, i.e. medial and final so a separate ANOVA was run on trill fragment realisations with realisation of manner of articulation and word-position as independent variables.

Only realisation of manner of articulation was found to have a general effect on the duration of the trill fragments, $F(1,193)=25.67$, $p<0.001$ and $\omega^2 = 0.1$ which indicates that the strength of this significant effect was medium-to-large. Word-position, $F(1,193)= 3.36$, $p>0.001$ and the interaction between word-position and realisation of manner, $F(1, 193)= 2.1$, $p>0.001$ both had non-significant effects on the duration of trill fragments. Both were also found to have 'small' effect size measures, $\omega^2=0.010$ and 0.005 respectively which might be suggesting that there are no significant durational differences among the different permissible combinations of word-position and realisation of manners of articulation. In both word-medial and word-final positions, trill fragments realised as taps (M=37.73, SD=13.36 in medial position and M=38.96, SD=17.99 in final position) were found to be shorter in duration than trill fragments realised as trills (M=49.33, SD=15.25 in medial position and M=59.85, SD=27.9 in final position) (see Fig.19). The strength of the difference in duration between both realisations was almost the same in both word-positions, d= 0.77 in medial position indicating a medium-to-large effect and d=0.87 in final position indicating a large effect.

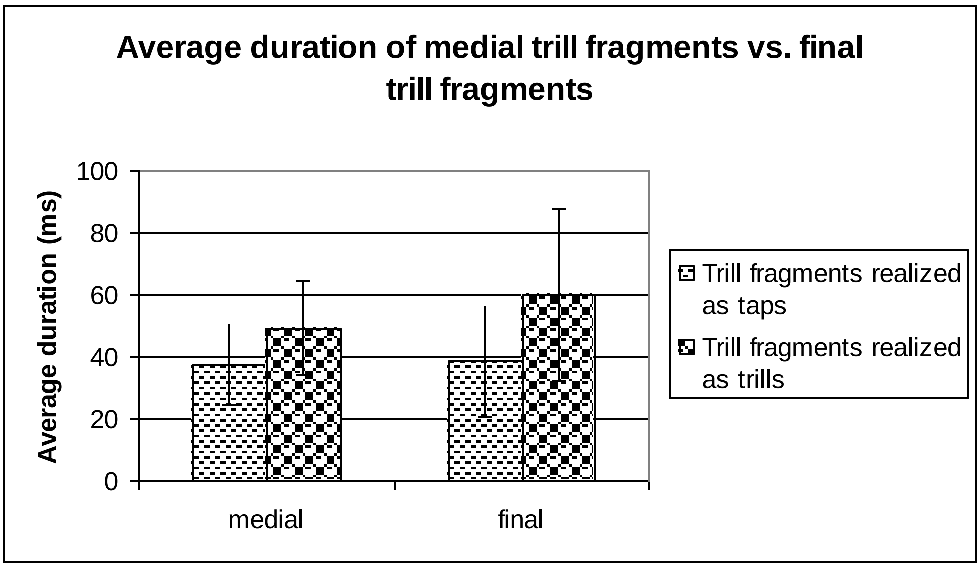


Fig.19. Average duration and SD of medial versus final trill fragments. Error bars=±1SD.

Since target trill ‘fragments’ and target trills both occur word-medially, a separate ANOVA was run on only the duration of trill fragments and target trills subset in the word-medial position, the only independent variable being realisation of manner of articulation. Realisation of manner of articulation of found to have a significant effect on their duration, $F(3,284)=67.47$, $p<0.001$ and $\omega^2 =0.36$ which indicates that the size of this effect was large . As shown in Fig.20, trills realised as taps were the shortest in duration (M=24.53, SD=8.2). Interestingly trills realised as trills (M=37.49, SD=16.35) and trill fragments realised as taps (M=37.73, SD=13.36) were not found to be significantly different from each other but were both significantly longer than the trills realised as taps, while trill fragments realised as trills had the longest duration (M=49.33, SD=15.25). The effect size of the durational differences between trills realised as taps and trills realised as trills, between trills realised as taps and trill fragments realised as taps , between trills realised as taps and trill fragments realised as trills were all found to be large (d=-1.24,d=-1.46 and d=-2.1 respectively). The effect of the difference in duration between trill fragments realised as taps and trills realised as trills was small consistent with its non-significant ‘p’ value (p>0.001, d=0.016). The strength of the durational differences between trill fragments realised as taps and trill fragments realised as trills, and between trills realised as trills and trill fragments realised as trills was found to be medium-to-large (d=-0.77 and d=-0.76 respectively).

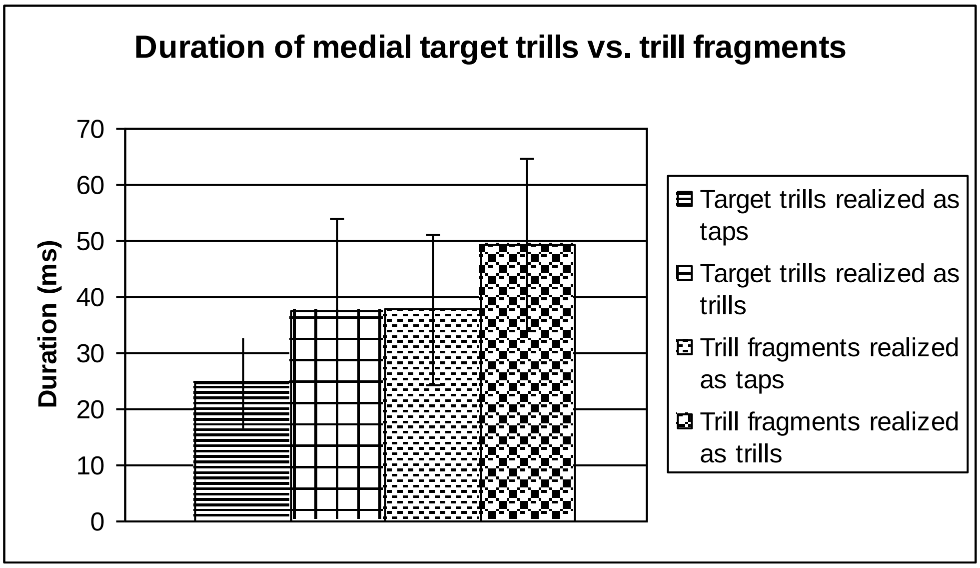


Fig.20. Average duration of medial target trills versus trill fragments. Error bars=±1SD.

<u>Summary</u>

In general, there was a significant effect of realisation of the manner of articulation of the target consonant on its duration, the effect being of a medium-to-large strength (ω^2 =0.131). Malayalam has lexically significant tap-trill contrasts in the intervocalic position. Nevertheless in the word-initial position and intervocalic position, the pattern was the same: target trills realised as taps were found to have significantly shorter duration than target trills realised as trills. Although target trills realised as taps and target taps realised as taps were found to have similar ranging mean duration values, the latter's duration only reached 'near' significance at p=0.002 in the intervocalic position and p=0.003 in the word-initial position with the duration of the target trills realised as trills. However, in both these cases, effect size was medium (d=-0.54 and d=-0.69 respectively). Also, these results may not be accurate due to unequal sample sizes in both word-positions. The trill fragments, irrespective of word-position, also showed durational differences based on whether they were realised as taps or trills. Trill fragments realised as taps were found to be significantly shorter than trill fragments realised as trills with effect size being either medium-to-large (d=0.77) in the word-medial position to large in the word-final position (d=0.87). Since trill fragments and target trills both occur in the word-medial position, their respective durations were tested in order to check for significant differences. Trill fragments realised as taps were significantly longer than trills realised as taps (large effect size, d=2.1) but significantly shorter than trill fragments realizes as trills (medium effect size, d=-0.76). Interestingly, trill fragments realised as taps were not significantly different in duration to the trills realised as trills. The trills realised as trills were found to be significantly shorter than the trill fragments realised as trills and this significance was found to be of medium strength (d=-0.76).

Word-position, irrespective of realisation of manner of articulation was found to have a significant strong effect on the tap-trill duration ($\omega^2=0.21$). Target taps and trills in the word-initial position were found to be significantly longer than target taps and trills in the intervocalic position. Trill fragments, however showed no significant durational differences based on whether they occurred word-medially or word-finally.

. <u>Preceding vowel duration</u>

Separate univariate ANOVA's were run on vowels preceding word-initial and word-medial tap and trill realisations Since the carrier phrase produced by the speakers was /avaɾoɖə____ en̪n̪ə parajuka/, the vowel preceding either of the rhotics in the word-initial position was always the schwa /ə/ occurring at the end of the first word /avaɾoɖə/ in the carrier phrase. Word-medially, however, there were several vowel contexts and so in this case vowel type was also an independent variable in the ANOVA along with realisation of manner of articulation of the target taps and trills when the rhotic was in word-initial position, the only independent variable was the realisation of manner of articulation of the target taps and trills.

The duration of /ə/ preceding target taps and trills was not shown to be affected by the actual realisation of the manner of articulation of the taps and trills, $F(3,219)=4.8$, $p>0.001$ and $\omega^2=0.048$ indicating that effect size was small. In general, duration of /ə/ preceding taps realised as taps and/ə/ preceding trills realised as taps were both shorter than /ə/ preceding trills realised as trills (see fig. 21 next page). The difference in duration of /ə/ preceding target taps realised as taps (M=72.19, SD=34.3) and its duration preceding target trills realised as trills (M=96.02, SD=48.08) was found to be of ‘near’ significance level, p=0.003 (see Fig.21 below). The p values may not be accurate due to the extremely unequal sample size (ranging from some categories having 122 tokens to one having 8 tokens). Despite the non-significant ‘p’ value, effect size of the duration difference was found to be medium (d=-0.64). Duration difference between /ə/ preceding target trills realised as trills (M=96.02, SD=48.08) and /ə/ preceding target trills realised as taps were also found to be non-significant, p>0.001 (M=73.92, SD=25.7) and d=0.45 indicates a small effect size. The duration of /ə/ preceding target taps realised as taps (M=72.19, SD=34.3) and /ə/ preceding target trills realised as taps (M=73.92, SD=25.7) were also found to be non-significant, p>0.001.

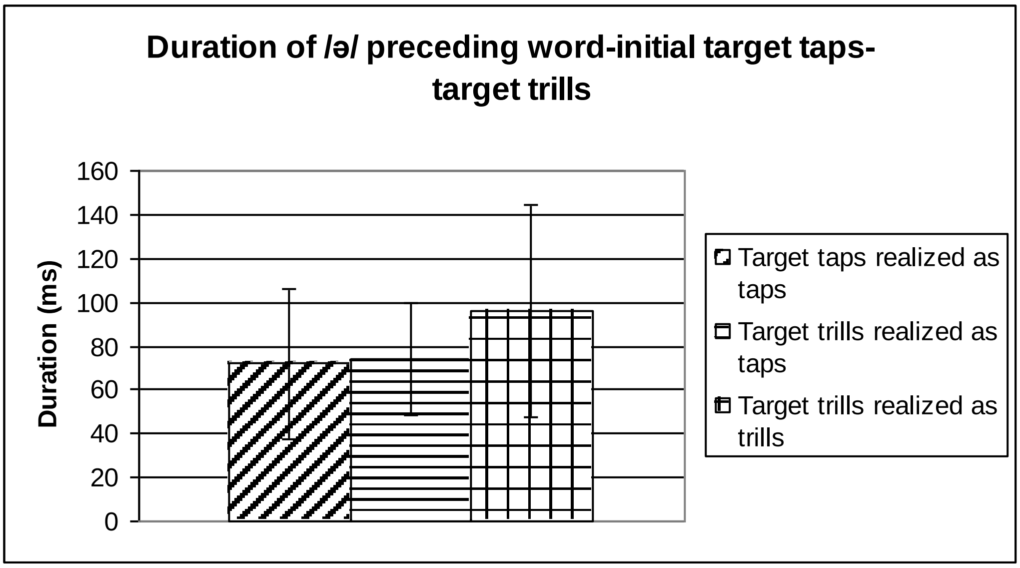


Fig. 21. Average duration of /ə/ preceding initial target taps versus target trills. Error bars=±1SD.

Word-medially, there were two independent variables in the ANOVA, realisation of manner of articulation of target taps and trills and preceding vowel type. Both the short and long vowels were included in the subset selected. Realisation of manner of articulation of the consonant that followed was found to have no significant effect on the duration of the preceding vowel irrespective of the vowel type, $F(2,286)=3.04$ $p>0.001$ and $\omega^2=0.005$ which indicates that the effect size was also very small. The preceding vowel type or vowel quality was found to have a significant effect on the vowel’s duration, $F(6, 286)= 69.02$, $p<0.001$ and $\omega^2=0.42$ which indicates that the strength of the significant effect was large. Irrespective of the realisation of the manner of articulation of the consonant it preceded, /a/ had the longest duration (M=136.73, SD=30.48) and /u/ was found to have the shortest duration (M=89.93, SD=19.71), and /i/ and /o/ had values in between. /i/, /o/ and /a/ were significantly longer than /u/ whereas /i/ and /u/ were significantly shorter than /a/. There were only a few cases of /o/ and /u/ in the dataset compared to /a/ and /i/. All the target short vowels were significantly shorter than all the target long vowels. Among the longer vowels too, /aa/ was the longest in duration and /uu/ the shortest.

The effect of the interaction between the realisation of manner of articulation of the target consonant and the vowel type/quality was found to be non-significant to the preceding vowels' duration, $F(10,286)=1.07$, $p>0.05$.

Fig.22 below shows duration of /a/ and /i/ preceding tap and trill realisations in the word-medial position as an example.

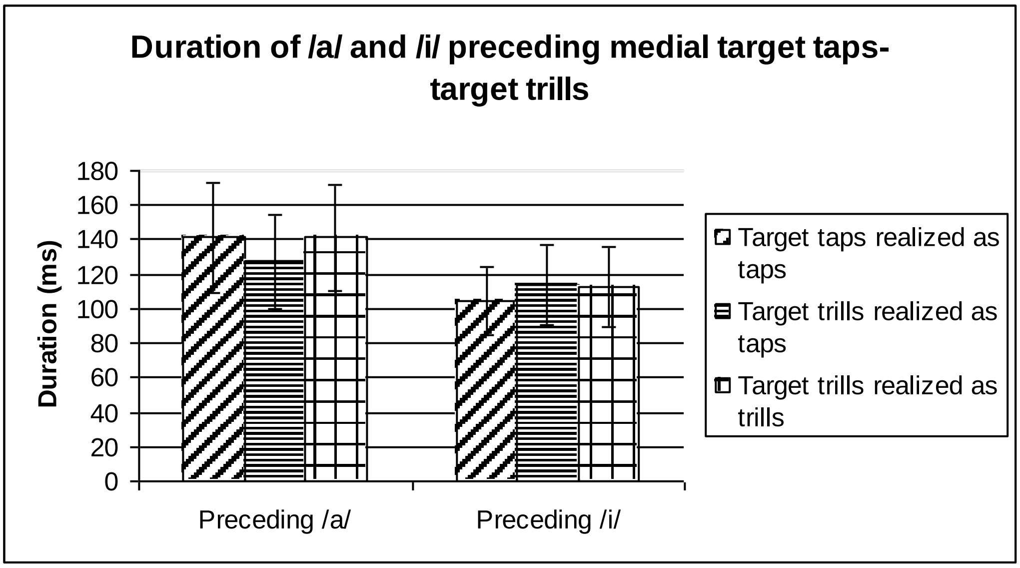


Fig.22. Average duration of /a/ and /i/ preceding taps and trills in word-medial position. Error bars=±1SD.

As shown in the chart above, the vowel /a/ preceding target taps and trills appears to be significantly longer than /i/ preceding target taps and trills. Although the 3 realisations (2 tap realisations and 1 trill realisation) appear to have slightly different durations, none of the three were significantly different from each other as discussed above.

Summary

Duration of the rhotics, both word-initially and medially, was affected by the actual realisation of the rhotic's manner of articulation. In general, trill *realisations* (target trills realised as trills) were found to have a longer duration than tap *realisations* (target taps realised as taps and target trills realised as taps). This difference did not always reach significance levels (significance taken at $p<0.001$). Word-initially and word-medially, duration of trills realised as trills was found to be greater than the duration of trills realised as taps ($p<0.001$) and effect sizes were large in both word-positions. Also, in both word-positions, taps realised as taps were shorter in duration than trills realised as trills and the strength of these difference although only 'nearly-significant' was found to be medium-sized. Word-position had a significant effect on duration of tap-trill realisations. Word-medial tap and trill realisations were found to be significantly shorter than word-initial tap and trill realisations and effect size was found to be medium-large for this difference.

The general pattern was the same with respect to the duration of trill fragments. Trill fragments realised as trills were found to be significantly longer than trill fragments realised as taps. Word-position was found to have no significant effect on the duration of the trill fragment tap or trill realisations. However the durational differences between the trill fragment tap and trill fragment trill realisations were found to have a medium-to-large sized effect in the word-medial position and a large sized effect in the word-final position.

The preceding vowel in word-initial rhotic cases was always /ə/ since the immediate preceding vowel to the target word is the last vowel in the first word of the carrier phrase /avaɾoɖə/. Its duration was not affected by the realisation of the manner of articulation of the rhotic it preceded. Effect sizes for the differences that existed amongst the durations of /ə/ preceding tap-trill realisations were also small. However, /ə/ preceding target trills realised as trills had a longer duration than /ə/ preceding target taps realised as taps and effect size for this difference was found to be medium. Word-medially, realisation of manner of articulation of the rhotic showed no significant effects on the duration of their preceding vowels, irrespective of vowel type. Vowel type, irrespective of the realisation of manner of articulation of the following consonant, was a significant factor that determined the preceding vowels' duration patterns ranging from /u/ < /i/</a/ and /uu/ < /aa/.

4.1.2.2 Formant Frequencies

Rhotics

Using Wilk's statistic, realisation of manner of articulation of the rhotic was found to have a significant effect on its first, second and third formant frequencies at onset, mid-point and offset, Onset: λ=0.313, $F(9,1282.73)=87.26$, $p<0.001$, and ω^2 = 0.68 indicating a large effect size, mid-point: λ=0.283, $F(9, 1282.73)=96.955$, $p<0.001$, and ω^2 = 0.71 indicating a large effect size and offset : λ=0.31, $F(9,1282.73)=88.67$, $p<0.001$, and ω^2 =0.69 indicating a large effect.

With respect to F1 onset, mid-point and offset values, as shown in fig.21 (below), taps realised as taps (M=383.03, SD=60.28; M=377.87, SD=49.7; M=393.71, SD=52.75) were found to have significantly lower F1 values than trills realised as taps (M=445.08, SD=64.45; M=443.86, SD=63.38; M=456.81, SD=62.03) and trills realised as trills (M=513.1,SD=114.4; M=493.69,SD=68.38; M=495.74,SD=58.69). Cohen's d values at all three points of measurement seemed to indicate a large sized effect (d=1.003, 1.2, and 1.12 respectively). Trills realised as taps were also found to have significantly lower F1 values at all three points of measurements than trills realised as trills. Cohen's d values indicated a large effect (d=1.81, 0.76 and 0.63 at onset, mid-point and offset respectively) (see fig. 23 below).

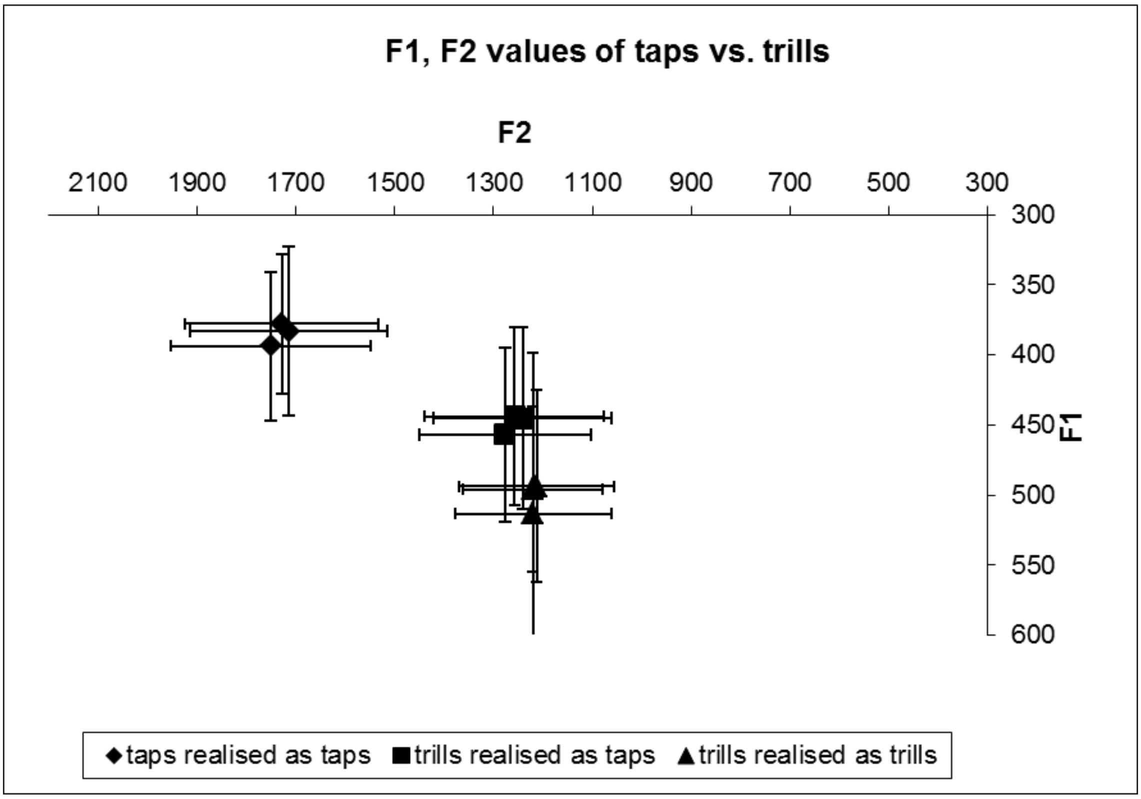


Fig.23 Average F1and F2 onset, mid-point and offset values of taps versus trills. Error bars=±1SD.

Taps realised as taps (M=1714.24, SD=200.47; M=1727.4, SD=195.72; M=1750.63, SD=202.65) were found to have significantly higher F2 values at onset, mid-point and offset, than trills realised as taps (M=1241.3, SD=180.35; M=1257.61, SD=181.34;M=1276.56,SD=172.82) (see fig. above) and Cohen’s d values indicated a large effect, d=2.45 at onset and d=2.47 at mid-point and offset. Taps realised as taps were also found to be have significantly higher F2 values than trills realised as trills (M=1220.21,SD=158.41; M=1212.65,SD=156.28; M=1220.16,SD=140.42) and Cohen’s d values indicated a large effect, d=2.58 and 2.74 and 2.8 at onset, mid-point and offset respectively. Trills realised as taps did not differ from trills realised as trills in their F2 values.

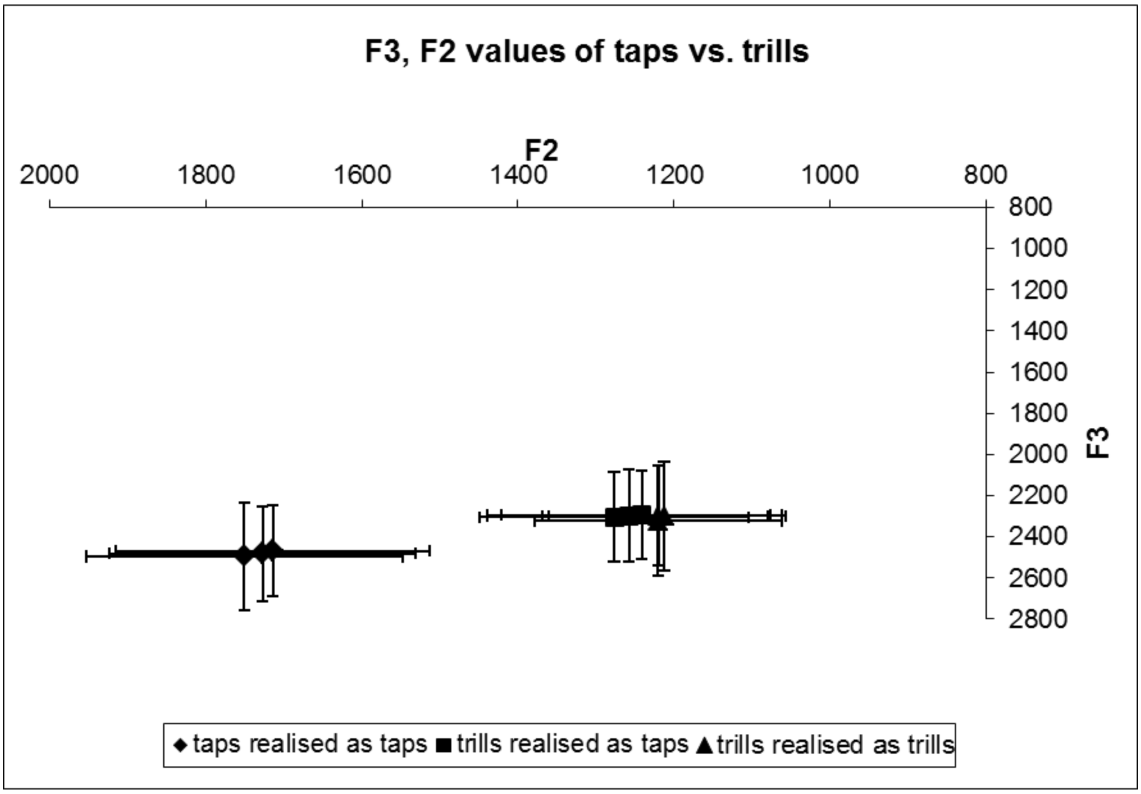


Fig.24 Average F3 and F2 onset, mid-point and offset values of taps versus trills. Error bars=±1SD.

As shown in the figure above, taps realised as taps (M=2468.97, SD=320.33; M=2482.15,SD=231.17; M=2495.32,SD=262.13) were found to have higher F3 values than trills realised as taps (M=2294.33,SD=215.58; M=2296.87,SD=223.16; M=2304.8,SD=217.41) and Cohen's d values indicated a moderate-to-large effect, d=0.62 at onset, d=0.81 at mid-point and d=0.78 at offset. Taps realised as taps were also found to have significantly higher F3 values than trills realised as trills (M=2323.29, SD=266.96; M=2298.64, SD=262.94; M=2298.69, SD=243.3) and Cohen's d values indicated a moderate and moderate-to-large sized effect, d=0.47 at onset and d=0.77 at mid-point and d=0.76 at offset. Trills realised as taps did not differ from trills realised as trills in their F2 and F3 values.

Using Wilk's statistic, word-position was found to have a non-significant effect on F1, F2 or F3 onset, mid-point and offset values of the rhotics, onset: $\lambda=1$, $F(3,527)=0.022$, $p>0.001$, mid-point: $\lambda=0.995$, $F(3,527)=0.818$, $p>0.001$ and offset: $\lambda=0.995$, $F(3,527)=0.874$, $p>0.001$. The interaction between word-position and realisation of manner of articulation of the rhotic was also not found to be significant, onset: λ=0.976, F(6,1054)=2.174, p>0.001; mid-point: λ=0.988, F(6,1054)=1.097, p>0.001 and offset: λ= 0.99, F(6,1054)=0.874, p>0.001.

Another MANOVA was conducted on taps realised as taps, trills realised as taps, trills realised as trills, trill fragments realised as taps and trill fragments realised as trills in the word-medial position and realisation of manner of articulation of the rhotic was the only independent variable that was factored. Using Wilk's statistic, realisation of manner of articulation of the rhotic was only found to have a significant effect on F1 onset, mid-point and offset values, onset: λ=0.87, F(9,686.46)=4.55, p<0.001 and ω^2 =0.103 indicating a medium-to-large effect size; mid-point: λ=0.843, F(9, 686.46)=5.561, p<0.001 and ω^2 =0.129 indicating a medium-to-large effect size; offset: λ=0.877, F(9,686.46)=4.231, p<0.001 and ω^2 =0.943 indicating a medium effect.

The univariate ANOVA's showed that trills realised as taps had significantly lower F1 values than trills realised as trills as mentioned earlier. Trills realised as taps (M=442.45, SD=67.57; M=443.12, SD=69.35; M=458.09, SD=65.07) were also found to have significantly lower F1 values than trill fragments realised as trills (M=493.18, SD=64.91; M=498.27, SD=58.36; M=486, SD=59.21) (see fig. 25 below). Cohen's d values indicated a medium-to-large or large effect size apart from at offset where the effect size was found to be small, d=0.77 at onset, d=0.86 at mid-point and d=0.45 at offset. As shown in fig. 8 below, trill fragments realised as taps (M=436.12,SD=69.87; M=438.27,SD=75.11; M=432.45,SD=72.96) were found to have significantly lower F1 values at onset, mid-point and offset than trills realised as trills (M=516.51, SD=139.56; M=493.16, SD=72.99; M=498.04, SD=61.72). Cohen's d values indicated medium-to-large or large effect sizes at the three points of measurement, d=0.69 at onset; d=0.74 at mid-point and d=1 at offset.

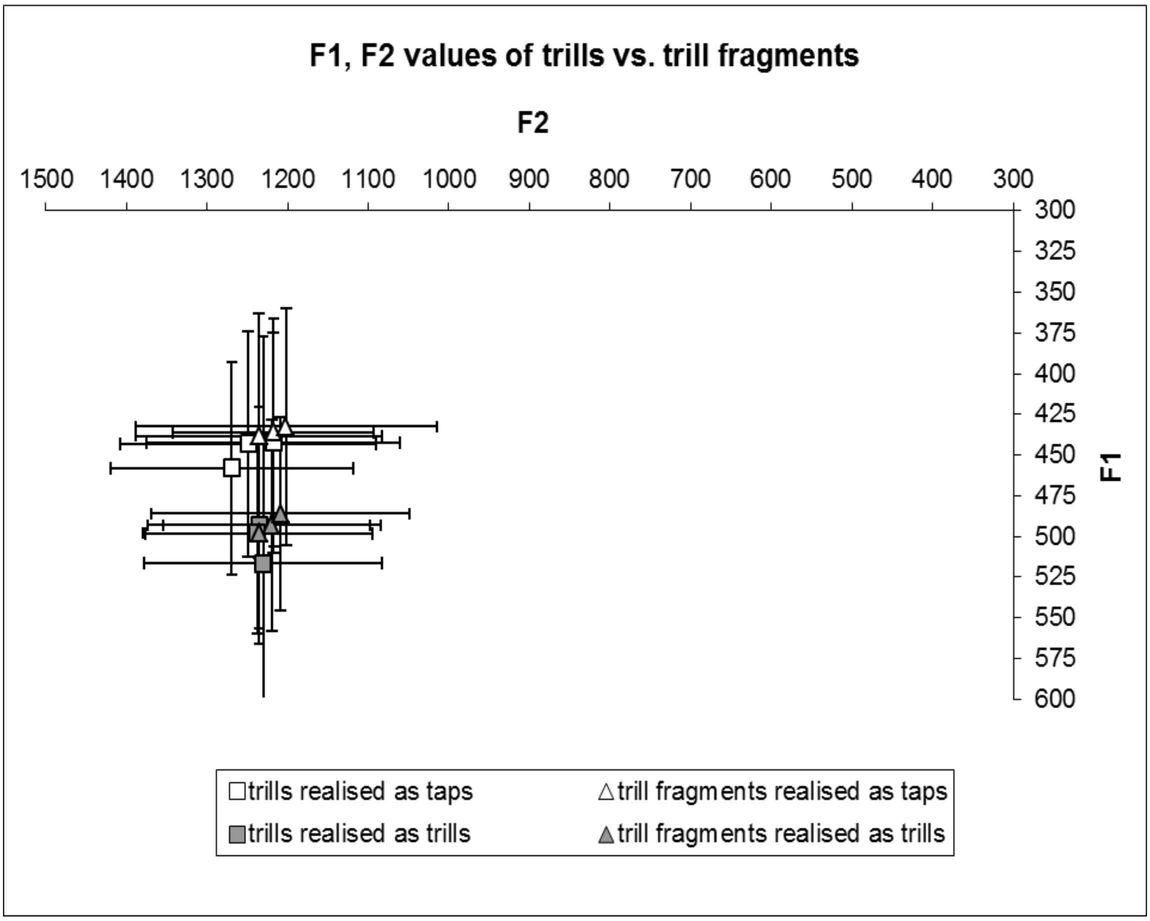


Fig. 25 Average F1 and F2 onset, mid-point and offset values of trills versus trill fragments. The two shapes indicate the trills and trill fragments and the two colour codes within each shape indicate the two different realizations of each category. Error bars=±1SD.

Trills realised as taps were not found to have significantly different formant patterns than trill fragments realised as taps and similarly trills realised as trills were not found to have significantly different formant patterns than trill fragments realised as trills (in both cases $p>0.01$). Trill fragments realised as taps were found to have (nearly) significantly lower F1 than trill fragments realised as trills ($p=0.002$), however, Cohen's d values indicated that differences in F1 values of the two groups had a large effect size, $d=0.87$ at onset; $d=0.98$ at mid-point and $d=0.87$ at offset.

A MANOVA was conducted on trill fragments realised as taps and trills both word-medially and word-finally with realisation of manner of articulation of the rhotic and word-position as independent variables. Using Wilk's statistic, only realisation of manner of articulation of the rhotic was found to have a significant effect on the formant patterns of trill fragments as mentioned in the previous paragraph, onset: $\lambda=0.865$, $F(3,190)=9.91$, $p<0.001$ and $\omega^2 = 0.12$ indicating a medium-to-large sized effect; mid-point: $\lambda=0.84$, $F(3,190)=12.16$, $p<0.001$ and $\omega^2=0.15$ indicating a large effect; offset:

λ=0.853, $F(3,190)=10.92$, $p<0.001$ and $\omega^2=0.13$ indicating a medium-to-large sized effect. Word-position was found to have NO significant effect on the formant patterns of trill fragments ($p>0.001$ at all three points of measurement, i.e. onset, mid-point and offset). The interaction between realisation of manner of articulation and word-position was also NOT found to have a significant effect on the formant patterns of trill fragments ($p>0.001$ at all three measurement points).

Preceding vowels

Two separate MANOVA's were conducted for vowels preceding rhotics in word-initial and word-medial position. This is because in the case of word-initial rhotics, the preceding vowel context was always the same, /ə/, whereas the vowel contexts varied when preceding word-medial rhotics. Separate MANOVA's were conducted for onset and mid-point and offset F1, F2, F3 measures.

The multivariate ANOVA conducted on /ə/ preceding word-initial rhotics had only one independent variable, realisation of manner of articulation of the rhotic it precedes. Using Wilk's statistic, realisation of manner of articulation of the rhotic was found to have a significant effect on the F1, F2 and F3 mid-point and offset values of the /ə/ preceding them, mid-point: λ=0.441, $F(9,528.27)=23.47$, $p<0.001$ and $\omega^2=0.54$ indicating a medium effect size and offset: λ=0.32, $F(9,528.27)=35.06$, $p<0.001$ and $\omega^2=0.66$ indicating a medium effect size.

The univariate ANOVA's within the MANOVA showed that the /ə/ preceding taps realised as taps (M=494.89,SD=80.68; M=441.82,SD=70.08) had significantly lower F1 values at both mid-point and offset than the /ə/ preceding trills realised as taps (M=545.07,SD=67.56; M=512.91,SD=65.48) (see fig. 26 below) and Cohen's d value indicated a medium sized effect at mid-point (d=0.66) but a large sized effect at the offset (d=1.04). /ə/ preceding taps realised as taps also had significantly lower F1 values at mid-point and offset than /ə/ preceding trills realised as trills (M=607.97,SD=66; M=576.4,SD=67.37). Effect size measures were found to be large at both mid-point and offset (d=1.46 and d=1.94 respectively). /ə/ preceding trills realised as taps were also found to have significantly lower F1 values than /ə/ preceding trills realised as trills and effect size was also found to be large at mid-point and offset (d=0.94 and d=0.96 respectively) (see fig. below).

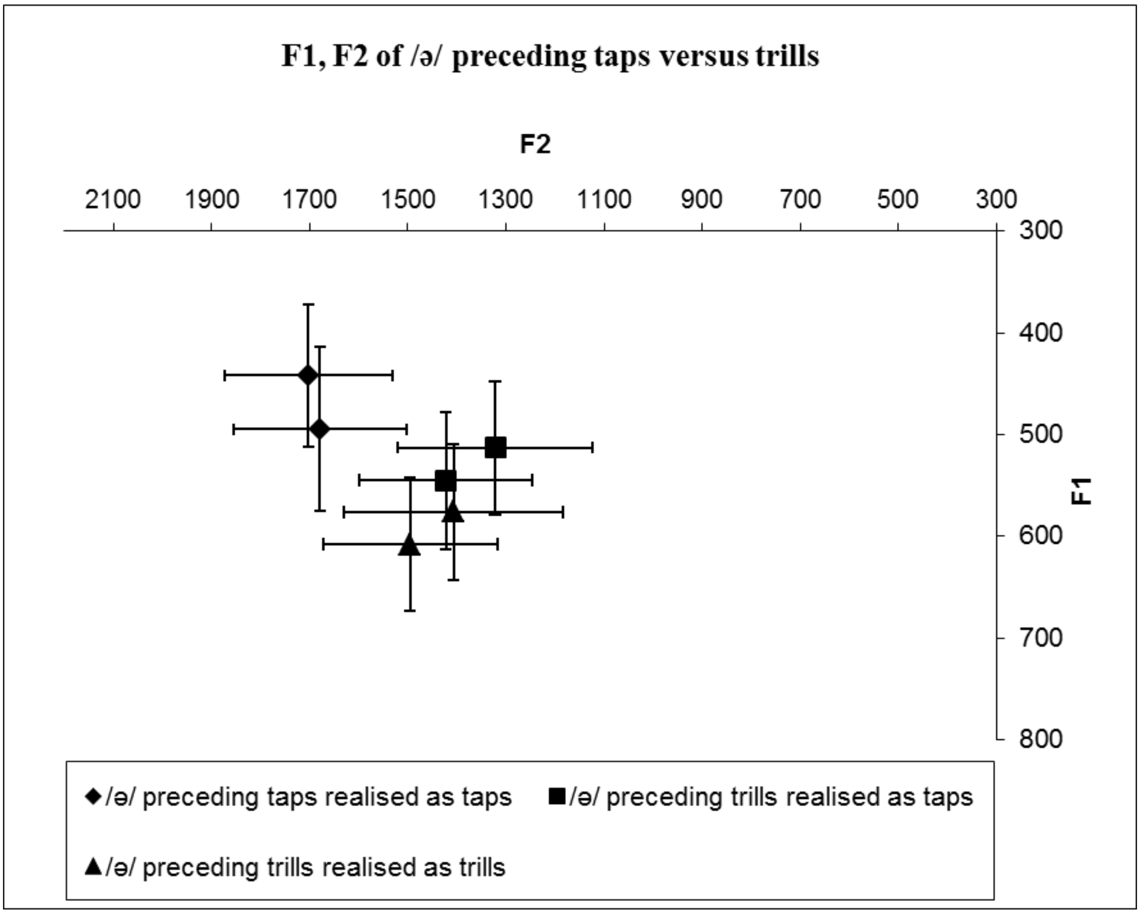


Fig.26 Average F1 and F2 mid-point and offset values of /ə/ preceding taps versus trills. Error bars=±1SD.

As shown in the above figure, with respect to F2 mid-point and offset values, /ə/ preceding taps realised as taps (M=1679, SD=175.79; M=1702.52, SD=170.6) were found to have higher F2 values than /ə/ preceding trills realised as taps (M=1422.32, SD=177.25; M=1321.72, SD=198.4) and d=1.46 and 2.12 respectively indicating a large effect size. /ə/ preceding taps realised as taps also had significantly higher F2 values than /ə/ preceding trills realised as trills (M=1495.23,SD=177.2; M=1406.54,SD=223.48) and d=1.04 and d=1.62 indicating a large effect size at mid-point and offset points respectively.

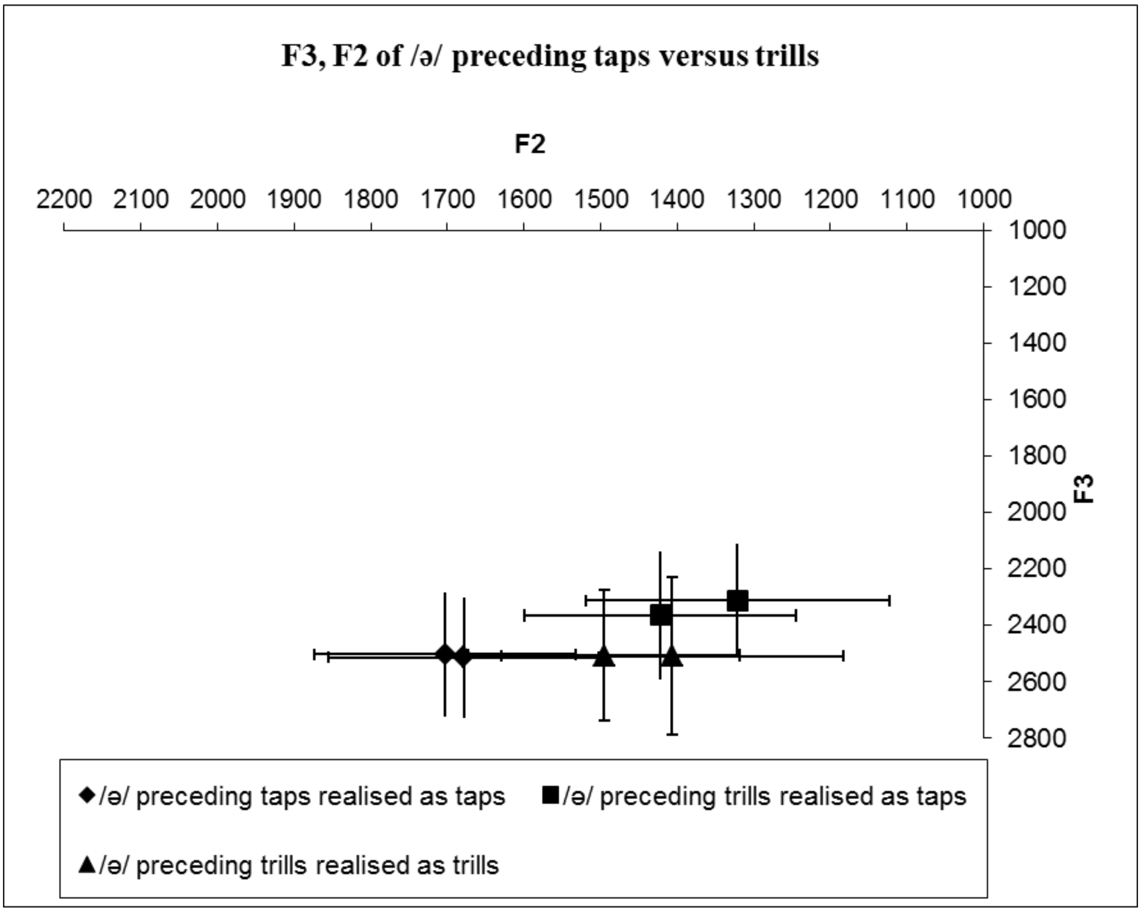


Fig.27 Average F3-F2 mid-point and offset values of /ə/ preceding taps versus trills. Error bars=±1SD.

/ə/ preceding taps realised as taps (M=2512.71, SD=213.24; M=2502.78, SD=221.28) were found to have significantly higher F3 values than /ə/ preceding trills realised as taps (M=2364.91, SD=224.92; M=2311.78, SD=200.36). Cohen's d values indicate a medium and large effect at mid-point and offset points respectively (d=0.68 and d=0.89) (fig.27). Interestingly /ə/ preceding trills realised as trills had F3 values in the same range as those preceding taps realised as taps but still was not found to be significantly different from those preceding trills realised as taps. However, effect size measures of F3 differences between /ə/ preceding trills realised as trills and /ə/ preceding trills realised as taps was found to be medium-to-large (d=0.62 and d=0.86).

With respect to the vowels preceding word-medial rhotics, two MANOVA's were conducted for each of the two points of formant measurement, mid-point and offset, with realisation of manner of articulation of the rhotic and vowel type as the independent variables. Both factors were found to have significant effects on the formant patters of the vowels preceding word-medial taps versus trills (see fig. 28, pg. 117):

1) Realisation of manner of articulation of the rhotic: λ=0.73, F (6,568) =16.31, p<0.001, ω^{2} = 0.25 at mid-point and λ=0.4, F (6,568) =54.09, p<0.001, ω^{2} = 0.59 at offset;

2) Vowel type: λ=0.06, F (18,803.76) =75.18, p<0.001, ω^{2} =0.94 at mid-point and λ=0.34, F (18,803.76) =20.67, p<0.001, ω^{2} =0.64 at offset.

Effect size measures indicated that there was a small effect of realisation of manner of articulation at mid-point and a medium-sized effect at offset. The ω^{2} measures for vowel type indicated that there was a large effect of vowel type on the formant patterns of vowels preceding the rhotics at mid-point and a medium sized effect at offset. The interaction between the two factors was also found to have a significant effect on the formant patterns of the vowels preceding taps versus trills at mid-point, λ=0.66, F(30,834.27)=4.17, p<0.001, and ω^{2} =0.27 indicating a large effect. At offset, however, the interaction between the two factors was found to be non-significant (p>0.01).

The ANOVA's revealed that realisation of manner of articulation of the rhotic had a significant effect on the F2 and F3 mid-point, offset and F1 offset measurements (p<0.001) and a nearly significant effect on the F1 mid-point values (p=0.002) of vowels preceding the word-medial rhotics. The Bonferroni and Tukey post hoc tests further showed vowels preceding taps realised as taps (M=520.62, SD=171.02; M=443.55, SD=86.62) had significantly lower F1 mid-point and offset values than those preceding trills realised as trills (M=583.37, SD=148.26; M=559.02, SD=91.5) (p<0.001) and Cohen's d=-0.37 at mid-point indicating a small effect size and d=-1.31 at offset indicating a large effect size. The difference between F1 mid-point values of vowels preceding taps realised as taps (M=520.62, SD=171.02) and those preceding trills realised as taps (M=547.39, SD=144.63), the former being lower than the latter, was found to only reach 'near' significance (p=0.003) whereas the difference between their respective F1 offset values (M=443.55, SD=86.62 and M=511.78, SD=90.37 respectively) was found to be significant (p<0.001). Cohen's d values indicated a small effect size at mid-point, d=-0.17 and a medium-to-large effect size at offset, d=-0.77. Vowels preceding trills realised as taps (M=547.39, SD=144.63; M=511.78, SD=90.37) were also found to have significantly lower F1 offset values than those preceding trills realised as trills (M=583.37, SD=148.26; M=559.02, SD=91.5) and Cohen's d value indicated a medium sized effect, d=-0.5 (Fig. 28, pg.117).

Vowels preceding taps realised as taps (M=1650.03, SD=432.75; M=1780.12, SD=257.66) were found to have significantly higher F2 mid-point and offset values than vowels preceding trills realised as taps (M=1413.03, SD=303.58; M=1313.97, SD=212.84) and those preceding trills realised as trills (M=1325.29, SD=281.64; M=1260.81, SD=198.91). Cohen's d values indicated that the F2 differences between vowels preceding taps realised as taps and those preceding trills realised as taps and trills at mid-point were of medium size and large size effects respectively (d=0.62, d=0.81) and at offset were both of large size effects (d=1.95, d=2.12). Vowels preceding trills realised as taps and trills realised as trills were not found to have significantly different F2 values ($p>0.01$) from each other.

Vowels preceding taps realised as taps (M=2558.09, SD=254.9; M=2534.99, SD=238.23) were found to have significantly higher F3 mid-point and offset values than those preceding trills realised as taps (M=2431.29, SD=221.9; M=2368.32, SD=217.26) ($p<0.001$) with effect sizes being medium sized at mid-point and medium-to-large sized at offset. Vowels preceding trills realised as trills were found to have significantly different F3 values as compared to those preceding trills realised as taps and taps realised as taps.

With regard to the effects of the second factor, vowel type, on the formant patterns of the vowels preceding taps versus trills, the trends were as follows

F1 mid-point- /uu/, /ii/, /u/, /i/ < /o/ < /a/, /aa/

F1 offset /uu/, /u/, /i/, /ii/ < /o/, /a/, /aa/

F2 mid-point- /uu/, /u/, /o/ < /aa/ < /a/ < /i/ < /ii/

F2 offset /uu/, /u/ < /aa/, /o/, /a/ < /ii/, /i/

F3 mid-point /o/, /uu/, /u/, /a/, /aa/ < /i/, /ii/

Also /o/ < /a/, /aa/ < /i/, /ii/

F3 offset: The range of average formant frequencies was found to be between 2338.4 for /o/ to 2532.36 for /i/ and was statistically found to belong to a homogenous subset, i.e., no significant differences in F3 means based on vowel type were found at offset.

Therefore, as was expected, F1 mid and offset values varied depending on the vowel height. Front and back high vowels had the lowest F1 values followed by the front and back close-mid and open-mid vowels. Front and back low vowels had the highest F1 values. F2 patterns of the vowels varied depending on whether they were back or front, the former having lower F2 values than the latter.

The interaction between realisation of manner of articulation of the following consonant and vowel type was found to be significant at mid-point but not at offset. To determine which of the combinations of the vowel type and realisation of manner of articulation were significant, MANOVA's were conducted with the data file split according to vowel type, and realisation of manner of articulation was the only independent variable.

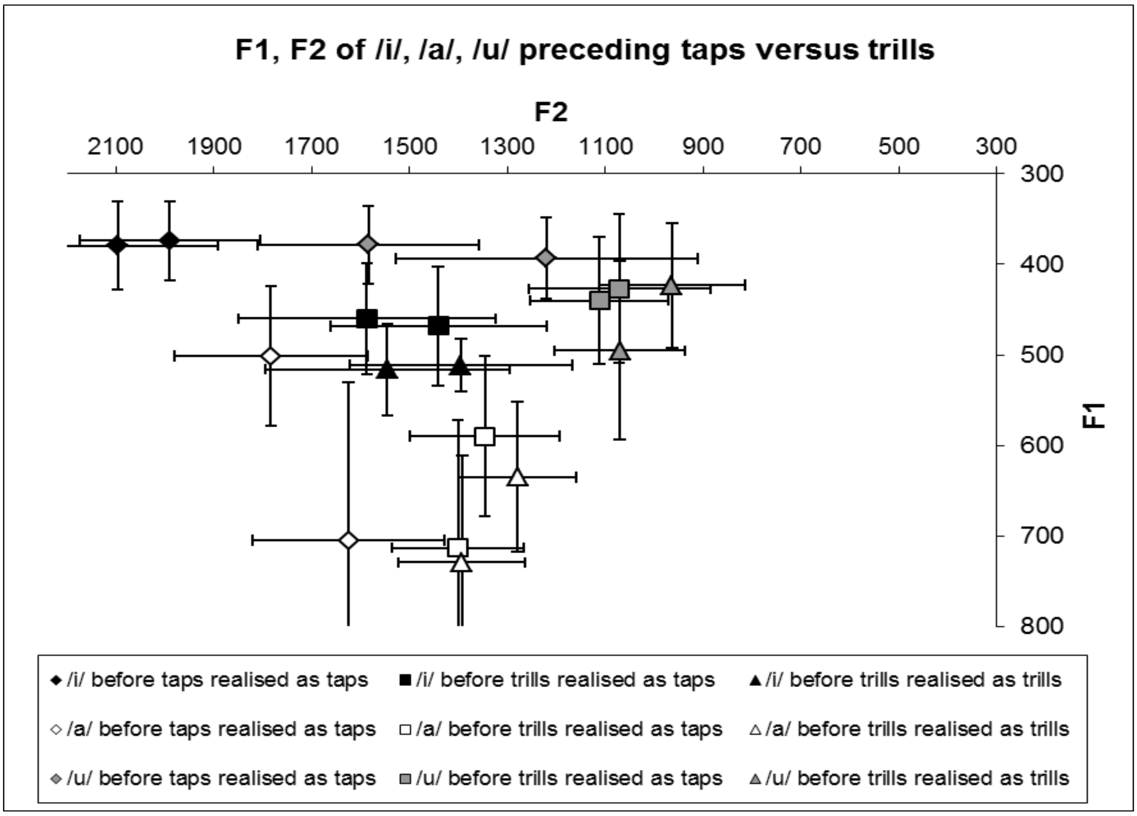


Fig.28 Average F1-F2 mid-point and offset values of /i/, /a/, /u/ preceding taps versus trills. The different shapes indicate the different realization of manner of articulation types and the three different colours within each category indicate the vowel type, i.e. /i/, /a/, /u/. Error bars=±1SD.

As shown in the figure above, /i/ preceding taps realised as taps had significantly lower F1 values and higher F2 values than /i/ preceding trills realised as taps and trills realised as trills at mid-point and offset. /ii/ and /u/ preceding taps realised as taps had significantly lower F1 and higher F2 mid-point and offset values than /ii/ and /u/ preceding trills realised as taps but had significantly lower F1 and higher F2 values only at offset than /ii/ and /u/ preceding trills realised as trills. /a/ preceding taps realised as taps had significantly lower F1 values than /a/ preceding trills realised as taps and trills realised as trills only at the offset. /a/ preceding taps realised as taps had significantly higher F2 values than /a/ preceding trills realised as taps and trills realised as trills both at mid-point and offset.

The long vowels /aa/ and /uu/ preceding taps realised as taps did not differ significantly in their F1 values from /aa/ and /uu/ preceding trills realised as taps and trills realised as trills. /aa/ preceding taps realised as taps had significantly higher F2 values at mid-point and offset than /aa/ preceding trills realised as taps but only higher F2 values at offset than /aa/ preceding trills realised as trills. /uu/ preceding taps realised as taps only had significantly higher F2 offset values than /uu/ preceding trills realised as taps but not /uu/ preceding trills realised as trills. Apart from /i/ and /ə/ at mid-point and /ii/ at offset, none of the other vowels in the data set differed in their F3 values depending on whether they preceded taps versus trill realisations (see fig.29 below). Almost all the vowels did not differ from each other in their F1, F2, F3 mid-point and offset values when preceding trills realised as taps versus preceding trills realised as trills, apart from the /i/ in its F1 mid-point values and /ə/ in its F1 mid-point and offset values (values being lower when /i/ and /ə/ preceded trills realised as taps versus when they preceded trills realised as trills).

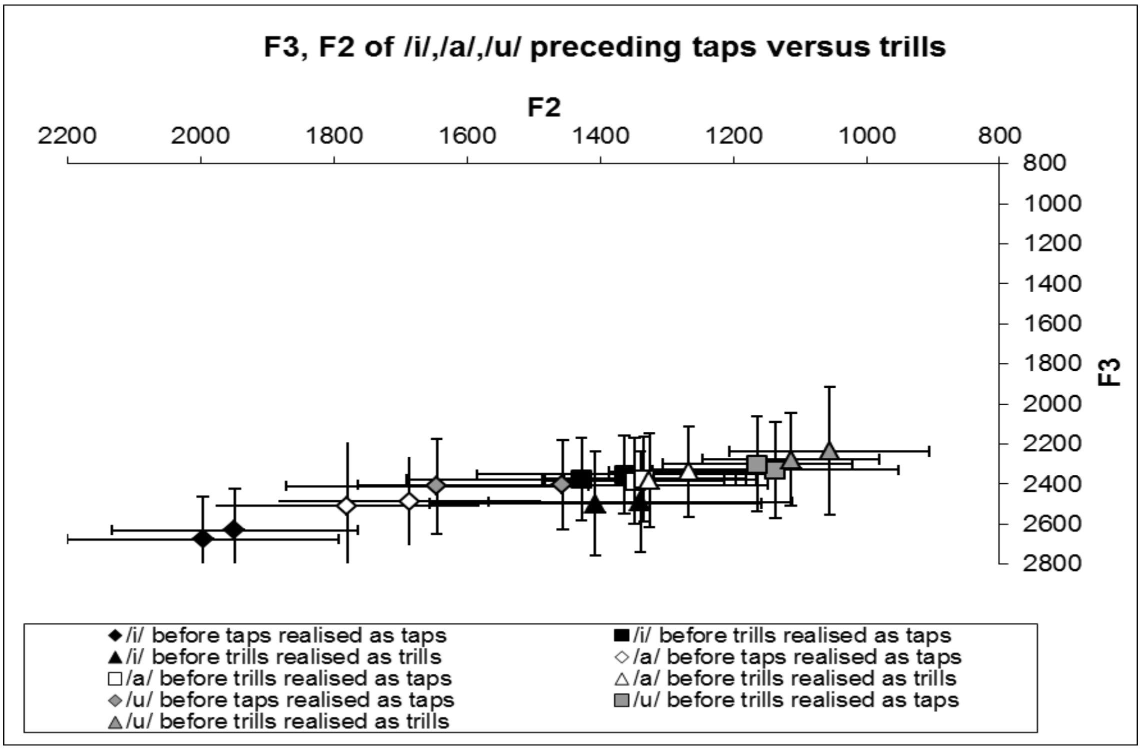


Fig.29 Average F3-F2 mid-point and offset values of /i/, /a/, /u/ preceding taps versus trills. The different shapes indicate the different realization of manner of articulation types and the three different colours within each category indicate the vowel type, i.e. /i/, /a/, /u/. Error bars=±1SD.

Following vowels

Two multi-variate ANOVA's (MANOVA) were conducted on the F1, F2 and F3 measures of the vowels following taps versus trills at onset and mid-point. There were three independent variables in the MANOVA's: Realisation of manner of articulation of the rhotic, word-position of the rhotic and vowel type. Using Wilk's Lambda, realisation of manner of articulation of the rhotic was found to have a significant effect on the formant patterns of the following vowels at onset and mid-point: λ=0.52, F (9, 1202.42) =40.44, $p<0.001$, $\omega^2 = 0.47$ at onset indicating a small effect size and λ=0.91, F (9, 1202.42) =5.28, $p<0.001$, $\omega^2 = 0.07$ at mid-point indicating a very small effect size. Using Wilk's statistic, word-position of the rhotic was found to have non-significant effect on the formant patterns of the following vowels at onset but a significant effect at mid-point: λ=0.99, F(3, 494)=2.01, $p>0.05$, ω^2 =0.004 and λ=0.95, F(3, 494)=9.24, $p<0.001$, ω^2 =0.044, indicating a very small effect size in both cases. Vowel type was found to be a significant factor that determined the formant patterns of the vowels following rhotics both at onset and mid-point: λ=0.45, F (27,1443.38)=16.62, $p<0.001$, and $\omega^2 = 0.52$ indicating a large effect size at onset and λ=0.23, F(27, 1443.38)=35.31, $p<0.001$, ω^2 =0.76 indicating a large effect size at mid-point too. The interactions between realisation of manner of articulation of the rhotic and word-position were found to be non-significant factors at onset and mid-point ($p>0.001$) and those between word-position and vowel type were also found to be non-significant at onset and mid-point ($p>0.001$). The interaction between realisation of manner of articulation of the rhotic and vowel type was found to be significant at the onsets but non-significant at the mid-points of the vowels following the rhotics: λ=0.88, F (30, 1450.66) =2.06, $p<0.001$, ω^2 =0.07 at onset and λ=0.91, F (30, 1450.66) =1.55, p.0.01, ω^2 =0.03 at mid-point. The ω^2 effect size measures indicated a medium-sized effect of this interaction at onset and a small effect size non-significant effect at mid-point. The interaction among realisation of manner of articulation and word-position of the rhotic and vowel type proved to be significant not at onset ($p>0.001$) but at mid-point, λ=0.95, F (9, 1202.42) =3.01, $p\leq0.001$, and ω^2 =0.03 indicating a small effect size.

The ANOVA's showed that realisation of manner of articulation had significant effects on the F1, F2 and F3 onset and F2 mid-point measures of the vowels following the rhotics ($p<0.001$) and a nearly significant effect on the F3 mid-point measures ($p=0.003$). The Bonferroni and Tukey post-hoc tests revealed that vowels following taps realised as taps (M=443.06, SD=73.45; M=543.47, SD=130.04) had significantly lower F1 onset and mid-point values than vowels following trills realised as taps (M=506.8, SD=84.22; M=571.73, SD=127.51) and trills realised as trills (M=530.75, SD=71.11; M=605.54, SD=118.85). Cohen's d values indicated that the effect size of the difference in F1 values between vowels following taps realised as taps and those following trills realised as taps were large at onset, d=-0.82, and small at mid-point, d=-0.22. Similarly, the effect size measures, Cohen's d values, indicated that the difference in F1 values between vowels following taps realised as taps and those following trills realised as trills were large at onset, d=-1.2, and small at mid-point, d=-0.49. Vowels following trills realised as taps and those following trills realised as trills did not differ significantly in their F1 patterns (see figs.30 on pg.121).

Vowels following taps realised as taps (M=1762.64, SD=231.03; M=1697.43, SD=349.05) were found to have significantly higher F2 onset and mid-point values than those following trills realised as taps (M=1366.5, SD=221.94; M=1523.41, SD=305.5) and those following trills realised as trills (M=1260.49, SD=167.35; M=1429.12, SD=285.05) (Fig. 30, pg.121). Cohen's d values of effect size indicated that the difference in F2 measures between vowels following taps realised as taps and those following trills realised as taps were large at onset, d=1.74, and moderate at mid-point, d=0.52. and the difference in F2 measures was found to have a large effect at both onset and mid-point between vowels following taps realised and taps and those following trills realised as trills: d=2.31 and d=0.8 respectively. The differences in F2 values between vowels following trills realised as taps and those following trills realised as trills were found to be significant at onset ($p<0.001$) and Cohen's d=0.52 indicating a moderate effect but the differences were not significant at mid-point ($p>0.01$) and d=0.31 indicating a small effect size.

Vowels following taps realised as taps (M=2516.48, SD=234.37; M=2535.08, SD=273.17) were found to have significantly higher F3 onset and mid-point values than vowels following trills realised as taps (M=2361.65, SD=214.43; M=2410.2, SD=216.16) and those following trills realised as trills (M=2348.74, SD=207.71; M=2389.91, SD=215.31) (Fig. 31, pg.122). Cohen's d values indicated that the F3 differences between vowels following taps realised as taps and those following trills realised as taps had a moderate effect size at onset, d=0.68, and a small effect size at mid-point, d=0.49. The F3 differences between vowels following taps realised as taps and those following trills realised as trills had a moderate effect size at onset and at mid-point, d=0.73 and d=0.56 respectively.

With regard to the effects of the second factor, vowel type, on the formant patterns of the vowels following taps versus trills, the trends were as follows

F1 onset & mid-point: /i/, /ii/, /u/, /uu/ < /e/, /ee/, /o/, /oo/ < /a/, /aa/

F2 onset: /aa/, /u/ < /a/, /o/, /oo/, /uu/ < /e/, /i/, /ee/, /ii/

F2 mid-point: /uu/, /oo/ < /u/, /o/, /aa/ < /a/ < /e/ < /ee/, /i/ < /ii/

F3 onset: /u/, /uu/, /o/, /oo/, /a/, /aa/ < /i/, /ii/, /e/, /ee/

F3 mid-point: /u/, /uu/, /aa/, /a/ < /e/ < /ee/, /i/, /ii/

As expected, both at onset and mid, the general trend was that F1 was inversely proportional to vowel height. As vowel height decreased, F1 values increased, i.e., in low vowels like /a/, F1 values were the highest as compared to high vowels like /i/ and /uu/ where F1 values were the lowest. F2 values of the vowels varied depending on whether they were back or front vowels. /uu/ had the lowest F2 being the most back vowel and /i/ had the highest F2 being the most front vowel and /aa/, /a/, /e/ and /ee/ had F2 values in between /u/ and /i/.

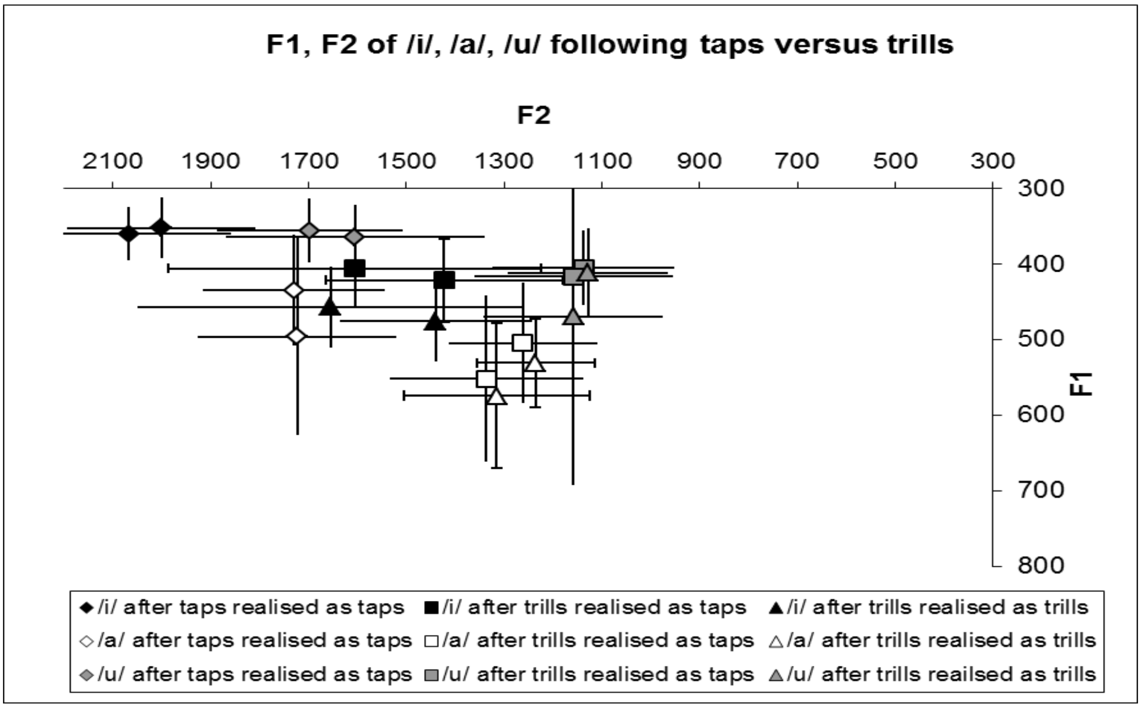


Fig.30 Average F1-F2 onset and mid-point values of /i/, /a/, /u/ following taps versus trills. The different shapes indicate the different realization of manner of articulation types and the three different colours within each category indicate the /i/, /a/, /u/. Error bars=±1SD.

The interaction between realisation of manner of articulation of the preceding consonant and vowel type was found to have a significant effect on the formant patterns of the following vowels. As shown in the figure above, /i/ and /a/ following taps realised as taps had significantly lower F1 and higher F2 values at onset and mid-point than /i/ and /a/ following trills realised as taps and trills realised as trills./u/ following taps realised as taps had significantly lower F1 mid-point values than /u/ following trills realised as taps and significantly lower F1 onset values than /u/ following trills realised as trills. /aa/ following taps realised as taps only had significantly lower F1 onset values than /aa/ following trills realised as trills and not /aa/ following trills realised as taps. However, /u/ and /aa/ following taps realised as taps had significantly higher F2 values than /u/ and /aa/ following trills realised as taps and trills realised as trills at onset and mid-point. /o/ seemed largely unaffected by whether it followed taps versus trill realisations except its F2 onset values which were significantly higher following taps realised as taps than following trills realised as trills.

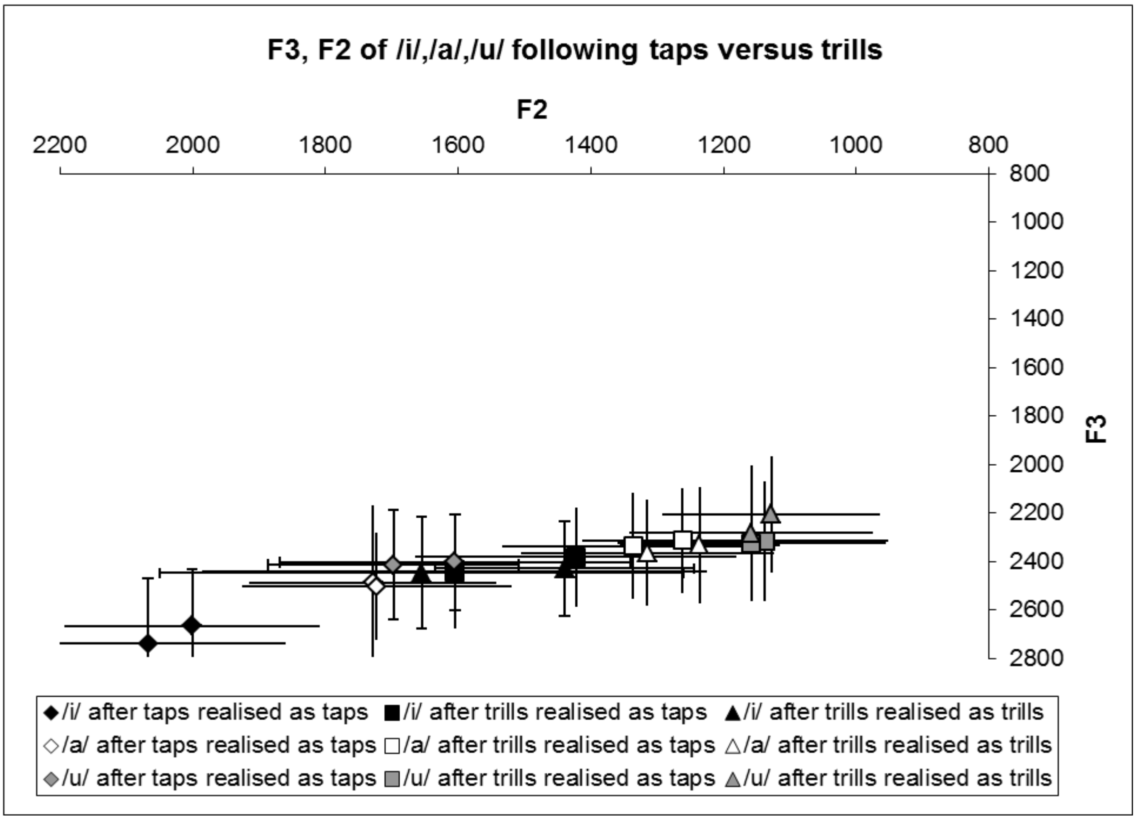


Fig.31 Average F3-F2 onset and mid-point values of /i/, /a/, /u/ following taps versus trills. The different shapes indicate the different realization of manner of articulation types and the three different colours within each category indicate the vowel type, i.e. /i/, /a/ , /u/. Error bars=±1SD.

F3 values of o/, /u/, and /aa/ at onset and mid-point were not affected by whether they followed tap versus trill realisations./a/ had significantly higher F3 onset and mid-point values when it followed taps realised as taps than when it followed trills realised as taps or trills realised as trills. /i/ following taps realised as taps had significantly lower F3 values than when following trills realised as taps but had higher F3 values only at mid-point than /i/ following trills realised as trills (see fig. 31 pg.122). None of the vowels' formant patterns, F1, F2 or F3, were affected by whether they followed trills realised as taps versus trills realised as trills apart from F2 onset values of /o/.

<u>Summary</u>

In general, word-initially and word-medially, realization of the manner of articulation had a significant effect on the formant patterns of the rhotics and the vowels preceding and following them. Not surprisingly, vowel quality also had a significant effect on the preceding and following vowels' formant patterns. The rhotics and the vowels surrounding them exhibited similar formant patterns: Taps realized as taps and vowels surrounding them had significantly lower F1 and higher F2 values than trills realized as taps and trills realized as trills and vowels surrounding them. In other words, the *target* taps (taps realized as taps) had lower F1 and higher F2 values than the *target* trills (trills realized as taps, trills realized as trills). F1 values seemed to be affected also by the *realisation* and target manner of articulation. In other words, while F1 values were lower for taps realised as taps as compared to trills realized as taps and trills realized as trills, F1 values were lower for trills *realized* as taps as opposed to trills *realized* as trills.

Vowel quality had the expected effects, i.e., F1 values increasing or decreasing depending on the height of the vowel: higher for more open, 'lower' vowels and lower values for more close, 'higher' vowels. F2 values were affected by the frontness or backness of the vowels: higher for fronter vowels and lower for back vowels.

Interaction between the realization of manner of articulation of the rhotic and vowel quality produced the following effects on the vowels surrounding the rhotics. Different vowel types were affected by the different realisations of manners of articulation of the rhotics differently. With respect to the preceding vowels, /ə/ (always the preceding vowel in the context of word-initial rhotics in the data set) and /i/ preceding taps realized as taps had significantly lower F1 and higher F2 values than /ə/ and /i/

preceding trills realised as taps and trills realised as trills. /ii/ and /u/ also showed the same patterns as /ə/ and /i/ except that they differed from /ii/ and /u/ preceding trills realised as trills only at the offset. /a/ was affected by manner of articulation of the rhotic that followed only at the offset and showed similar patterns as that of the other vowels: lower F1, higher F2 preceding taps realised as taps as opposed to when preceding trills realised as taps and trills realised as trills. Only the F2 values of /aa/ and /uu/ were affected by the manner of articulation of the rhotic that followed. /uu/ preceding taps realised as taps had higher F2 offset values than /uu/ preceding trills realised as taps but not trills realised as trills.

With respect to the following vowels, /i/ and /a/ following taps realised as taps had significantly lower F1, higher F2 values at onset and mid-point than /i/ and /a/ following trills realised as taps and trills realised as trills. /u/ and /aa/ had significantly lower F1, higher F2 values when they followed taps realised as taps than when they followed trills realised as taps and trills realised as trills but /u/ and /aa/ following taps realised as taps differed in their F1 values from /u/ and /aa/ following trills realised as trills only at the onset. /u/ following taps realised as taps differed in its F1 values from /u/ following trills realised as taps only at the mid-point. /o/ was largely unaffected by whether it followed tap or trill realisations.

This section described the auditory and acoustic results for the rhotics and their surrounding vowels in the present study produced by 8 male speakers of Malayalam. The auditory and acoustic results seem largely consistent with each other. The next section will interpret the above results from the auditory and acoustic analysis for the two laterals in Malayalam as produced by the 8 male speakers in this study.

4.2 Discussion I

This section aims to interpret the auditory and acoustic results obtained for the rhotics in the light of the research questions addressed in the current study and also in the light of broader phonetic issues relevant to recent research in the area. The auditory and acoustic analyses, both individually and in combination, gave rise to a wealth of information regarding the nature of the speakers' productions of taps and trills in Malayalam.

4.2.1 Auditory Analyses

The auditory analysis revealed that there was considerable variation in the realisations of target trills across-and-within-speakers, the latter mainly based on the word-position of the rhotic. Target taps on the other hand were always realised as taps by all speakers in both word-positions, initial and medial. Word-initially, where Malayalam does not have tap-trill minimal pairs, speakers produced a larger number of trill variants than in the intervocalic position where minimal pairs occur. Word-initially, speakers realised target trills as taps, trills or approximants whereas intervocalically speakers realised target trills as either taps or trills. Word-initially, only 3 out of 8 speakers produced a higher percentage of their target trills as trills whereas intervocalically, all the 8 speakers produced a higher percentage of their target trills as taps. The word-initial position seems to allow for more variation in number of trill variants produced by the speakers and also more variation between speakers with regard to the amount of trill versus non-trill variants produced than the intervocalic position. This could be due to the fact that this word-position does not have as significant a functional load as the intervocalic position in Malayalam since it is in the latter case that the two rhotics form minimal pairs. Another reason for the relatively greater degree of variation in the word-initial position as opposed to the intervocalic position between speakers and in terms of number of trill variants produced could be the nature of the task and elicitation style of the data in this study. The words in the data list were read as part of a carrier phrase. Depending on the varied individual reading styles, the length of the pause after the first word /avaɾoɖə/ and before the target word varied greatly. Some speakers paused for enough length of time so as to help induce aerodynamic vibration for the upcoming word-initial trill of the following word. Others read it continuously making the word-initial trill effectively a phrase-medial/intervocalic trill, which could have subsequently resulted in relatively lesser amount of time to produce the aerodynamically induced trill, resulting in fewer trill variants and more tap or approximant articulations instead. Intervocalically, the incidence of trill realisations was even less compared to the word-initial position. Jones (forthcoming) in his review of trill variability in 19 languages also found that trill realisations were relatively uncommon and made up only one third of all the /r/ instances (Jones forthcoming). He also observed that trills were rarer in connected speech instances in the data than the word-list instances or citation forms.

There were three main impressionistic findings: Firstly, target taps and target trills irrespective of their phonetic realisations differed from one another in that the latter was slightly further retracted and a more open articulation than the former. Secondly, apart from the difference in tongue body position of retracted (trills) versus fronted (taps), the two also differed in the nature of constriction. Irrespective of their realisations, target trills were produced ‘apical’, i.e. with the tip of the tongue making the constriction at the alveolar ridge, whereas target taps were produced ‘laminal’, i.e., with the blade of the tongue making the constriction. The former has a darker resonance while the latter has a clearer resonance. Thirdly, the vowels surrounding target trills and taps were systematically different from each other in that the vowels surrounding target trills were more open and back than those surrounding target taps. The above three findings seem to suggest that the speakers may vary the realisations of the manner of articulation of one of the two rhotics but keep the place of articulation (alveolar versus retracted alveolar), the tongue body position (fronted versus retracted) and the nature of constriction (laminal versus apical) consistently different between the two rhotics. The clear versus dark resonance difference between the two rhotics has been previously observed for other sound groups in Malayalam, namely the singleton-geminate lateral and nasal minimal pairs where the geminate is clearer and the singleton darker (Local and Simpson, 1999), and the dental-alveolar distinction (Dart and Nihalani, 1991). Therefore it could be the case that speakers of Malayalam use clear versus dark feature as an impressionistic device to differentiate between various groups of subtly different sounds. Alternatively, the clear versus dark feature could be a manifestation of the place of articulation differences and/or differences in tongue body positions between the tap-trill, geminate-singleton, and dental-alveolar sounds. The current results are also similar to those found by Simpson (1996) for Albanian rhotics, an alveolar tap and trill, which were also found to differ like the Malayalam rhotics, in their resonance: Clearer taps versus darker trills. Simpson does not mention a perceptible difference in place of articulation between the two rhotics and attributes the difference between the rhotics to differences in their ‘tongue configuration’. He describes tongue configuration as involving two separate articulatory processes associated with tongue body (advanced versus retracted) on the one hand and the front of the tongue (apical versus laminal).

Apical trills are by far the most frequently occurring trills in the languages of the world that have trills in their inventories since trills are more easily produced if the vibrating articulator has relatively small mass. Compared to other parts of the tongue, the tip has the smallest mass and hence apical trills are the most common trills found (Ladefoged and Maddieson, 1996). An apical articulation by virtue of its definition, i.e., tongue tip against the passive articulator, is a 'concave' configuration as opposed to a laminal articulation which is a 'convex' configuration (Simpson, 1996). In general, apico-alveolars have also been associated in the literature with the feature of 'retraction', i.e. a retracted tongue dorsum (Bhatt, 1974, Hamann, 2002). Hamann points out that X-ray tracings of apicals in Ladefoged and Maddieson (1996) and Butcher (1992) would suggest that apicals generally show a retracted tongue dorsum. There is however objection in the literature to this view (Stevens et al. 1986) that suggest that a fronted tongue body is more favourable for an apico-alveolar articulation. Nevertheless, combining the above facts, i.e., that the most common trills in the world's languages are apical trills, that apico-alveolar articulations perhaps favour a retracted tongue dorsum and also taking into account the similar results of the present study and the rhotics in Albanian in both of which the apico-alveolar trills have a 'dark' resonance, one could speculate that 'dark' resonance/velarization is the less marked feature and more favourable even, for production of apical trills. In other words, the preference in general for apical trills in the world's languages that have trills, the association of apicality with a retracted tongue dorsum combined with the latter's association with velarization/ 'dark' resonance, could be suggesting that 'velarization'/'dark resonance' is conducive to production of trills.

It is also clear from the auditory analysis results that apart from the differences between the two rhotics themselves, there were systematic differences between the vowels surrounding them that had a strong auditory effect, in fact, perhaps were more auditorily prominent than differences between the rhotic segments. The preceding vowels in anticipation of the following 'clear' tap or 'dark' trill were raised and closer or lowered and more open respectively. The following vowels also exhibited coarticulation, i.e. perseverative coarticulatory effects of the preceding 'clear' tap or 'dark' trill and were produced raised and closer or lowered and more open respectively. The coarticulatory effects of the clear tap versus dark trill, the anticipatory coarticulatory effects in particular, were auditorily perceptible even on the first consonant of the target words, most noticeably on velar consonants in the data set, for e.g. in words like /kara/, /kaRa/, kari/, /kaRi/, /kuRi/, etc. The /k/ in words such as these was fronted when followed further on by a clear tap and retracted when followed further on by a dark trill. An alternate view to the 'coarticulatory' effects of the tap versus trill, is Simpson's idea

(1996: 14-15) that these anticipatory and perseverative effects on surrounding sounds should perhaps be addressed as the phonetic exponents of the velarization of trills or the palatalization of taps (in this study) having greater temporal effect than the trill or tap itself. This alternate view of coarticulation forms part of the Firthian Prosodic Analysis dealt with in more detail in Chapter 1 (pg. 22) and chapter 7 (pg. 258).

4.2.2 Acoustic Characteristics

In the previous sub-section, results of the auditory analysis was discussed and interpreted in the context of similar work on other languages and previous work on Malayalam. This section will address the questions, issues and ideas emerging from the results of the acoustic analyses based mainly on observation of waveforms and spectrograms and two sets of measures, duration and formant frequencies.

Observing the spectrograms along with listening to the sounds revealed more detailed information about the nature of the speakers' tap and trill realisations. Although not as 'natural' as spontaneous speech, the use of carrier phrases to elicit data from speakers helped avoid the hyper articulation often associated with reading out citation forms and therefore was more natural than the latter. Results indicated that speakers were almost always producing 'tap approximants' instead of canonical taps and also produced non-canonical trills. In other words, even when a realisation sounded like a tap, the waveform and corresponding spectrogram showed the continuous formant structure of approximants and a reduced waveform of a tap, perhaps indicating a tap with an incomplete closure or a weak momentary closure (see fig.11 pg. 89 above). Similarly, although the incidence of trill realisations were fewer in general, in most instances where a realisation was categorised as being a perceptual 'trill', the waveform and spectrograms did not show a canonical trill with close and open phases repeated depending on the number of contacts. Instead there was an initial drop in waveform amplitude followed by a cluster of aperiodic spikes on the waveform and corresponding striations on the spectrogram with a fairly continuous formant structure (see figs. 13, 16 pgs. 90, 93 above). The occurrence of these non-canonical tap-trill realisations may be attributed to real speech rarely showing canonical versions of sounds, especially not in phrases (as opposed to words in isolation or even isolated sounds combined with the stringent articulatory requirements associated with the production of a trill and also the connected speech effect produced by reading out a carrier phrase.

Willis and Bradley (2008:94) found in their study of Dominican Spanish that nearly 50% of taps in the data set were reduced or lenited forms and the rest of the 50% were produced with measurable occlusions. The most common trill variants found in Dominican Spanish productions were a pre-breathy voiced tap, pre-breathy voiced trill, breathy-voice frication (Willis 2006;2007). Results similar to that of the present study were found in Jones' (forthcoming) review of trill variability in 19 languages. There was evidence, in sample dataset from many languages reviewed by Jones, of trills realised as 'tapproximants' (e.g. Polish), non-continuant taps (e.g. Bulgarian) and perceived as 'taps'. Jones points out however those languages reviewed in his study are those that only have a single rhotic contrast, unlike languages like Spanish that contrast between the taps and trills and hence the tap and approximant realisations he observed could be considered as patterns of allophonic variation due to qualitatively different production targets (2010:18). Languages which contrast taps and trills or have multiple rhotic contrasts were not included in Jones' review and hence the results from his review have been compared to general results from this study with caution as patterns of trill variability may be very different in languages that have single rhotic contrasts versus those that have tap-trill or multiple rhotic contrasts. In the present study, it has been difficult to say definitively whether the tap, 'tapproximant', approximant realisations of target trills are cases of trill weakening or trill failure or qualitatively different productions of /r/. Taking into account the observations of the spectrograms and waveforms together with the perceptual information from the auditory analysis, it seems unlikely that trill weakening or trill failure is the source of the tap, tap-approximant, approximant, and non-continuant tap realisations of target trills. It seems more likely that these realisations are the consequence of qualitatively different implementations of the trill. Nevertheless an articulatory study and an in-depth analysis of more data are needed before more conclusive remarks can be made in this regard.

4.2.2.1 Duration

Consonant Duration

Word-position and realisation of the manner of articulation of the rhotic were found to have significant effects on rhotic duration. Word-medial tap-trill realisations were found to be significantly shorter than word-initial tap-trill realisations. This difference in duration of the rhotic based on word-position could be due to the following reason. Trills in word-initial position in the current data set were preceded by the /ə/ of the first word /avaroɖə/ of the carrier phrase / avaroɖə __ en̪n̪ə parajuka/ and different speakers read out the carrier phrase differently, some pausing enough to create time to produce the word-initial trill often even hyper articulating it thereby lengthening the trill segment. Other speakers, instead of pausing before the trill, lengthened the /ə/ allowing enough time thereby to prepare for the upcoming trill. Word-medially, however, speakers would not be able to either pause before the rhotic without breaking the lexical item into meaningless sounds or lengthen the precede vowel which would alter the way the lexical item sounded. More importantly, the word-medial or intervocalic position is where Malayalam has lexical tap-trill minimal pairs so in effect there is less freedom to adjust the surrounding sounds to aid the production of trills and thereafter sustain it.

Word-initially, trills realised as taps and taps realised as taps were shorter than trills realised as trills. Word-medially, trills realised as taps were the shortest in duration followed by taps realised as taps both of which were shorter than trills realised as trills. Trills realised as taps were significantly shorter than taps realised as taps in this word-position with a medium-to-large effect size. In both word-positions, the durational difference between taps realised as taps and trills realised as trills was only found to reach 'near'-significance levels but effect size of these differences was found to be medium. This discrepancy between the non-significant 'p' value and medium effect size could be due to unequal sample sizes affecting the statistics. Nevertheless it brings to light the importance of calculating effect size alongside the 'p' value to obtain more accurate results. These results showed that realisation of the manner of articulation and not the target manner of articulation of the rhotic has a significant effect on its duration. This further implies that word-medially, where Malayalam has a lexical tap-trill minimal pairs, duration does not appear to be a cue speakers use to maintain the contrasts since the large majority of target trills were realised as taps by all speakers. Furthermore, trills realised as taps word-medially were significantly shorter than taps realised as taps which is opposite to what one might expect. If the target trills are not realised as trills and are realised as taps instead, then one might expect that these trills that are realised as taps would be 'longer' than the taps realised as taps keeping with the duration characteristics of their target manner of articulation. The shorter duration of trills realised as taps than taps realised as taps can perhaps be attributed to the apicality of the former versus the laminality of the latter. The trills realised as taps were produced apical and taps realised as taps were produced laminal and all other things being constant, it would be quicker to move the tip of the tongue towards the alveolar ridge than the blade which is slightly bigger in mass than the tongue tip.

In the one previous study on Malayalam rhotics by Srikumar and Reddy (1988), both rhotics in the language are described as being 'trills' and so the predictions regarding the duration of the two rhotics were different to those of the present study. They found no appreciable difference in duration between the two rhotics and claimed that the two were either equal in duration or the advanced rhotic (which is the *target* tap in this study) was longer than the retracted one (which is the *target* trill in this study). In the present study, one rhotic was always *realised* as an advanced lamino-alveolar tap whereas the large majority of the other rhotic was *realised* by all speakers in the study as a retracted apico-alveolar tap particularly in the intervocalic position. The most significant limitation of Srikumar and Reddy's study is that they do not take into consideration the difference between ***target*** manner of articulation and actual phonetic ***realisation*** of the manner of articulation. Their study is not only based on just one speaker who is Srikumar himself but their methodology involved reading a word-list in isolation, i.e. without the context of a carrier phrase. The productions were devoid of any influences from neighbouring words and were controlled for speech rate since it involved words in a word-list read in isolation and therefore most unlike spontaneous speech. Not surprisingly then, the reader assumes that all target trills were realised as trills in Srikumar and Reddy's study since there is no mention of any deviation from the target. It is highly unlikely if not impossible that trills, which are known to be highly variable sounds, due to the stringent conditions required to successfully produce them, are always realised as trills in natural speech. As shown in this study, the actual realisation of manner of articulation of the rhotics has a significant effect on their duration in Malayalam. It is therefore imperative to gauge the relationship between the target and actual phonetic realisation, number, type and frequency of variants produced by speakers and their individual effects on auditory impressions and acoustic measures, in order to understand the real picture behind the nature of speakers' productions.

Research on other languages that have contrastive tap-trill pairs such as Spanish also presents an inconclusive picture with regard to duration as an acoustic cue used to maintain tap-trill contrast. Also note several varieties of Spanish are spoken in different parts of the world, e.g. Spanish spoken in Europe (Peninsular Spanish) and Spanish spoken in the Americas (Mexican Spanish, Puerto Rican Spanish, Dominican Spanish) to name a few. Therefore it is imperative that the there is some variety in the way that tap-trill contrasts are maintained in these different varieties. Even within research on the same varieties, there have been contradictions in the results obtained. For instance, while Hammond (1999) claims that the tap-trill contrasts in many dialects of Spanish is neutralized, others like Willis and Bradley (2008) showed in their study of Dominican Spanish that not only are tap-trill contrasts maintained but that duration is a major cue used to maintain the rhotic contrasts with the trills being almost thrice as long as the taps,. Henrikson and Willis (2010) in their study on Jerezano Andalusian Spanish found that irrespective of whether the trills were realised as canonical trills or not, all their durations were still much longer than the average duration of Spanish taps mentioned in the literature (20ms cf.: Willis and Bradley, 2008; Martinez Celdran & Rallo, 1995 and Quilis, 1993 cited in Henrikson and Willis, 2010). These results are opposite to the results of the present study where the realisation of the manner of articulation of the rhotics determines their duration. Target trills realised as taps were shorter in duration than target taps realised as taps while target trills realised as trills were longer than both target taps realised as taps and target trills realised as taps. Although some studies on Spanish like Hammond (1999) question the maintenance of tap-trill contrasts in several Spanish dialects and suspect tap-trill neutralization, by and large, a large majority of the work in the area seems to suggest the rhotic contrasts are maintained and that duration is perhaps the most consistent cue in this contrast maintenance. As discussed above, in Malayalam, duration does not appear to be a significant cue in contrast maintenance between the two rhotics.

Preceding vowel duration

For word-initial rhotics in the data set, the preceding vowel context was always a /ə/ since the preceding vowel was always the final vowel of the preceding word /ə/. The duration of /ə/ preceding target trills realised as trills was longer than /ə/ preceding taps realised as taps and trills realised as taps but both differences were not found to reach significance levels. The duration of /ə/ preceding taps realised as taps and that of /ə/ preceding trills realised as taps was almost the same. Although not statistically significant, realisation of the manner of articulation of the rhotic was found to affect the duration of the rhotic: longer before trill realisations (trills realised as trills) and shorter before tap realisations (taps realised as taps and trills realised as taps). The author acknowledges, however, that the results for duration of /ə/ word-initially could perhaps be skewed since the reading style varied across the 8 speakers and while some paused after the /ə/ and before the next target word containing the /ə/, others lengthened the /ə/ to prepare for the upcoming trill.

Word-medially, the target and realisation of the manner of articulation of the rhotic were not found to have any significant effect on the duration of its preceding vowel. The duration of the vowels did not appear to differ significantly based on whether they preceded target taps or target trills, or, trill realisations or tap realisations. These results are different from those obtained by Srikumar and Reddy (1988) who found that vowels preceding the retracted rhotic were shorter than those preceding its advanced counterpart. In the present study, only the vowel quality of the preceding vowels was found to have a significant effect on its duration. /u/ had the shortest duration among the short vowels and /a/ the longest with /i/ and /o/ having mean duration values in between that of /u/ and /a/. These results for /u/, /i/ and /a/ mirror those found by Srikumar and Reddy (1988). The pattern was similar among the long vowels with /uu/ being the shortest and /aa/ the longest. Therefore, according to the results of the present study, duration of the vowels preceding the two rhotics does not appear to be a distinguishing cue between the rhotics.

4.2.2.2 Formant Frequencies

Rhotics

The target manner of articulation of the rhotic was found to have significant effects on formant frequencies of the rhotics. F1, F2, and F3 frequencies of the rhotics were determined by their target manner of articulation and only their F1 frequencies appear to be determined by both target and actual realisation of the manner of articulation. Target taps (taps realised as taps) were found to have significantly lower F1, higher F2 and higher F3 than target trills (trills realised as taps and trills realised as trills).

The lower F1 indicates a small jaw opening and a larger back cavity created by a relatively front constriction and the higher F2 indicates a raised tongue body and thereby a clear resonance. The higher F3 could also be suggestive of a relatively fronter place of articulation. In other words target taps seem to be fronter and more raised with a clearer resonance than target trills which seem to be retracted and more open with a darker resonance.

F1 frequencies were found to be affected by the realisation of the manner of articulation of the rhotic too. There was a significant three way contrast in F1 frequencies among taps realised as taps, trills realised as taps and trills realised as trills with F1 frequency measures being the lowest for taps realised as taps and the highest for trills realised as trills. Trills realised as taps had F1 values in between the other two groups, i.e. higher F1 values than taps realised as taps and lower F1 values than trills realised as trills. F1 is often associated with the nature and size of the constriction involved in an articulation and therefore a cue to the manner of articulation of a sound. F2 and F3 are associated mostly with the place of articulation and tongue configuration. Here F2 and F3 do not appear to be affected by the realisation of the manner of articulation of the rhotics and instead appear to be determined only by the target manner of articulation. Also note that irrespective of their realisations, target taps were always produced lamino-alveolar and target trills were produced apico-alveolar and so what may seem like the effect of the 'target manner of articulation' on the F2, F3 values of the rhotics may actually be the effect of the place of articulation differences between the target taps and trills. The acoustic differences between the two rhotics, low F1, high F2, and higher F3 of the taps versus the high F1, low F2, and lower F3 of the trills confirm the auditory analysis results of this study that the taps sound more close, clearer and more advanced as opposed to the trills that sound more open, darker and more retracted. The results of the present study will now be compared with results from similar studies.

Srikumar and Reddy's description of the acoustic characteristics of the two rhotics in Malayalam is unclear: "While /r/ exhibits no formants on the spectrogram representing its articulation indicating a complete closure without any interruption as simple tap /r̠/ exhibits formants"(1988:46). Does this mean /r/ was realised more like a tap produced with a complete closure and thereby showed no formants on the spectrogram? If yes, then why is there no other mention of the different realisations of target trills in the study? How many target trills were realised as taps or any other variants? Since their study approached both rhotics as ‘trills’, did tokens of both have trill and non-trilled variants? The spectrogram of /ṟ/ in their study (which is what is equivalent to the target trill in this study) is also said to show two or three low frequency formants below 2100 Hz and spectrograms of /r/ are said to show a brief but marked interruption in its formant structure. In the present study, the target trill (equivalent to what is described as /ṟ/ in Srikumar and Reddy’s study) showed two or three low frequency formants below 2350 Hz. Spectrograms of the target tap (equivalent to /r/ in Srikumar and Reddy’s study) in this study showed no marked interruption in its formant structure and instead were characterised by reduction in waveform amplitude and a relatively continuous formant structure similar to that of approximants perhaps indicating an incomplete closure. This difference in the formant structure of the rhotics between the two studies can be mainly attributed to the data elicited from speakers. In Srikumar and Reddy’s study, the data consisted of single words read out by Srikumar himself devoid of influences by neighbouring words and controlled for speech rate thereby producing more textbook-like trills and taps whereas in the present study the target words were read out as part of a carrier phrase by eight speakers unaware of the specific objectives of the research carried out and not controlled for speech rate. It is no surprise then that in the present study; speakers produced taps and trills with incomplete closures owing to the carrier phrase context which was designed to enable a mode of data elicitation closer to spontaneous speech than isolated words produced in a more controlled setting.

Srikumar and Reddy’s study suggests that the formant structure of the more retracted trill in Malayalam varies depending on the immediate vowel context or quality: It is slightly fronter and opener before front vowels. Analyses of the spectrograms of the target trill productions (most of which were realised as taps) in the present study also revealed that the trills tend to be slightly fronter (F2 higher, F3 appears slightly higher) before front vowels. The significance of these values however has not been tested. The above observation is merely a qualitative observation of the difference in formant structure on the spectrograms of trills in front versus back vowel contexts. Quantitative analyses have not been conducted on the effects of the surrounding vowels on the taps and trills.

. The distinct formant features of the two rhotics in Malayalam shown in the present study are different from the patterns found in Tamil. Firstly, the literature is inconclusive regarding the phonetic characteristics of the two rhotics in Tamil. While some have referred to the two as ‘post-alveolar taps’ intervocalically and trills and flaps in free variation word-initially (Balasubramanian, 1982a; 1982b), others more recently have described one as ‘pre-alveolar’ and the other as ‘post-alveolar (Narayanan, et al., 1996); and the manner of articulations although not explicitly mentioned the reader could assume are trills mainly due to the use of the trill symbol /r/ but several authors use /r/ as a general symbol for any ‘r’ sound so Narayanan, et al’s study is unclear about their stand on the manner of articulation of these rhotics. Irrespective of the different terms used to describe the targets, the results of both studies showed that the realisations of both rhotics show little or no difference between each other. Narayanan, et al. found that the acoustic characteristics of the two rhotics in Tamil were similar to one another except for a slight difference in F3 values: higher for the post-alveolar than pre-alveolar rhotic by an average of about 100Hz. Results of McDonough & Johnson’s (1997) articulatory and acoustic study of the liquids in the Brahmin dialect of Tamil were similar to that of Narayanan et al. Although the former preferred to analyse the two rhotics in Tamil as an alveolar flap and retroflex flap, the spectrograms of each of the two rhotics revealed that their F1 and F2 formant structures were the same and the only difference was in their F3 transitions, which is similar to the results found by the latter. What Narayanan et al. called the ‘post-alveolar’ rhotic or what McDonough & Johnson referred to as the retroflex flap both showed a huge lowering of F3 from halfway into the preceding vowel as compared to the relatively steady low F3 of the ‘pre-alveolar’ rhotic or the ‘alveolar flap’ respectively. These results are completely different from the results of the present study where more distinct formant structures were exhibited by the two rhotics where they differed in their F1, F2 and F3 values: Lower F1, higher F2, and higher F3 for the advanced rhotic versus higher F1, lower F2, and lower F3 for the other more retracted rhotic.

Simpson’s study of the Albanian liquids (1996) does not elaborate on the contrastive formant structure of the rhotic segments themselves apart from a brief mention of the sharp drop in F3 and F4 of the tap as evidence of its alveolar stricture. Nevertheless, from the figures of tap and trill tokens in his data, the F1-F2 patterns of the tap versus trill appear to be similar to the results of the present study. The clear tap has a relatively lower F1 and rising F2 as opposed to the higher F1 and steady, lower F2 of the darker trill tokens.F3 patterns appear to be in the same range for both taps and trills. There are neither any formant frequency measures given, nor any mention of statistical tests carried out to validate significance of differences between the acoustic patterns for the two rhotics. Therefore it is difficult to draw a direct and more comprehensive comparison between Simpson's study and the present one.

The present study, unlike previous studies on Malayalam rhotics, is based on more than one speaker and the data elicited did not involve citation forms and instead involved reading out target words in carrier phrases. Results suggest that with respect to maintenance of contrast between the two rhotics, whether they are realised as taps or trills may have lesser role to play than other dimensions such as fronted alveolar versus retracted alveolar and laminal versus apical etc. Contrast maintenance and the different dimensions of contrast among the liquids in Malayalam will be dealt with in more detail in the general discussion in chapter 7.

<u>Surrounding Vowels</u>

The preceding vowel context for word-initial rhotics in the data set was always /ə/ since that was the final vowel of the word preceding the target word in the carrier phrase /avaɾoɖə __ en̪n̪ə parajuka/. The vowel types varied for the word-medial rhotics. Realisation of manner of articulation of the following rhotic and in the word-medial position vowel type were found to have a significant effects on the F1 and F2 mid-point and offset values of vowels preceding tap and trill realisations. Short vowels /ə/, /i/, /a/ preceding taps realised as taps had lower F1 values than /ə/, /i/, /a/ preceding trills realised as taps and trills realised as trills. /ə/, /i/ preceding trills realised as taps had lower F1 values than /ə/, /i/ preceding trills realised as trills./u/ and /ii/ showed similar patterns to those of the other short vowels except that /u/, /ii/ preceding taps realised as taps had significantly lower F1, higher F2 values than /u/ preceding trills realised as trills only at offset. Among the long vowels, F1 values of only /ii/ were significantly affected by whether it preceded taps realised as taps versus trills realised as taps or trills realised as trills. Only the F2 values of the other long vowels, /aa/ and /uu/ were significantly influenced by whether they preceded taps realised as taps versus trills realised as taps or trills realised as trills and also the influence was significant mainly at the offset.

In general these patterns seem to suggest that vowels tend to be more close and advanced before taps realised as taps and more open and retracted before trills realised as taps and trills realised as trills. Apart from /ə/ and /i/ which were slightly more open before trills realised as trills than before trills realised as taps, the other vowels in the data set do not seem to differ significantly between when they precede trills realised as taps versus when they precede trills realised as trills. This then implies that it is the target manner of articulation of the rhotics that has the most significant effects on their preceding vowels' quality: Close and advanced before target taps versus open and retracted before target trills. These results from the acoustic analyses are also consisted with the author's auditory impressions during auditory analysis.

The coarticulatory effects of the manner of articulation of the rhotics on their preceding vowels appear to spread to the offset and also the mid-point for all the short vowels and only to the offset for the long vowels. The longer duration of the /ii/, /aa/ and /uu/ compared to /i/, /a/, /u/ may be inhibiting the coarticulatory effects of the rhotics that follow to only the offset. Or it could be that the anticipatory preparations for the production of the following rhotic need not begin at the mid-point for /ii/, /aa/ and /uu/ since they are long in duration and therefore the coarticulatory effects do not appear until later. Also note that in the case of the longer vowels apart from /ii/, it is mainly the F2 values that are significantly influenced by the presence of the following tap versus trill whereas in the case of the shorter vowels, both F1 and F2 values are affected. This might then suggest that F2 is the most robust acoustic cue in terms of vowel quality differences between tap and trill minimal pairs.

With respect to the following vowels, the pattern was largely similar to those exhibited by preceding vowels. /i/ and /a/ following taps realised as taps had lower F1 and higher F2 values than /i/, /a/ following trills realised as taps and trills realised as trills at onset and mid-point. /u/ following taps realised as taps had lower F1 mid-point values than /u/ following trills realised as taps and lower F1 onset values than trills realised as trills. /u/ following taps realised as taps had higher F2 values at onset and mid-point than /u/ following trills realised as taps and trills realised as trills. The only long vowel in the following vowel context in the data set was /aa/. /aa/ following taps realised as taps had higher F2 onset and mid-point values than /aa/ following trills realised as taps and trills realised as trills. /aa/ following taps realised as taps had lower F1 onset values than /aa/ following trills realised as trills.

In general, vowels following taps realised as taps tend to be close and more advanced than those following trills realised as taps and trills realised as trills. This pattern is similar to that exhibited by the vowels preceding the two rhotics. As was the case with the preceding vowels, it seems to be that the most consistent acoustic cue differentiating quality of vowels following tap versus trill sequences is the F2. While the F1 and F2 of the short vowels tend to be affected by the nature of the surrounding rhotic, it is mainly the F2 of the long vowels that tend to be affected by the surrounding rhotic. The acoustic results appear to be also largely consistent with the author's auditory analysis of surrounding vowel quality differences in the context of tap versus trill sequences in Malayalam. The next part of this section will compare the results of the present study with those of previous studies in Malayalam and similar studies in other languages.

In his study of Albanian liquids, Simpson (1996) found that open vowels before and after the dark trill were more retracted than before the clear tap which was also consistent with his impressionistic observations. But he also found that close vowels before and after the dark trill were more open and advanced than they were before the clear tap and this result was not consistent with his impressionistic observations that vowels surrounding the clear taps sounded further forward than the same vowels surrounding the dark trills. These results are different from those of the present study in that the current findings suggest that in general both close and open vowels surrounding clear taps were produced closer and further forward than those surrounding dark trills. Simpson only measured formant frequencies of vowel portions at the mid-point and perhaps measuring the formant frequencies at more than one point might have revealed a different picture. In the present study, measurements were made at the mid-point and offset of preceding vowels and onset and mid-point of the following vowels thus enabling a more dynamic view of the formant transitions occurring during the course of a vowel portion. Also there is no mention of any statistical tests conducted to validate the significance of the differences in formant frequencies observed between the rhotics of their surrounding vowels in Simpson's study.

Srikumar and Reddy found in their study that in Malayalam, the close vowels tend to be more open before the advanced rhotic than the retracted one whereas the open vowels showed the opposite pattern. They also found that /a/ and /i/ following the advanced rhotic were more open than /a/ and /i/ following the retracted rhotic see tables 11 and 13 below). In the present study, however, all the short vowels, irrespective of whether they were close or open, were closer before the more advanced rhotic (which is the target tap in this study) and more open before the more retracted rhotic (which is the target trill in this study). Among the long vowels, although the F1 values of /uu/ were not found to differ significantly based on whether it preceded tap or trill realisations unlike the short vowels, it was also not found to show the opposite patterns to that shown by the open vowels like /a/, /aa/ etc. As shown in the tables 10 and 11 below, note that the standard deviation values for the F1 frequencies were high in the present study and therefore there was considerable overlap between the values for the different rhotics across the eight speakers. There was no mention of any statistical tests done in Srikumar and Reddy's study to check for the significance of the differences they found between the two rhotics and so it is difficult to fully assess the strength of the differences reported by them between vowels surrounding the two rhotics. However the results of the present study and that done by Srikumar and Reddy (1988) had certain similarities in that both found that all vowels were fronter before the advanced rhotic and retracted before the retracted rhotic which was expected as a consequence of the consonantal place of articulation.

		Taps realised as taps		Trills realised as taps		Trills realised as trills	
		Mean	SD	Mean	SD	Mean	SD
/a/	F1 mid	705	88	713	49	729	7
	F1 offset	561	62	590	61	635	7
/i/	F1 mid	379	57	460	63	516	6
	F1 offset	373	46	468	72	511	3
/uu/	F1 mid	362	38	397	65	404	5
	F1 offset	398	49	454	85	431	1
/a/	F2 mid	1625	171	1401	91	1322	7
	F2 offset	1783	197	1346	145	1279	8
/i/	F2 mid	2097	165	1587	224	1345	25
	F2 offset	1990	175	1412	248	1395	27
/uu/	F2 mid	943	145	876	148	1003	5
	F2 offset	1522	203	1029	166	1165	1

Table 10. F1-F2 mid-point and offset values of /a/, /i/ and /uu/ preceding target taps versus target trills in word-medial position in the present study.

		advanced trill	retracted trill
F1	/a/	700	740
	/i/	560	520
	/uu/	500	400
F2	/a/	1875	1525
	/i/	2250	2250
	/uu/	1000	900

Table 11. Formant values given in Srikumar and Reddy (1988:48) of /a/,/i/, /uu/ preceding the two rhotics in Malayalam. The advanced 'trill' they refer to is what is referred to in the present study as target taps and the retracted trill is referred to as target trills in the present study.

		Target taps realised as taps		Target trills realised as taps		Target trills realised as trills	
		Mean	SD	Mean	SD	Mean	SD
/a/	F1 onset	475	63	563	59	537	[illegible]
	F1 mid	655	90	650	64	640	[illegible]
/i/	F1 onset	353	41	421	47	403	[illegible]
	F1 mid	322	43	467	37	430	[illegible]
/a/	F2 onset	1765	192	1317	134	1235	[illegible]
	F2 mid	1724	233	1451	201	1125	[illegible]
/i/	F2 onset	2052	165	1613	205	1597	[illegible]
	F2 mid	2134	109	1833	222	2083	[illegible]

Table 12. F1-F2 onset and mid-point values of /a/, /i/ following target taps versus target trills in word-medial position in the present study.

		advanced trill	retracted trill
F1	/a/	760	700
	/i/	625	600
F2	/a/	1890	1450
	/i/	2375	1625

Table 13. Formant values given in Srikumar and Reddy (1988:48) of /a/,/i/ following the two rhotics in Malayalam. The advanced ‘trill’ they refer to is what is referred to in the present study as target taps and the retracted trill is equivalent to ‘target trills’ in the present study.

The differences in range of values obtained and the patterns observed in both studies as shown in the tables 10-13 above could be due to a variety of reasons namely the differences in methodology of the two studies, i.e., number and type of participants used, nature of data, classification of results and different analytical methods etc. While Srikumar and Reddy’s study was based on Srikumar reading out citation forms of words containing one or the other rhotic in Malayalam with no mention of any variation in the realisation of the target articulations, the present study was based on productions from eight speakers reading out carrier phrases containing the target articulations and took into account the variation in the number and type of realisations of the target articulations.

Comparing Tables 10 and 12, results suggest that /a/ has lower F1 and higher F2 when following the taps than preceding it. The F2 of /a/ rises from mid-point to offset when it precedes taps and remains steadily high when it follows taps. This may be due to the carry-over effects of the tap being stronger than its anticipatory effects on /a/. With respect to /i/ on the other hand, F2 values seem to decrease slightly from mid-point to offset when it precedes taps while it increases slightly from onset to mid-point when it follows taps. This balanced, small rise and fall in F2 in /i/ preceding and following the taps respectively might be indicative of /i/ being more resistant to coarticulatory effects of the tap than /a/ due to lack of any articulatory conflict between the production requirements for /i/ and /ɾ/ since both are front and raised articulations.

Both /a/ and /i/ had higher F1 values when preceding the trill than when following it suggesting that /a/ and /i/ were more open when preceding the trill than when following it. The coarticulatory effects of the trill on F1 values appear to begin later and end earlier for /a/ while it appears to begin earlier and end later for /i/. F2 values of /a/ remain fairly low and steady when preceding and following the trill whereas those of /i/ were significantly lower when /i/ preceded rather than when it followed the trill. The rise in F2 of /i/ following the trill from onset to mid-point is significantly more than the fall in F2 of /i/ preceding the trill from mid-point to offset. This might suggest that the trill had stronger anticipatory effects on the F2 of /i/ than carry-over effects.

To summarize, the coarticulatory effects of the trill appear to be last longer on /i/ than /a/ perhaps due to the contradictory articulatory gestures involved in the production of /i/ and /r/. The anticipatory effects of the trill were found to be stronger than its carry-over effects. The opposite appears to be true for taps. The coarticulatory effects of the tap appear to be more marked for /a/ than /i/ and carry-over effects of the tap seem stronger than its anticipatory effects. These patterns fit well with the notion in previous research on coarticulation that coarticulatory effects are strongly dependent on contrasting articulatory constraints for adjacent phonemes (Recasens, 1987; Farnetani & Recasens, 1993 etc.). However the patterns observed in the present study are preliminary and based only on relative differences in formant frequencies of /a/ and /i/ between mid-point and offset when they precede taps and trills, and, between onset and mid-point when they follow taps and trills. No proper measures of coarticulation like duration of transitions, slope, etc. were made since it was beyond the scope of the present study and therefore the patterns observed above are inconclusive.

Trill Fragments

Traditional Dravidian grammarians differentiated between trills occurring in the word-initial position and intervocalic position on the one hand and those occurring word-medially in a post-vocalic pre-consonantal position and word-finally in a post-vocalic position on the other hand. Trills occurring in the latter environments are referred to as ‘fragments’ (Pillai, 1996). The alveolar lateral and retroflex lateral in Malayalam also occur in the same environments and hence are then called lateral fragments which will be dealt with in the next chapter on laterals. In order to test whether there is a phonetic basis for justifying a separate classification of trills occurring in these environments, the data set for the present study included these ‘fragment’ tokens and were auditorily and acoustically analysed individually and in comparison with the regular trills or non-fragmental trills

Auditorily there were two types of realisations that speakers produced for trill fragments: Taps and trills. A large majority of all speakers’ word-medial trill fragments were realised as trills whereas there was much more inter-speaker variation with respect to the realisation of word-final trill fragments. Intervocalic non-fragmental trills were largely realised as taps and very few were realised as trills. Trill fragments realised as taps sounded like the tap realised as taps and trills realised as taps in the data set and the trill fragments realised as trills sounded like the trills realised as trills but often sounded like a trill followed by a short vocalic element. The production of a short vocalic element as part of the trill realisations of trill fragments may be to sustain the voicing of the trill and thereby strengthen the percept of a trill especially in the word-medial case since the fragment is followed by a another consonant (plosive/fricative/affricate).

Although perceptually trill fragments realised as taps sounded like regular taps and those realised as trills sounded like regular trills, spectrograms of trill fragments realised as taps showed a reduced waveform amplitude and a relatively continuous formant structure like that of approximants perhaps indicating a tap with an weak or incomplete closure. Spectrograms of trill fragments realised as trills showed an initial reduction in waveform amplitude followed by a cluster of bursts in the waveform and corresponding vertical striations in the spectrogram which maybe denoting the number of contacts (see fig.15, pg. 92 above).

Acoustic analyses results revealed the following: With respect to duration measures, realisation of the manner of articulation of the trill fragments had a significant effect. Trill fragments realised as taps were shorter than trill fragments realised as trills word-medially and word-finally. The word-medial position is the word-position common to trill fragments and regular trills and results revealed that trills realised as taps had the shortest duration followed by trill fragments realised as taps and trills realised as trills which were interestingly not significantly different from each other. Trill fragments realised as trills had the longest duration and was significantly longer in duration than trills realised as trills. All durational differences were of medium-to-large or large sized effects.

With respect to the formant frequencies, only the F1 values of the trills and trill fragments were found to be significantly affected by the realisation of the manner of articulation of the rhotics. Trills realised as taps did not differ significantly from trill fragments realised as taps and trills realised as trills did not differ significantly from trill fragments realised as trills. Trill fragments realised as taps were found to have significantly lower F1 values than trill fragments realised as trills and trills realised as trills. Trills realised as taps also had significantly lower F1 values than trill fragments realised as trills and trills realised as trills. Trills realised as taps did NOT differ significantly from trill fragments realised as taps in their formant values. Trills realised as trills also did NOT differ significantly from trill fragments realised as trills. In other words, the difference in formant values, in this case, only the F1 values, between target trills and target trill fragments was only based on whether they were realised as taps or trills. Irrespective of whether the target articulation was a regular trill or trill fragment, if it was realised as a tap, F1 values were significantly lower than if it was realised as a trill..

It appears to be the case therefore that trill fragments did not sound different from regular trills and did not differ in their formant patterns. The only acoustic difference between trill fragments and regular trills was in their duration ranging from trills realised as taps being the shortest to trill fragments realised as trills being the longest. Trills realised as taps < trill fragments realised as taps, trills realised as trills < trill fragments realised as trills. Another difference between the trill fragments and regular trills was in the higher incidence of trill realisations among productions of trill fragments than regular target trills. This might have more to do with the phonotactic environment in which word-medial trill fragments occur, i.e., post-vocalic and pre-consonantal context. Jones (forthcoming) in his review of trill productions in 19 single rhotic languages, although cautious about generalising results based on an ‘uncontrolled and unbalanced’ sample, seems to suggest that trill production is favoured more in consonantal contexts particularly in codas. He attributes the higher incidence of trill realisations in V_C context in the data sample he reviewed to the lesser degree of articulatory constriction often associated with coda consonants which maybe promoting the conditions required for successful trill production. Also, presumably, the perceptual salience of a consonant in a post-vocalic and pre-consonantal context is strengthened if the trill is realised as a trill and not a tap since the latter is a weaker articulation and more prone to lenition.

Summary

Auditory analysis results suggest that while all taps by all speakers were realised as taps, trills were largely realised as taps by most speakers. Irrespective of the realisation, all target trills were produced apical and retracted whereas target taps were produced laminal and fronted. The trills had a darker resonance while the taps had a clearer resonance. As shown in figs. 32 and 33 below, vowels surrounding target trills were more open and retracted whereas those surrounding target taps were raised and advanced. These results were confirmed in the acoustic analyses which showed a higher F1, lower F2 for trills and their surrounding vowels versus a lower F1, higher F2 for taps and their surrounding vowels.

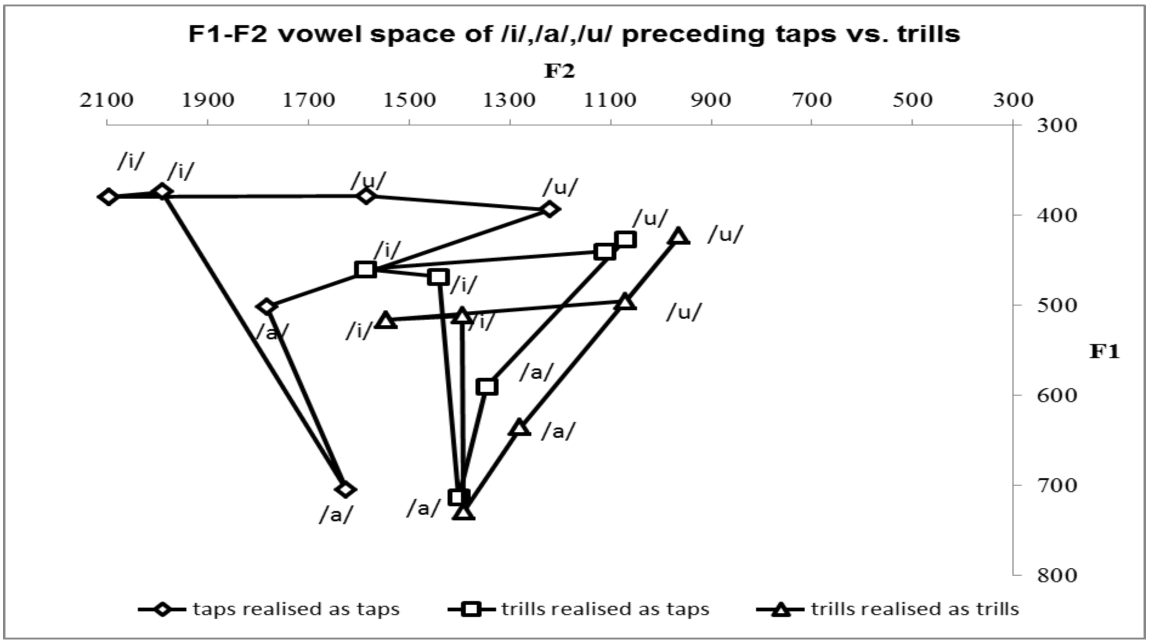
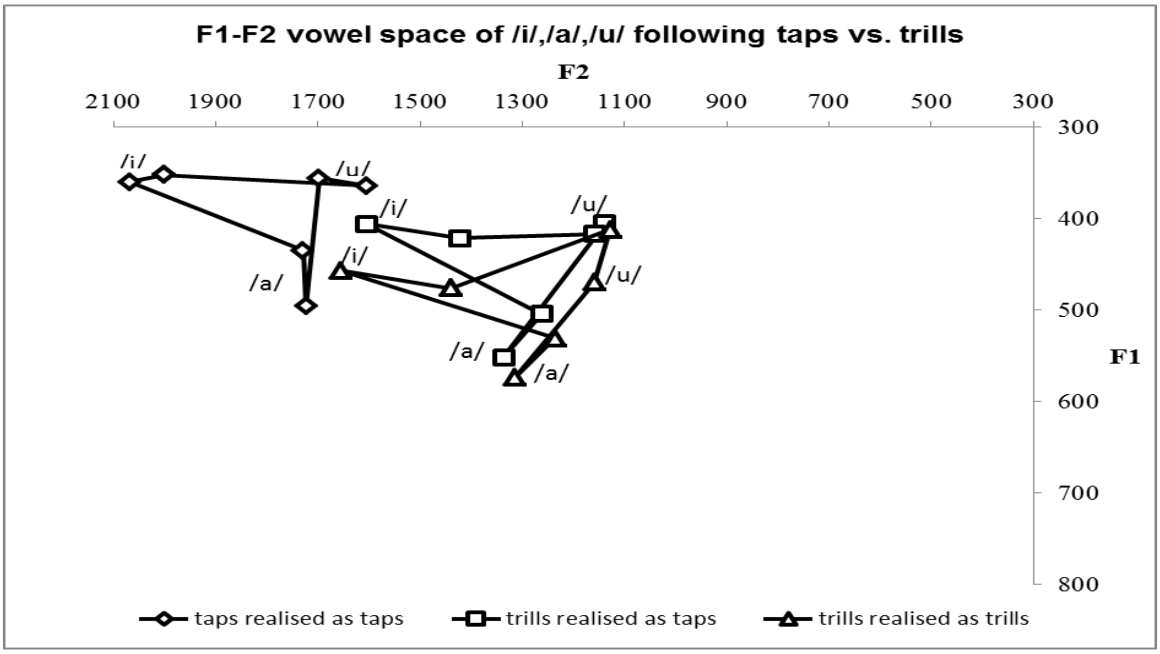


Fig.32. F1-F2 vowel space of /i/, /a/./u/ preceding rhotics in Malayalam.



Fig,33. F1-F2 vowel space of /i/,/a/,/u/ following rhotics in Malayalam.

Note that while the basic patterns in figs. 32 and 33 regarding the vowels surrounding target taps versus target trills are the same (lower F1 and higher F2 surrounding target taps versus higher F1 and lower F2 surrounding target trills), the vowel space of /i/,/a/,/u/ preceding taps versus trills appears to be much larger than the vowel space of /i/,/a/,/u/ following taps versus trills. And taking into account the figure below of the neutral vowel space in Malayalam modified from Radhakrishnan's study[4] (2009), together with the smaller vowel space for the following vowels might suggest that the carryover effects of the rhotics are perhaps greater than their anticipatory effects on surrounding vowels. Also, comparing the three figures seems to suggest that in general the vowel space surrounding rhotics is much smaller than the neutral vowel space which could be seen as reflecting a great degree of anticipatory and perseverative coarticulatory effects of the rhotics on its surrounding vowels.

[4] Although Radhakrishnan's plotting of the vowel space map in Malayalam is not directly comparable to the data in the present study, a modification of it (based on plotting formant values of /i/,/a/,/u/ from the vowel space map presented on pg 38, in an F1, F2 x-y scatter plot) has been included nevertheless in order to provide the reader with some sort of reference point to compare and contrast the vowel space of Malayalam in a liquid environment (as evident from result of present study) with the vowel space in a non-liquid , neutral environment

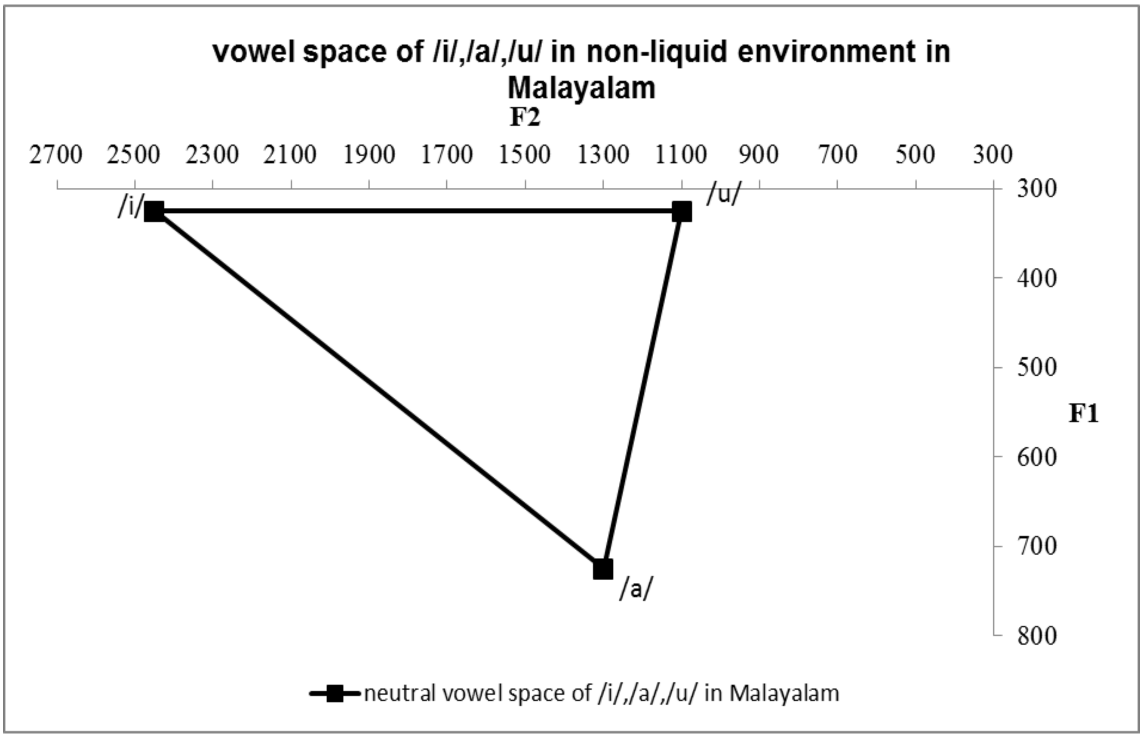


Fig.34. F1, F2 Vowel space of /i/,/a/,/u/ in neutral environment in Malayalam modified from Radhakrishnan (2009:64) (the original figure presented on pg. 38). The mean values of the highest and lowest F1, F2 measures for /i/, /a/ and /u/ based on Radhakrishnan (2009: 64) were calculated and plotted on an x-y scatter plot as shown above.

Regarding the identity of the two rhotics, most speakers produced a large majority of their target trill tokens as taps and almost all their target taps as taps. Based on observations of waveforms and spectrograms and results of the auditory analysis, it is speculated that the target trills realised as taps are not cases of trill weakening or failure but more likely that it is a case of qualitatively different productions of the target trill. In other words, it seems that the trills realised as taps may not be very different with respect to manner of articulation from taps realised as taps. Manner of articulation may not have a prominent role in distinguishing between the two rhotics in Malayalam. Instead, other inter-related contrast maintenance strategies appear to be more robust cues in distinguishing between the two rhotics namely differences in tongue configuration (apicality giving rise to a concave tongue configuration versus laminality giving rise to a convex tongue configuration), resonance characteristics (darker in the apical rhotic versus clearer in the laminal rhotic), surrounding vowel quality (retracted and more open surrounding the apical rhotic/target trill versus advanced and more close surrounding the laminal rhotic/target taps).

Duration of the two rhotics in Malayalam was affected more by the realisation of the manner of articulation of the rhotic and less by its target manner of articulation. In general, trill realisations were longer than tap realisations as was expected but note that most speakers produced most target trills as taps in the study. Trills realised as taps were shorter than taps realised as taps in the intervocalic position and this was attributed to the apical place of articulation of the former as opposed to the laminal place of articulation of the latter. Both these groups were shorter than trills realised as trills. If duration was a reliable acoustic cue in distinguishing between the two rhotics, then one or the other rhotic would be consistently longer or shorter in duration than the other irrespective of its realisation. The results of the present study seem to suggest that duration may not be a robust acoustic correlate of the differences between the two rhotics in Malayalam.

Trill fragments sounded like the regular non-fragmental trills in the present study. Word-medial trill fragments had a higher incidence of trill realisations than intervocalic non-fragmental/regular trills. Higher incidence of trill realisation in post-vocalic, pre consonantal environments has been reported in other languages also. Results of the present study provided no evidence in favour of classifying trill fragments as a separate phonetic category from regular/non-fragmental trills. They appear to be more of a positional variant of the regular trills.

This chapter described the auditory and acoustic results obtained for the rhotics in the study and attempted to explain the patterns observed in the context of similar research in other languages and previous work on Malayalam and/or other Dravidian languages. The next chapter will describe the results obtained for the laterals in the study.

CHAPTER 5
RESULTS AND DISCUSSION II: Laterals

This chapter presents the results of the auditory and acoustic analyses conducted on the productions of eight native speakers of Malayalam. The previous chapter dealt with the speakers' productions of the rhotics in the data set. This chapter focuses on the speakers' productions of the two laterals in Malayalam, i.e. the alveolar lateral and the retroflex lateral. Apart from the laterals, the chapter also describes the results for the two lateral fragments in the language, i.e., the alveolar lateral fragment and the retroflex lateral fragment.

This chapter has two main subsections: results from the auditory analysis and results from the acoustic analyses. The auditory analysis results describe findings from the author's auditory impressions of the target tokens and their surrounding sounds. The acoustic analysis results describe findings based on two sets of measurements, duration and formant frequencies of the target tokens and their surrounding vowels. This section includes results from the statistical analyses conducted on the data using SPSS with significance measured at the 0.001 level.

5.1 Results II

5.1.1 Auditory analyses

Almost all target alveolar laterals were realized as alveolar laterals. Only three of the 338 tokens were realized as alveolar taps and all three were produced by the same speaker. All target retroflex laterals produced by all speakers were realized as retroflex laterals. The alveolar laterals, irrespective of their realization, also seemed to be produced laminal while the retroflex laterals were produced sub-apical. The former sounded 'clear' while the latter sounded 'dark'. The vowels surrounding the lamino-alveolar lateral sounded more fronted and raised while vowels surrounding the retroflex lateral sounded retracted and lowered.

All alveolar lateral *fragments* were realized as alveolar laterals and all retroflex lateral *fragments* were realized as retroflex laterals and therefore from henceforth any mention of 'alveolar lateral fragments' and 'retroflex lateral fragments' imply that they were realized as alveolar laterals and retroflex laterals respectively. The alveolar lateral fragments sounded like the alveolar laterals while the retroflex lateral fragments sounded darker and more velarized than the retroflex laterals.

5.1.2 Acoustic Analyses

Duration (ms) and formant frequencies (Hz) are two kinds of measurements made on each target token and its surrounding vowels.

5.1.2.1 Duration

Consonant Duration

The target alveolar and retroflex laterals in Malayalam only commonly occur in the intervocalic position. They also occur word-finally but in these positions and in specific word-medial contexts traditional grammarians refer to them as being ‘fragments’ (for details about ‘fragments’ in the literature on Malayalam, see chapter 2, pgs. 40-41). The target alveolar and retroflex laterals in Malayalam only lexically contrast in the intervocalic position. The lateral ‘fragments’ occur word-medially preceded by a vowel and followed by another consonant and also occur word-finally preceded by a vowel.

Two univariate ANOVA’s each were run on the duration of laterals and duration of the vowels preceding them. Firstly, since the intervocalic position is the only position where the target laterals contrasted lexically and therefore is the most important of the word-positions for the laterals, a separate ANOVA was run on the word-medial(which includes the intervocalic context) target non-fragment laterals and the fragment laterals. There was only one independent variable: realization of manner of articulation of the lateral. The realization of manner of articulation of the lateral was found to have a general significant effect on the duration of the lateral, $F(4,539) = 10.69$, $p<0.001$ and $\omega^2 = 0.067$ which indicates that the strength of the effect was medium. The Bonferroni and Tukey post-hoc tests revealed that alveolar laterals realized as alveolar laterals ($M=50.39$, $SD=10.19$) were significantly longer in their duration than retroflex laterals realized as retroflex laterals ($M=40.83$, $SD=12.29$) (see fig.35, pg. 151). However, the standard deviation values in proportion to the mean values imply there was considerable overlap between the duration measures of both categories. Effect size measures showed that the strength of this difference in duration between the alveolar and retroflex lateral was large ($d=-0.87$). Note however that the actual difference in mean values between the alveolar and retroflex laterals is only about 10ms so despite the statistical significance and large effect size measure, the durational difference does not appear be a robust distinguishing cue between the laterals.

With respect to the differences in duration between target fragment laterals and the target non-fragment laterals, the patterns were as follows: Retroflex lateral fragments realized as retroflex lateral (M= 52.26, SD=23.86) were found to be significantly longer than retroflex lateral realized as retroflex lateral (M=40.83, SD=12.29) and d=0.69 which indicates that the size of this duration effect was medium (see fig.35 below). However, the statistically significant durational differences were actually only a difference of about 12ms and therefore the result must be interpreted with caution. The duration of the retroflex lateral fragment realized as retroflex lateral (M=52.26, SD=23.86) was found to be non-significant to the duration of the alveolar lateral fragment realized as alveolar lateral (M=53.13, SD=25.22). Alveolar lateral fragment realized as alveolar lateral (M=53.13, SD=25.22) was found to be significantly longer in duration than the retroflex lateral realized as retroflex lateral (M=40.83, SD=12.29), d=0.69 indicating a medium effect size. Alveolar lateral fragment realized as alveolar lateral (M=53.13, SD=25.22) was found to be not significantly different in duration to alveolar laterals realized as alveolar lateral (M=50.39, SD=10.19).

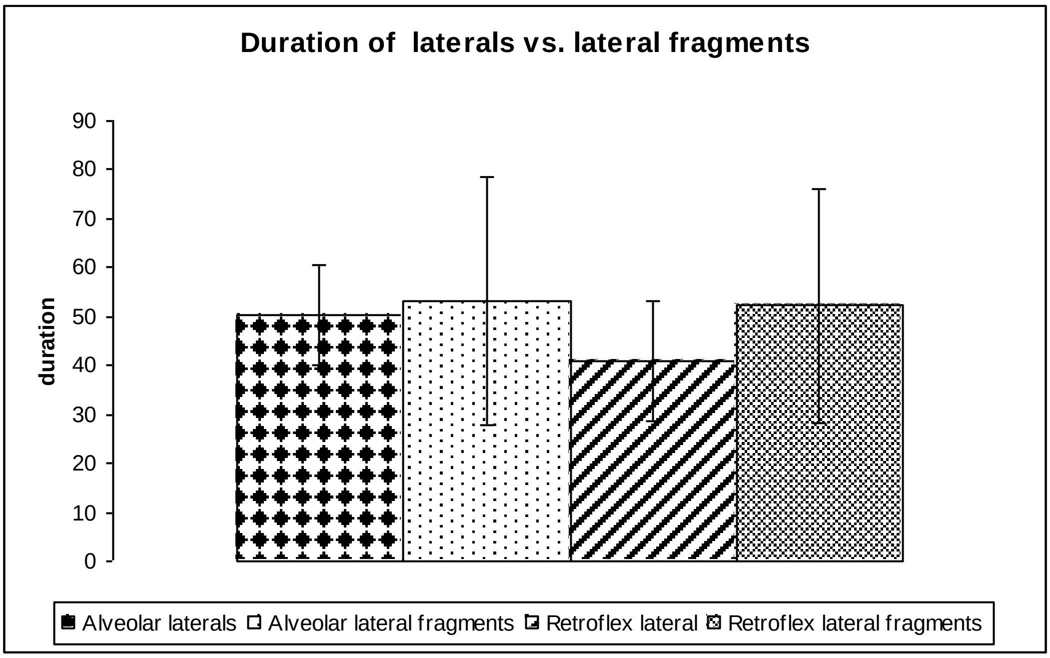


Fig.35. Average duration (ms) of word-medial laterals (alveolar, retroflex) versus lateral fragments (alveolar, retroflex). Error bars=±1SD.

Another ANOVA was run on the lateral fragments with two independent variables: realization of manner of articulation and word-position. Both factors were found to have a significant effect on the duration of lateral fragments: realization of manner of articulation, $F(1,301) = 2.593$, $p<0.001$ and $\omega^2 = 0.005$ indicating that this factor only had a very small effect despite its p value being 'significant'. In other words, the effect size of the durational difference between alveolar lateral fragments (M=60.08, SD=26.1) and retroflex lateral fragments (M=56.63, SD=25.17) was very small. The second factor, word position, also was found to have a significant effect on duration of lateral fragments, $F(1,301) = 21.197$, $p<0.001$ and $\omega^2 = 0.058$ indicating that word-position had a medium sized effect on duration of lateral fragment. In other words, the effect size of the durational difference between *medial* alveolar and retroflex lateral fragments realized as alveolar and retroflex laterals respectively (M=52.75, SD=24.57) and *final* alveolar and retroflex lateral fragments realized as alveolar lateral and retroflex lateral respectively (M=66, SD=25.28) was of medium strength. The effect of the interaction between the two factors was found to be non-significant, $F(1,301) = 1.71$, $p>0.001$.

<u>Summary</u>

The word-medial position is the most important context for laterals in Malayalam since it is only in that position that the two laterals in Malayalam form minimal pairs. Realization of manner of articulation of the lateral was found to have a medium sized significant effect on the duration of laterals and lateral fragments ($p<0.001$, $\omega^2 = 0.067$). More specifically, the alveolar laterals realised as alveolar laterals were found to be significantly longer in duration than retroflex laterals realized as retroflex laterals and the effect of this duration difference was large (d=0.87). Also, both types of lateral fragments, i.e. alveolar lateral fragments realized as alveolar laterals and retroflex lateral fragments realized as retroflex laterals were found to be significantly longer in duration than the retroflex laterals (non-fragment) realized as retroflex laterals. The effect size of the durational differences in both these cases was found to be medium sized (d=0.69). There was no significant durational difference between the alveolar fragment laterals realized as laterals and the alveolar (non-fragment) laterals realized as alveolar laterals. There was also no significant durational difference between the two types of lateral fragments, i.e. alveolar and retroflex. However, a separate ANOVA run on only the lateral fragments in word-medial and word-final positions revealed that word-position had a significant medium sized effect on their duration (ω^2 =0.058). Word-final lateral fragments were found to be significantly longer in duration than word-medial lateral fragments. It must also be noted that despite the statistical significance of some of the above results, the actual difference in mean duration values between the groups was 10-12ms and therefore duration does not seem to be a major distinguishing cue between the two laterals or between the two lateral fragments or between the laterals and their respective lateral fragment counterparts.

<u>Preceding vowel duration</u>

Two univariate ANOVA's were run on preceding vowel duration. First ANOVA was run on vowels preceding word-medial laterals and lateral fragments with two independent variables: realization of manner of articulation and preceding vowel type. The second univariate ANOVA was run on vowels preceding word-medial and word-final lateral fragments with two independent variables: realization of manner of articulation and word-position.

The first ANOVA run on word-medial laterals and lateral fragments showed that both factors, realization of manner of articulation and preceding vowel type had a significant effect on the duration of laterals and lateral fragments but the strength of these effects varied. Realization of manner of articulation was found to have a medium sized significant effect on the duration of vowels preceding laterals and lateral fragments, $F(3,513) = 35$, $p<0.001$ (ω^2 =0.058). The Bonferroni and Tukey post-hoc tests revealed the following significant effects, $p<0.001$:

- Vowels preceding alveolar laterals realized as alveolar laterals (M=147.37, SD=62.51) had a longer duration than vowels preceding retroflex laterals realized as retroflex laterals (M=124.61, SD=66.79). However effect size was small, d=0.35.
- Vowels preceding alveolar lateral fragments realized as alveolar laterals (M=124.47, SD=50.38) had shorter duration than vowels preceding retroflex lateral fragments realized as retroflex laterals (M=154.93, SD=51.38). Effect size was medium, d=-0.6.
- Vowels preceding alveolar laterals realized as alveolar laterals (M=147.37, SD=62.51) had longer duration than vowels preceding alveolar lateral fragments

realized as alveolar laterals ($M=124.47$, $SD=50.38$). However, effect size was small, $d=0.39$.

- Vowels preceding retroflex laterals realized as retroflex laterals ($M=124.61$, $SD=66.79$) had shorter duration than vowels preceding retroflex lateral fragments realized as retroflex laterals ($M=154.93$, $SD=51.28$). However, effect size was small, $d=-0.5$.

The second factor, preceding vowel type was also found to have a significant effect on the duration of laterals and lateral fragments, $F(8,513)=131.49$, $p<0.001$ and $\omega^2=0.56$ indicating that the preceding vowel type had a large effect size. However the post-hoc tests revealed that the statistical significance of this factor's effect on duration was a consequence of grouping short and long vowels together in the data subset. The actual significance in this case resulted from all the short vowels being significantly shorter than all the long vowels and not due to vowel quality. Also, the sample size of shorter vowels and longer vowels in the data set which also contributed to the statistical significance of the factor.

The effect of the interaction between realization of manner of articulation and preceding vowel type was found to be significant, $F(8,513)=4.9$, $p<0.001$ but the effect size was extremely small, $\omega^2=0.018$.

The second ANOVA that was run on vowels preceding word-medial and word-final lateral fragments showed a significant effect of both independent variables on their duration: Realization of manner of articulation $F(1,300)=30.26$, $p<0.001$, $\omega^2=0.073$ and word-position $F(1,300)=40.13$, $p<0.001$, $\omega^2=0.095$, both factors also indicating a significant medium sized effect on the duration of vowels preceding lateral fragments ($\omega^2=0.073$ and, $\omega^2=0.095$ respectively). In other words, duration of vowels preceding retroflex lateral fragments ($M=174.47$, $SD=53.48$) were found to be longer in duration than alveolar lateral fragments ($M=138.92$, $SD=60.2$) and duration of vowels preceding word-medial lateral fragments (alveolar and retroflex) ($M=138.04$, $SD=52.91$) were found to be significantly shorter than the duration of vowels preceding word-final lateral fragments (alveolar and retroflex) ($M=178.96$, $SD=60.7$). The effect of the interaction between the realization of manner of articulation and word-position was found to be non-significant, $F(1,300)=0.411$, $p>0.001$.

Summary

Realisation of manner of articulation of the laterals was found to have a medium sized significant effect on the duration of vowels preceding laterals and lateral fragments. Vowel duration varied significantly depending on whether it preceded alveolar laterals versus retroflex laterals (longer vs. shorter, small effect size) and alveolar lateral fragments versus retroflex lateral fragments (shorter vs. longer, moderate effect size) and alveolar laterals versus alveolar lateral fragments (longer vs. shorter, small effect size) and retroflex laterals versus retroflex lateral fragments (shorter vs. longer, moderate effect size). The vowels preceding the two lateral fragments, i.e. alveolar and retroflex lateral fragments realized as alveolar and retroflex laterals respectively differed significantly in duration depending on the lateral fragments' word-position: shorter in word-medial position and longer in word-final position (moderate effect size).

5.1.2.2 Formant Frequencies

The two laterals in Malayalam occur commonly in the word-medial and word-final positions. In the word-final position, however, traditional grammarians treat them differently and refer to them as 'fragments' (cf. Chapter 2, pgs. 40-41). Lateral 'fragments' also occur word-medially preceded by a vowel and followed by a consonant. The formant frequency patterns of the lateral consonants, preceding and following vowels are presented here.

Lateral consonants

With regard to the lateral consonants formant patterns, a MANOVA was conducted at three points of measurement, onset, mid-point and offset. The first MANOVA was conducted on word-medial laterals and lateral fragments at the three points of measurement separately. There was one independent variable: realization of place of articulation of the lateral which was found to be a significant factor that determined the formant patterns of the laterals at onset, mid-point and offset : $\lambda=0.5$, $F(9,1302.2)=47.43$, $p<0.001$, $\omega^2=0.49$ at onset, $\lambda=0.53$, $F(9,1302.2)=42.61$, $p<0.001$, $\omega^2 = 0.46$ at mid-point and $\lambda=0.56$, $F(9,1302.2)=39.15$, $p<0.001$, $\omega^2=0.43$ at offset. All the ω^2 effect size measures indicate a large sized effect at all three points of measurements.

As shown in Fig. 36, the alveolar laterals realized as alveolar laterals had significantly lower F1 values than retroflex laterals realized as retroflex laterals at onset, mid-point and offset (also see table 14 below). Cohen's d values of effect size were as follows: d=-0.99 at onset, d=-1.25 at mid-point and d=-1.03 at offset, indicating that effect of the difference in F1 values between alveolar laterals and retroflex laterals was large. The alveolar laterals realized as alveolar laterals were found to have significantly higher F2 and higher F3 values than retroflex laterals realized as retroflex laterals at onset, mid-point and offset (see fig. 37 and table 15 pgs. 157,158). Effect size measures showed that the effect of these F2 and F3 differences between the two lateral groups were large and moderate-to-large respectively.

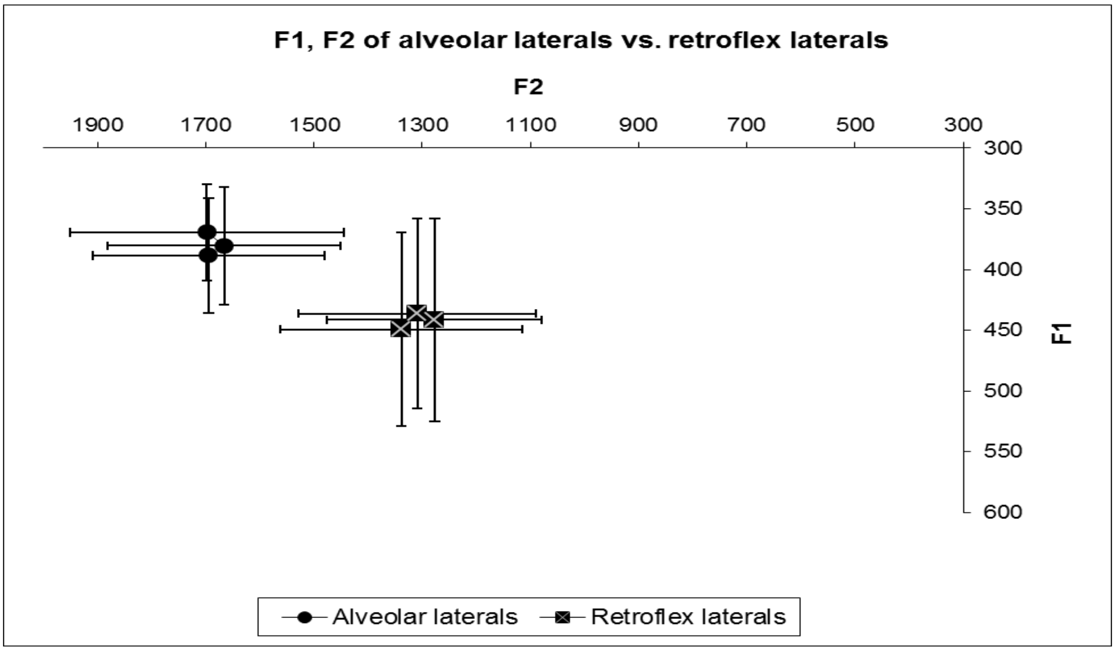


Fig.36. Average F1and F2 onset, mid-point and offset values of alveolar laterals versus retroflex laterals. Error bars=±1SD.

		Alveolar laterals		Retroflex laterals		Cohen's d
		Mean	SD	Mean	SD	
F1	onset	381	48	442	84	-0.99
	mid	369	40	436	78	-1.25
	offset	389	47	449	80	-1.03
F2	onset	1666	215	1277	198	1.86
	mid	1698	253	1309	219	1.61

Table 14. Mean and SD of F1, F2, F3 onset, mid-point and offset values of alveolar laterals versus retroflex laterals.

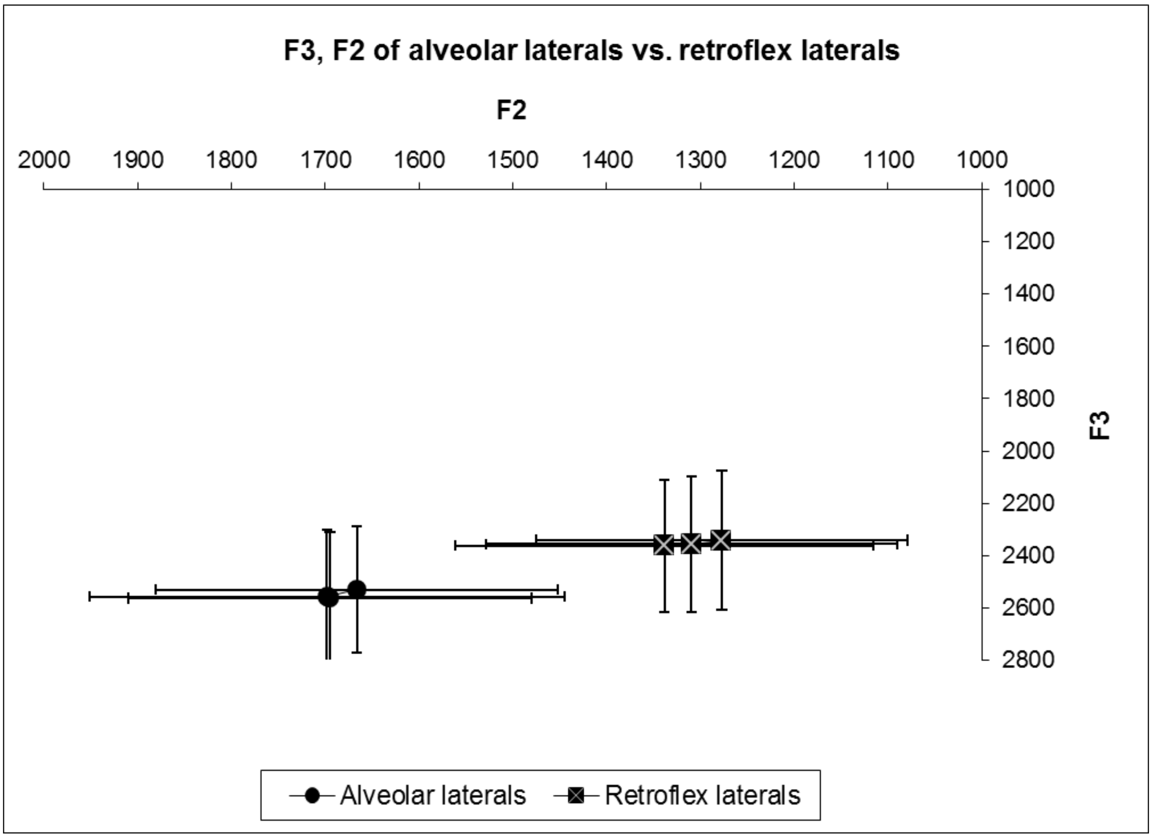


Fig.37. Average F3 and F2 onset, mid-point and offset values of alveolar laterals versus retroflex laterals. Error bars=±1SD.

As shown in figs. 38 and 39, the lateral fragments also showed a similar pattern to that of their non-fragment counterparts in that the alveolar lateral fragments were found to have significantly lower F1 mid and offset values, and higher F2 onset, mid, offset values than the retroflex lateral fragments ($p<0.001$) (Table 15 below). However, difference in F3 values between the two groups was found to be only 'nearly' significant with small to moderate effect size. Differences in F1 values were found to have a small-to-moderate effect while those in F2 values were found to be large and although differences in F3 were statistically non-significant ($p>0.001$), effect size was small-to-moderate (see table 15, figs. 38 and 39 below).

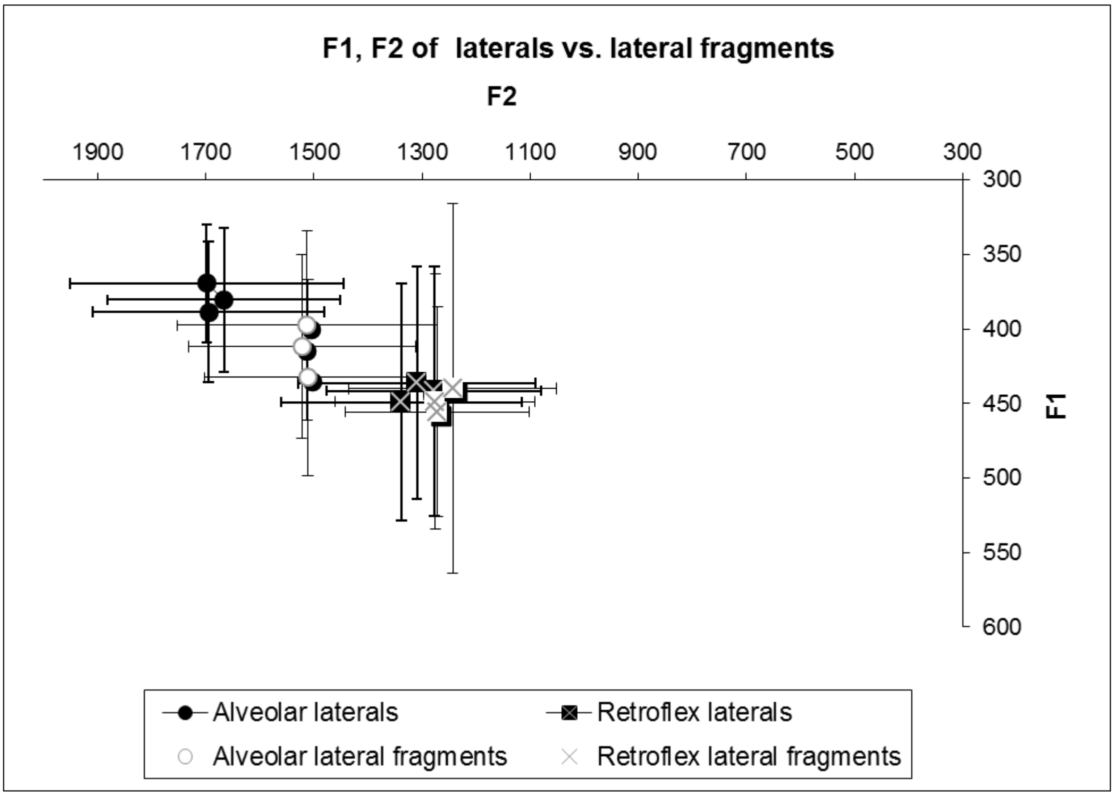


Fig.38 Average F1 and F2 onset, mid-point and offset of laterals (alveolar, retroflex) versus lateral fragments (alveolar, retroflex). Error bars=±1SD.

		Alveolar lateral fragments		Retroflex lateral fragments		Cohen's d
		Mean	SD	Mean	SD	
F1	onset	433	66	456	71	
	mid	412	61	449	85	-0.51
	offset	398	63	440	124	-0.47
F2	onset	1511	191	1271	170	1.32
	mid	1522	210	1276	185	1.24
	offset	1512	241	1243	191	1.22
F3	onset	2488	245	2368	224	0.51
	mid	2499	252	2371	244	0.52
	offset	2488	253	2381	270	0.41

Table 15. Mean and SD of F1, F2, F3 onset, mid-point and offset values of alveolar lateral fragments versus retroflex lateral fragments.

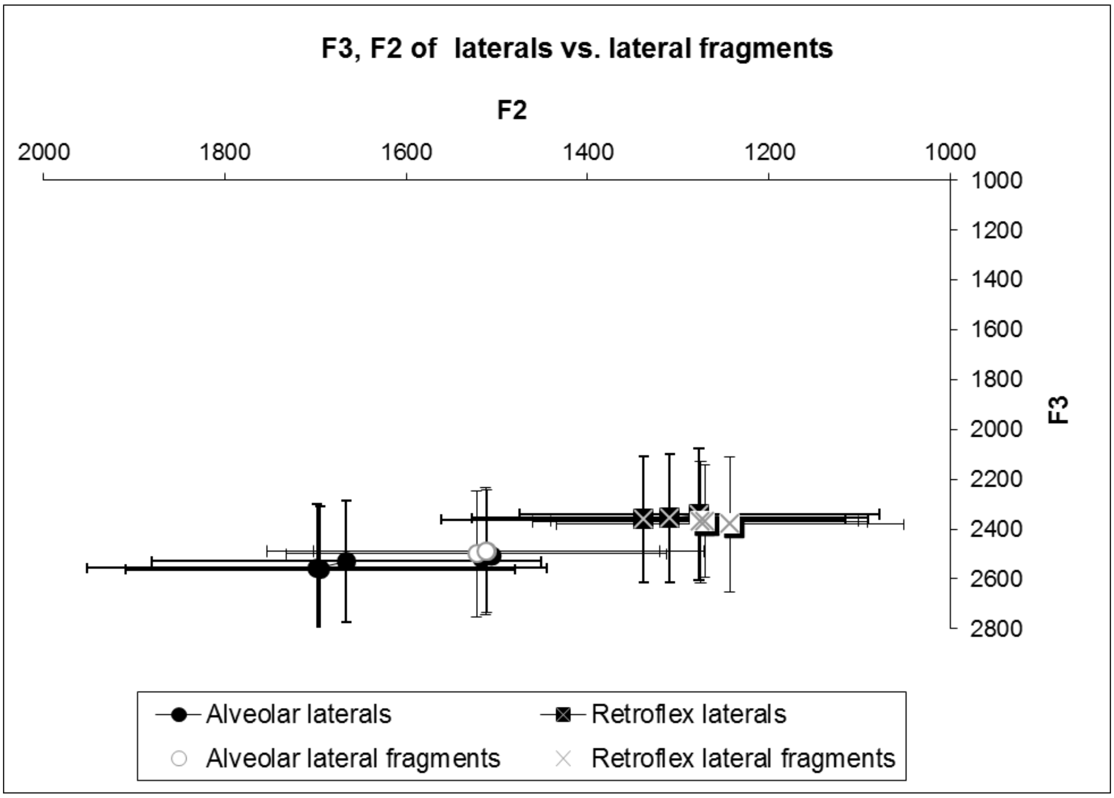


Fig.39. Average F3and F2 onset, mid-point and offset values of laterals (alveolar, retroflex) versus lateral fragments (alveolar, retroflex). Error bars=±1SD.

As shown in figs. 38 and 39 above and table 16(next page), alveolar ('non-fragment') laterals were found to have significantly lower F1 and higher F2 values than the alveolar and retroflex lateral *fragments*. Effect sizes for differences between alveolar 'non-fragment' laterals and alveolar lateral fragments were moderate-to-large while those between alveolar 'non-fragment' laterals and retroflex lateral fragments were large. The alveolar lateral fragments were found to have a significantly lower F1 offset, higher F2 and F3 onset, mid and offset values than retroflex non-fragment laterals. Effect sizes for these differences were moderate-to-large at F1 offset, large at F2 onset, mid-point and offset and moderate at F3 onset, mid-point and offset (see figs. 38 & 39 above, table 16 below). The retroflex non-fragment laterals were not found to be significantly different from their fragment counterparts with respect to any of the three formant frequencies.

		Alveolar laterals		Alv.Lat Fragments		Retroflex laterals		Rtf.Lat Fragments	
		Mean	SD	Mean	SD	Mean	SD	Mean	SD
F1	onset	381	48	433	66	442	84	456	71
	mid	369	40	412	61	436	78	449	85
	offset	389	47	398	63	449	80	440	124
F2	onset	1666	215	1511	191	1277	198	1271	170
	mid	1698	253	1522	210	1309	219	1276	185
	offset	1695	215	1512	241	1338	223	1243	191
F3	onset	2529	243	2488	245	2341	265	2368	224
	mid	2556	257	2499	252	2356	259	2371	244
	offset	2562	253	2488	253	2362	253	2381	270

Table 16. Mean and SD of F1, F2, F3 onset, mid-point and offset of word-medial laterals versus lateral fragments.

Preceding vowels

A MANOVA was conducted on the vowels preceding the word-medial laterals and lateral fragments for mid-point and offset measurements separately with realization of manner of articulation of the following lateral and vowel quality as independent variables. Using Wilk's statistic, both factors, realization of manner of articulation of the following lateral and vowel quality were found have significant effects on the formant patterns of the vowels preceding word-medial laterals and lateral fragments:

1) Realization of manner of articulation of following lateral: λ=0.84, F (9, 1243.8) =10.37, p<0.001, ω^2 =0.14 at mid-point; λ=0.68, F (9, 1243.8) =23.7, p<0.001, ω^2 =0.31 at offset. ω^2 measures for both mid-point and offset measurements given above indicate that the factor had a large effect on formant patterns of the vowels preceding the laterals.

2) Vowel quality: λ=0.07, F (24, 1482.66) =90.88, p<0.001, ω^2 =0.93 at mid-point; λ=0.38, F (24, 1482.66) =24.52, p<0.001, ω^2 ==0.6 at offset. The ω^2 measures indicate that vowel quality had a large effect on the formant patterns of the vowels preceding medial laterals and lateral fragments.

The interaction between the two factors, i.e., realization of the place of articulation of the following lateral and vowel quality was found to have no significant effect on the formant patterns of preceding vowels (p>0.001).

With respect to the first factor, i.e., realization of place of articulation of the following lateral, the ANOVA's showed that vowels preceding alveolar laterals had significantly higher F2 and higher F3 mid-point and offset values than vowels preceding retroflex laterals (see table 17 below). Cohen's'd values of effect size indicate that the F2 differences between the vowels preceding alveolar versus retroflex laterals were large (d=0.88 at mid-point and d=1.73 at offset) and F3 differences were small at mid-point but moderate at offset (d=0.4 and d=0.63 respectively).

	PRECEDING VOWELS							
	Alveolar laterals		Alv.lat fragments		Retroflex laterals		Rtf.lat fragments	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
F1 mid	538	146	704	70	534	149	645	146
F1 offset	480	89	553	74	482	104	524	101
F2 mid	1486	409	1424	130	1173	261	1254	161
F2 offset	1668	240	1540	170	1270	211	1301	168
F3 mid	2482	266	2442	238	2376	255	2370	216
F3 offset	2496	205	2457	229	2309	238	2368	192

Table 17. Mean and SD of F1, F2, F3 mid-point and offset values of vowels preceding laterals versus lateral fragments.

Vowels preceding alveolar lateral fragments were found to have significantly lower F1 at mid-point, higher F2 at mid-point and offset than vowels preceding retroflex lateral fragments. Cohen's d values shown in the table above indicate that the effect size of F1 differences between the vowels preceding alveolar lateral fragments versus those preceding retroflex lateral fragments was moderate (d=0.56) while the effect size of F2 differences between the two groups was large (d=1.18 at mid-point and d=1.41 offset).

As shown in table 17 above, vowels preceding alveolar laterals (non-fragments) were found to have significantly lower F1 values at mid-point and offset and higher F2 values at offset than vowels preceding alveolar lateral fragments. Cohen's d values of effect size for F1 differences between vowels preceding alveolar laterals versus alveolar fragments were large at mid-point and offset (d=-1.35 and d=-0.86 respectively). Effect size for F2 differences at offset, d=0.59, was moderate.

Vowels preceding alveolar laterals (non-fragments) were also found to have significantly lower F1 values, higher F2 values at mid-point and offset and higher F3 offset values than vowels preceding retroflex lateral fragments. Effect size of the F1 differences, d=-0.74 at mid-point and d=-0.48 at offset, were moderate-to-large at mid-point and small-to-moderate at offset. Effect size of the F2 differences, d=0.67 at mid-point and d=1.66 at offset were moderate at mid-point and large at offset respectively while the F3 offset differences were moderate (d=0.63).

Vowels preceding alveolar lateral fragments had significantly higher F1, higher F2 values at mid-point and offset and higher F3 offset values than vowels preceding retroflex (non-fragment) laterals. The effect of the F1 differences were large at mid-point and moderate-to-large at offset, d=1.48 and d=0.77 respectively and effect of the F2 differences were large at both mid-point and offset, d=01.22 and d=1.39 respectively. F3 differences were also large, d=0.86.

Vowels preceding retroflex laterals (non-fragments) were found to have significantly lower F1 values at mid-point and offset than vowels preceding retroflex lateral fragments. Effects of these F1 differences were moderate-to-large at mid-point (d=-0.75) and small at offset (d=-0.41) (see table 17 previous page).

With regard to the second factor that determines the formant patterns of vowels preceding laterals and lateral fragments, i.e., vowel quality, the trends were as follows:

F1 mid: /uu/, /ii/, /i/, /u/ < /ee/, /o/, /oo/ < /a/, /aa/

F1 offset: /ii/, /i/, /u/, /uu/ < /ee/, /o/, /oo/ < /a/, /aa/

(/ii/, /i/, /u/, /uu/) < (/u/, /uu/, /ee/) < (/ee/, /o/, /oo/) < (/o/, /oo/, /a/, /aa/)

Therefore, as was expected, F1 mid and offset values varied depending on the vowel height. Front and back high vowels had the lowest F1 values followed by the front and back close-mid and open-mid vowels. Front and back low vowels had the highest F1 values.

F2 patterns were as follows:

F2 mid: (/uu/) < (/oo/, /u/, /o/) < (/o/, /aa/) < (/aa/, /a/) < (/i/, /ee) < (/ee/, /ii/)

F2 offset: (/u/, /oo/, /aa/, /o/) < (/oo/, /aa/, /o/, /uu/, /a/) < (/i/, /ee/, /ii)

F2 patterns of the vowels varied depending on whether they were back or front, the former having lower F2 values than the latter.

Even though the general effect of the interaction between the two factors, i.e., realization of manner of articulation of the liquid and the preceding vowel type, was found to be non-significant, a further MANOVA was conducted on the data set split by preceding vowel type with realization of manner of articulation of the following consonant as the only independent variable. This was done in order to obtain a more specific result as to which vowels were affected by the presence of the following liquid and the latter's formant patterns. None of the vowels, /i/, /a/, /aa/, /o/, /oo/ and /u/, differed significantly in their F1 and F3 mid-point and offset values irrespective of whether they preceded alveolar laterals versus retroflex laterals (see figs. 40 & 41 pgs. 163,164) or alveolar laterals/retroflex laterals versus alveolar/ retroflex lateral fragments.

/a/, /aa/, /oo/, /u/ preceding alveolar laterals had significantly higher F2 values at mid-point and offset than when preceding retroflex laterals. As shown in fig.40 (below), /i/ preceding alveolar laterals had significantly higher F2 values compared to /i/ preceding retroflex laterals only at offset. Only preceding vowels common to the alveolar lateral fragments and alveolar laterals were /a/ and /aa/ and out of these, only /a/ preceding alveolar laterals had significantly higher F2 offset values than /a/ preceding alveolar lateral fragments. The preceding vowel types common to the alveolar lateral fragments and the retroflex lateral fragments were /a/ and /aa/ and of these, only /aa/ preceding alveolar lateral fragments had significantly higher F2 mid-point and offset values than /aa/ preceding retroflex lateral fragments. No F1 and F3 differences were found between /a/, /aa/ preceding alveolar lateral versus alveolar lateral fragments or preceding alveolar lateral fragments versus retroflex lateral fragments./a/, /aa/ and /u/ were the preceding vowels common to retroflex laterals and retroflex lateral fragments and none of these vowels differed in their F1, F2 or F3 measures depending on whether they preceded retroflex laterals versus retroflex lateral fragments.

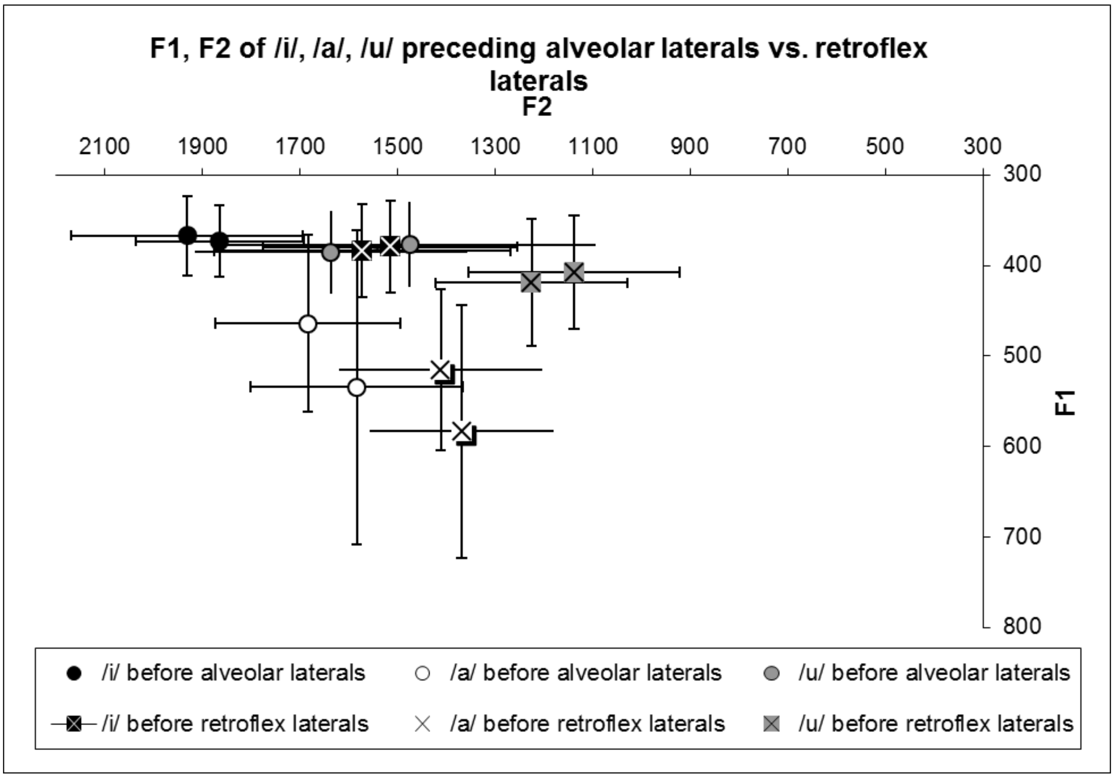


Fig. 40. Average F1 and F2 mid-point and offset values of /i/, /a/, /u/ preceding alveolar laterals versus retroflex laterals. The two shapes indicate the two lateral types and the three different colours indicate /i/, /a/, /u/ preceding each of the two laterals. Error bars=±1SD.

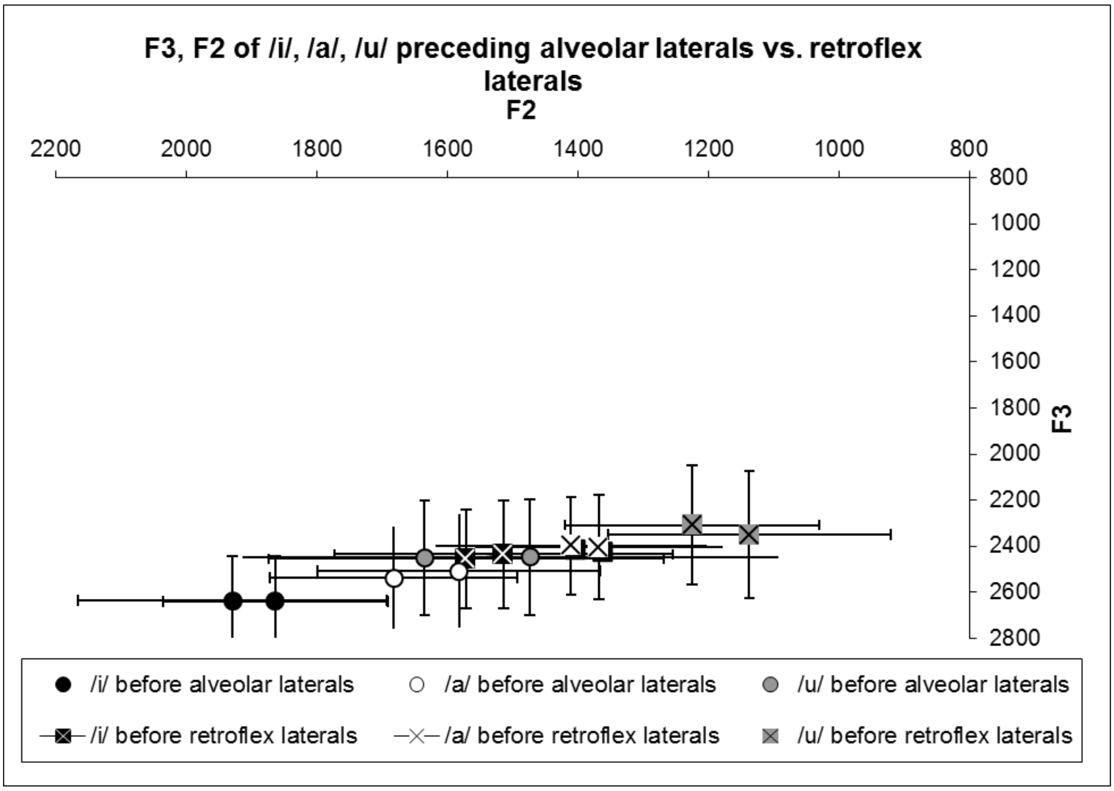


Fig.41. Average F3 and F2 mid-point and offset values of /i/, /a/, /u/ preceding alveolar laterals versus retroflex laterals. Error bars=±1SD.

Following vowels

A MANOVA was conducted on the vowels following word-medial laterals and lateral fragments at their onsets and mid-points separately with two independent variables: Realization of manner of articulation of consonant and vowel quality. Both factors and their interaction were found to have a significant effect on the formant patterns of the vowels following laterals and lateral fragments:

1) Realisation of manner of articulation of the preceding consonant: λ=0.64, F (9, 1236.5) =27.6, p<0.001, ω^2 =0.35 at onset and λ=0.85, F (9, 1236.5) =9.51, p<0.001, ω^2 =0.13. ω^2 measures of effect size at onset and mid-point indicate a large effect of the factor on the following vowels' formant patterns.

2) Vowel quality: λ=0.38, F (15, 1402.77) =38.57, p<0.001, ω^2 =0.61 at onset and λ=0.33, F (15, 1402.77) =46.41, p<0.001, ω^2 =0.66 at mid-point. ω^2 measures of effect size at onset and mid-point indicate that the factor had a moderate effect on the formant patterns of the vowels following medial laterals and lateral fragments.

The interaction between realization of manner of articulation of the consonant it followed and the quality of the vowel was also found to have a significant effect on its formant patterns: λ=0.89, F (9, 1236.5) =6.95, p<0.001, ω^2 =0.09 at onset; λ=0.87, F (9, 1236.5) =6.97, p<0.001, ω^2 =0.1 at mid-point. ω^2 effect size measures indicate that the interaction of the two factors had a large effect on the formant patterns of the vowels following laterals and lateral fragments.

With regard to the first factor, i.e., realization of manner of articulation, the ANOVA's showed that vowels following alveolar (non fragment) laterals had significantly lower F1, higher F2 and F3 values at onset and mid-point, than vowels following retroflex (non-fragment) laterals, alveolar lateral fragments and retroflex lateral fragments (see table 18 below).

FOLLOWING VOWELS								
	Alveolar laterals		Alv.lat fragments		Retroflex laterals		Rtf.lat fragments	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
F1 mid	476	62	525	81	521	112	516	88
F1 offset	578	127	620	97	544	149	573	111
F2 mid	1727	230	1452	231	1477	271	1304	224
F2 offset	1773	290	1528	244	1648	367	1409	252
F3 mid	2551	218	2374	237	2444	194	2401	207
F3 offset	2596	244	2445	216	2556	219	2450	193

Table 18. Mean and SD values of F1,F2,F3 onset and mid-point values of vowels following laterals (alveolar, retroflex) versus lateral fragments (alveolar, retroflex).

Effect size for F1 differences between vowels following alveolar versus retroflex non-fragment laterals (d=-0.49 at onset, d=-0.25 at mid-point) were small, and between vowels following alveolar non-fragment laterals and those following fragment laterals was moderate at onset but small at mid-point (d=-0.61, d=-0.36 at onset, mid-point respectively); F1 differences between vowels following alveolar non-fragment laterals and retroflex fragment laterals also had a small effect (d=-0.49).

Effect size for F2 differences between vowels following alveolar and retroflex non-fragment laterals was large at onset, small at mid-point (d=1.02, d=0.39 respectively), and that between vowels following alveolar non-fragment and fragment laterals was large at both onset and mid-point (d=1.19, d=0.88 respectively). Effect size of F2 differences between vowels following alveolar non-fragment laterals and retroflex lateral fragments was large at onset and mid-point (d=1.85, d=1.29).

Effect size of F3 differences between vowels following alveolar and retroflex non-fragment laterals was moderate at onset (d=0.51); F3 differences between vowels following alveolar non-fragment laterals versus fragment laterals was moderate-to-large at onset and moderate at mid-point (d=0.79, d=0.64 respectively). F3 differences between vowels following alveolar non-fragment laterals and those following retroflex fragment laterals was large at onset and small at mid-point (d=0.83, d=0.47 respectively).

Vowels following alveolar lateral fragments had significantly higher F1 values at mid-point and higher F2 values at onset than vowels following retroflex lateral fragments (see table 18 above). Effect size measures, d=0.45 for F1 differences and d=0.65 for F2 differences, showed that F1 differences were small while F2 differences were of a moderate effect. Vowels following retroflex non-fragment laterals only differed from vowels following retroflex lateral fragments in their F2 onset and mid-point values. The former had significantly higher F2 values than the latter and effect size measures indicate that the difference in F2 was moderate (d=0.68 and d=0.73 at onset and mid-point respectively).

With regard to the second factor that determined the formant patterns of vowels following laterals and lateral fragments, i.e., vowel quality, the trends were as follows:

F1 onset: /uu/, /i/ < /ee/, /e/, /a/, /aa/

F1 mid: (/i/, /uu/) < (/e/, /ee/) < (/ee/, /a/) < (/a/, /aa/)

As expected, both at onset and mid, the general trend was that F1 was inversely proportional to vowel height. As vowel height decreased, F1 values increased, i.e., in low vowels like /a/, F1 values were the highest as compared to high vowels like /i/ and /uu/ where F1 values were the lowest.

F2 patterns were as follows:

F2 onset: /uu/ < /aa/, /e/, /a/, /ee/ < /i/

F2 mid: /uu/ < (/aa/, /a/, /e/) < (/a/, /e/, /ee/) < (/ee/, /i/)

F2 values of the vowels varied depending on whether they were back or front vowels. /uu/ had the lowest F2 being the most back vowel and /i/ had the highest F2 being the most front vowel and /aa/, /a/, /e/ and /ee/ had F2 values in between /u/ and /i/.

The interaction between the two factors, i.e. realization of manner of articulation of the liquid and the following vowel type was found to have a significant effect on the formant patterns of the vowels following the laterals and lateral fragments. /i/ and /a/ were the only two vowels commonly preceding alveolar and retroflex laterals. As shown in figs. 42 and 43 (next page), both /i/ and /a/ following alveolar laterals had significantly lower F1, higher F2 and higher F3 onset and mid-point values than /i/ and /a/ following retroflex laterals.

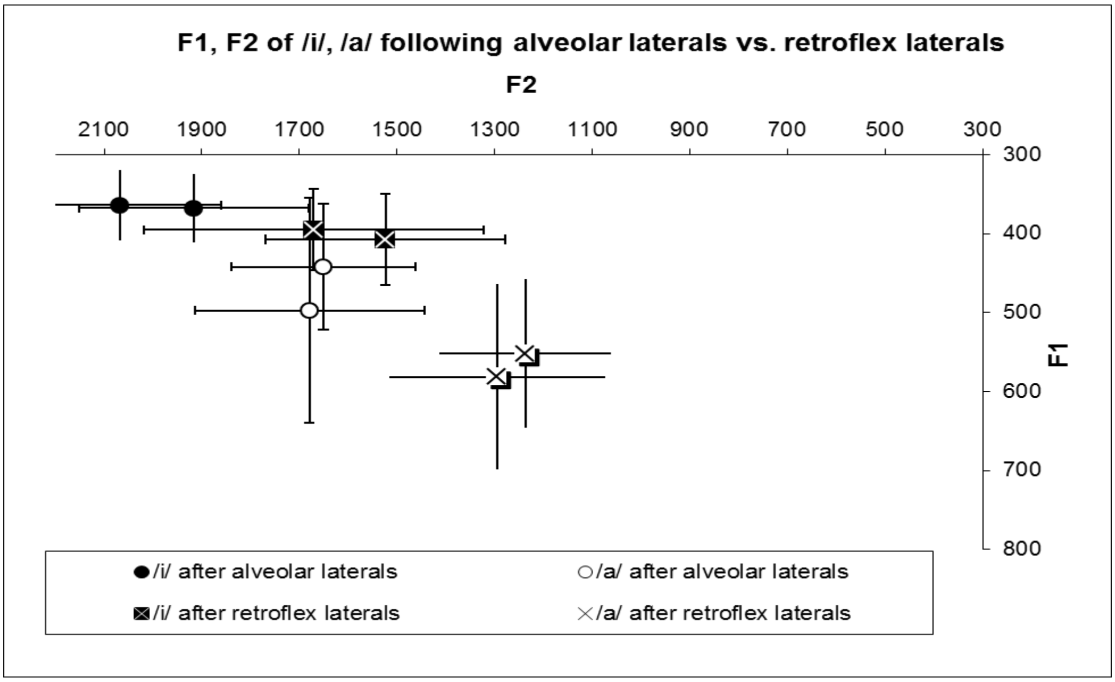


Fig.42. Average F1 and F2 onset and mid-point values of /i/, /a/ following alveolar laterals versus retroflex laterals. Error bars=±1SD.

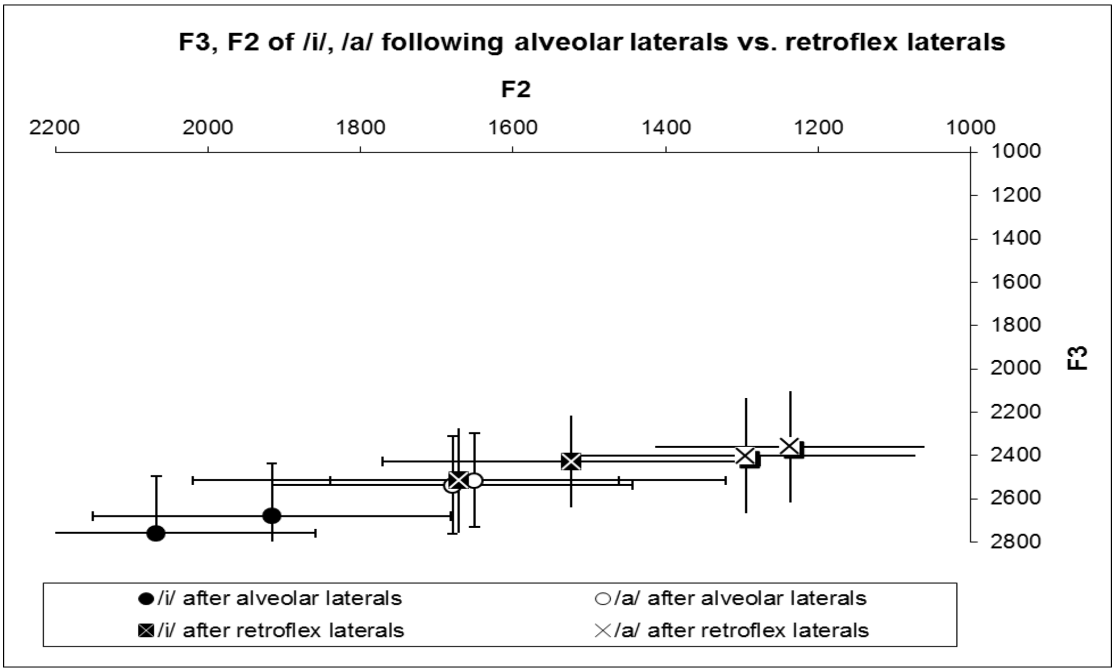


Fig. 43. Average F3 and F2 onset and mid-point values of /i/, /a/ following alveolar laterals versus retroflex laterals. Error bars=±1SD.

/a/, /aa/ and /e/ were the common vowel types following alveolar lateral fragments and retroflex lateral fragments. Of these, /e/ following alveolar lateral fragments had significantly lower F1, higher F2, higher F3 onset and mid-point values than /e/ following retroflex lateral fragments. /a/ following alveolar lateral fragments had significantly higher F2 and higher F3 onset values than /a/ following retroflex lateral fragments. /aa/ was not found to differ significantly in F1, F2 or F3 values based on whether it followed alveolar lateral fragments versus retroflex lateral fragments. Alveolar laterals and alveolar lateral fragments have /a/, /aa/, /ee/ as common following vowels. /a/, /aa/ and /ee/ following alveolar laterals had significantly higher F2 onset values than /a/, /aa/ and /ee/ following alveolar lateral fragments. The only vowel type in the data set that was common to retroflex laterals and retroflex lateral fragments was /a/. /a/ following retroflex laterals had significantly higher F1 onset values than /a/ following retroflex lateral fragments.

Comparison with Rhotics

A MANOVA was conducted on all the word-medial consonants in the data set with realisation of manner of articulation as the only independent variable. The word-medial position is the only word-position in which the two rhotics and two laterals in Malayalam commonly occur and hence only word-medial rhotics and laterals were compared to each other. Realization of manner of articulation of the consonant was found to have a significant effect on the F1, F2 and F3 onset, mid-point and offset values of the consonants: $\lambda=0.34$, $F(30,3338)=49.21$, $p<0.001$, $\omega^2=0.65$ at onset, $\lambda=0.34$, $F(30,3338)=49.78$, $p<0.001$, $\omega^2=0.65$ at mid-point and $\lambda=0.38$, $F(3,3338)=43.09$, $p<0.001$, $\omega^2=0.61$ at offset. The ω^2 measures of effect size at all three points of measurements indicate a large effect of realization of manner of articulation of the liquid on the liquid's formant patterns.

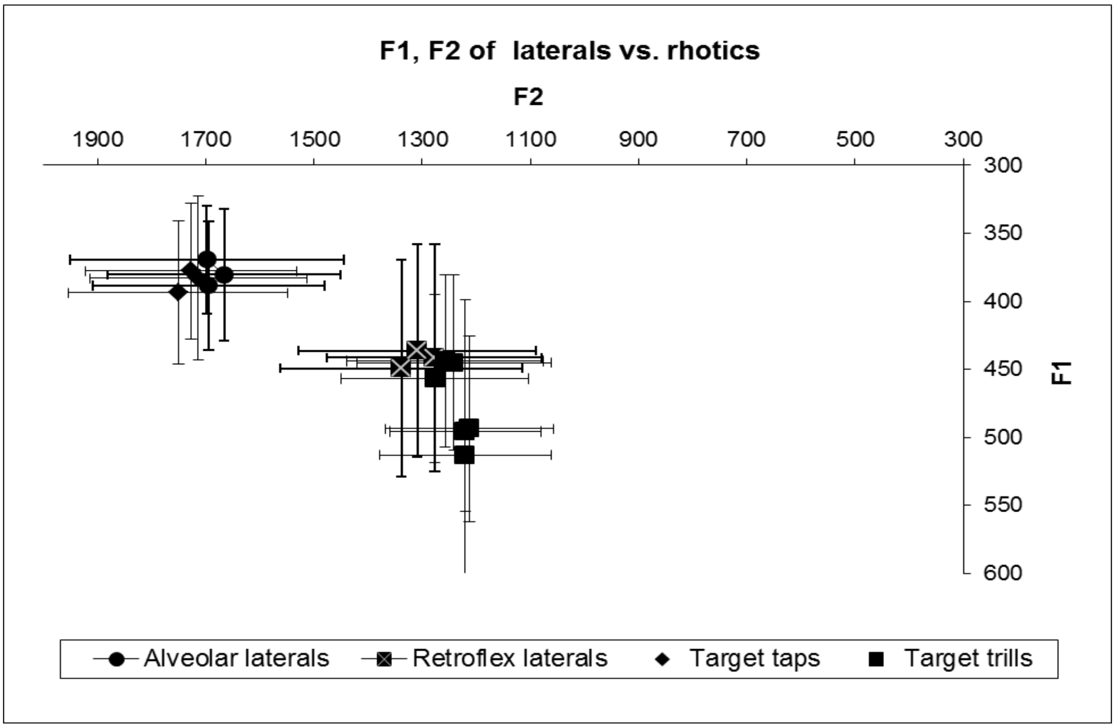


Fig.44. Average F1 and F2 onset,mid-point and offset values of the laterals and rhotics in Malayalam. Error bars=±1SD.

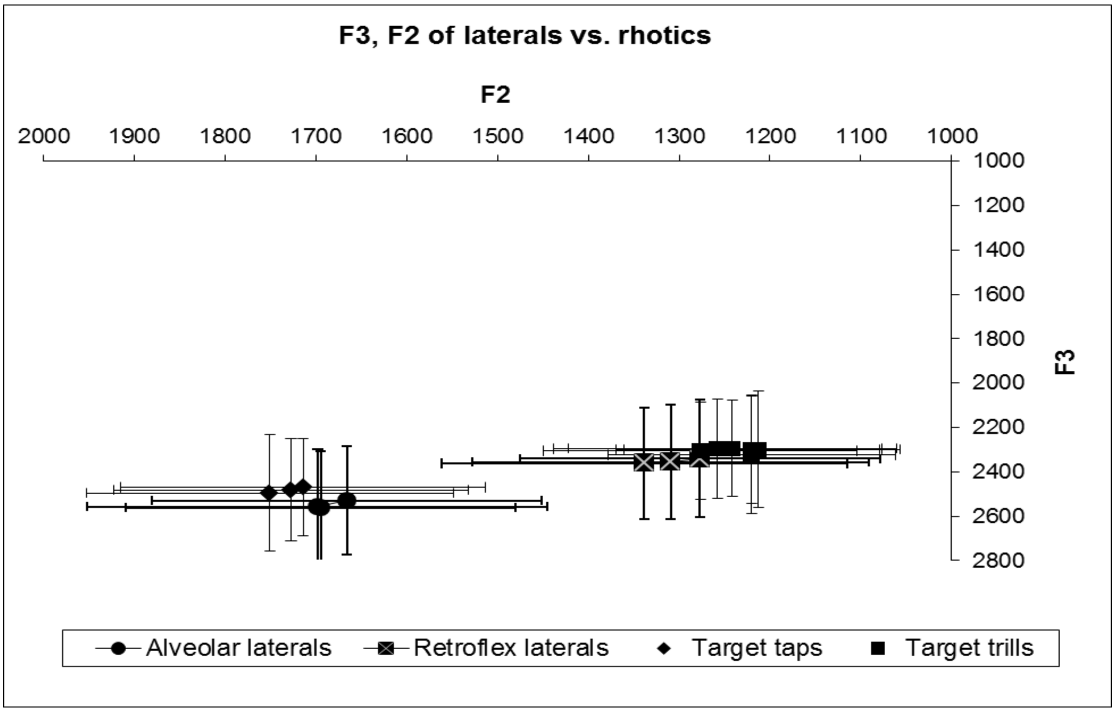


Fig.45. Average F3 and F2 onset, mid-point and offset values of the laterals and rhotics in Malayalam. Error bars=±1SD.

Post-hoc tests revealed that the target taps (taps realised as taps) did not differ significantly in F1, F2 or F3 measures from the alveolar laterals whereas they differed significantly in F1, F2 and F3 measures from retroflex laterals. Taps were found to have lower F1, higher F2 and higher F3 mid values than retroflex laterals (see figs. 44, 45 on previous page). Target trills (trills realised as taps and trills realised as trills) in general showed the opposite trend in terms of their differences with the two laterals. Target trills were found to be acoustically similar to the retroflex laterals (except for F1 onset values which were higher for trills realised as trills than retroflex laterals) whereas they differed significantly from the alveolar laterals in F1, F2 and F3 values (see figs 44, 45 pg. 169 above and table 19 below). Target trills were found to have higher F1, lower F2 and lower F3 values than alveolar laterals in Malayalam (Figs. 44 and 45 pg. 169 above and table 19 below).

	Alv. Laterals		Rtf. laterals		TP-TP		TR-TP		TR-TR	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
F1 onset	381	48	442	84	383	60	445	64	513	114
F1 mid	369	40	436	78	378	50	444	63	494	68
F1 offset	389	47	449	80	394	53	457	62	496	59
F2 onset	1666	215	1277	198	1714	200	1241	180	1220	158
F2 mid	1698	253	1309	219	1727	196	1258	181	1213	156
F2 offset	1695	215	1338	223	1751	203	1277	173	1220	140
F3 onset	2529	243	2341	265	2469	220	2294	216	2323	267
F3 mid	2556	257	2356	259	2482	231	2297	223	2299	263
F3 offset	2562	253	2362	253	2495	262	2305	217	2299	243

Table 19. Mean and SD of F1, F2 and F3 onset, mid-point and offset values of laterals and rhotics. TP-TP refers to target taps realised as taps, TR-TP refers to target trills realised as taps and TR-TR refers to target trills realised as trills.

Summary

Laterals in Malayalam differ mainly in their place of articulation: One is lamino-alveolar and the other sub-apical retroflex. Realisation of place of articulation was found to have a significant effect on the formant patterns of the laterals. Alveolar laterals which were always realised as alveolar laterals by all speakers had significantly lower F1, higher F2 and higher F3 values than retroflex laterals which were always realised as retroflex laterals by all speakers. Alveolar lateral fragments realised as alveolar laterals had significantly lower F1 mid-point and offset values, higher F2 values than retroflex lateral fragments realised as retroflex laterals. F3 differences between the two groups were statistically non-significant but of a moderate effect size, the alveolar lateral fragments having higher F3 values than their retroflex counterparts. Alveolar laterals had significantly lower F1, higher F2 values than alveolar lateral fragments and retroflex lateral fragments. Alveolar lateral fragments had significantly lower F1 offset, higher F2, and F3 onset, mid-point and offset values than retroflex laterals. Retroflex laterals and their fragment counterpart did not differ from each other in any of the three formant patterns.

With respect to the vowels preceding the laterals, both realisation of place of articulation and vowel quality had significant effects on mainly their F2 patterns. Vowels preceding alveolar laterals had significantly higher F2 values than those preceding retroflex laterals. The trend was the same between the vowels preceding the alveolar and retroflex lateral fragments. Vowels preceding alveolar laterals had significantly higher F2 offset values than those preceding alveolar lateral fragments. None of the vowels differed in their F1, F2 or F3 values depending on whether they preceded retroflex laterals versus retroflex lateral fragments.

With respect to the vowels following the laterals also, the realisation of place of articulation of the lateral and vowel quality and the interaction of the two factors had significant effects on their formant patterns. Vowels following alveolar laterals had significantly lower F1, higher F2 and higher F3 values than those following retroflex laterals. Long vowels in the data set were not affected by whether it was preceded by alveolar lateral fragment versus retroflex lateral fragment and depending on the quality of the short vowel, the effect of alveolar lateral fragment versus retroflex lateral fragment on its formant structure varied, Vowels following alveolar laterals had significantly higher F2 onset values than those that followed alveolar lateral fragments. Vowels following retroflex laterals had significantly higher F1 onset than those that followed retroflex lateral fragments.

The two laterals were found to share different relationships with the two rhotics in Malayalam. While the target taps and alveolar laterals on the one hand had lower F1, higher F2 and higher F3 values, the target trills and retroflex laterals on the other hand had higher F1, lower F2 and lower F3 values.

This section describes the auditory and acoustic analyses results for the laterals and lateral fragments in Malayalam. The next section will discuss the results obtained for the laterals in the present study in the context of results from previous studies in Malayalam or similar works on other languages.

5.2 Discussion

This section aims to interpret the above findings on the laterals in Malayalam, in the light of the research questions addressed and current phonetic research in the area. The laterals were included in the present study mainly to provide comparative and/or contrastive data as evidence for or against classifying the fifth liquid in Malayalam as a third rhotic or a third lateral. Therefore the present study only considered the singleton laterals in Malayalam since the rhotics and fifth liquid do not occur as geminates and so a direct comparison among the five liquids requires only the singleton laterals.

5.2.1 Auditory analysis

Almost all the target alveolar laterals were realised as alveolar laterals by all the speakers except for three tokens by one speaker which were realised as alveolar taps. All target retroflex laterals were realised by all speakers as retroflex laterals. Alveolar laterals were realised as lamino-alveolar while retroflex laterals were realised as sub-apical. The former sounded ‘clearer’ and the latter ‘darker’. The vowels surrounding alveolar laterals sounded more fronted and raised while those surrounding retroflex laterals sounded retracted and lowered. As was the case with the rhotics in the present study, the difference in place of articulation and the related differences in their respective resonance characteristics, i.e. clear versus dark feature of alveolar versus retroflex laterals maybe causing their surrounding vowels to be fronted versus retracted and raised versus lowered respectively. Like auditory impressions of the Malayalam laterals in the present study, Simpson (1996) also observed in his study of Albanian liquids the clear versus dark difference in resonance between the two laterals, a clear alveolar lateral and a dark dental lateral. The surrounding vowels were also perceived as being advanced and raised versus retracted and more open respectively. The significance of resonance effects in contrast maintenance will be dealt with in more detail in Chapter 7, the general discussion chapter.

5.2.2 Acoustic Characteristics

This section will focus on the questions and issues pertaining to the results of the acoustic analyses of the laterals in the present study.

5.2.2.1 Duration

Consonant Duration

The intervocalic position is the most significant context for laterals in Malayalam since the two laterals are lexically contrastive in this word-position. It is also the only common word-position in which both the laterals occur. Statistically, alveolar laterals were found to be significantly longer in duration than retroflex laterals. Although, these differences were significant with effect sizes being medium or large, the actual differences in duration between the laterals was about 10ms. Moreover, the Standard Deviation values were high in relation to the mean value, which implies that there was considerable overlap in duration measures between the two laterals across the eight speakers. Taking into account the high SD values and 10ms mean difference in duration, it seems that duration may not play an important role in differentiating between the alveolar and retroflex laterals in Malayalam. There were no specific predictions outlined in this thesis regarding the duration of the laterals playing any role in their contrast maintenance.

Vowel duration

Vowel duration was significantly affected by the realisation of manner of articulation of the laterals: Longer when preceding alveolar laterals and shorter when preceding retroflex laterals but the effect size of this difference was small. The standard deviation values were high relative to the mean duration values implying that there was considerable overlap between duration measures of the two laterals between- speakers and/or within-speaker. This result for vowel duration preceding the laterals in Malayalam may be reflecting the patterns observed for the lateral consonants themselves, i.e., statistically significant durational difference of longer alveolar laterals versus shorter retroflex laterals but high standard deviation values indicating overlapping mean duration values across speakers and/or within-speakers. Vowel quality was also not found to be a significant factor in determining their duration. Duration of the laterals and their surrounding vowels in general do not appear to be a robust acoustic correlate of the distinction between the two laterals or their surrounding vowels in Malayalam.

5.2.2.2. Formant Frequencies

Laterals

Realisation of the place of articulation was found to have a significant effect on the formant patterns of the laterals in Malayalam. The alveolar laterals were found to have lower F1, higher F2 and higher F3 values than retroflex laterals at onset, mid-point and offset. The first formant frequency of laterals has previously been found to be directly proportional to the width of the lateral opening (Fant, 1960). The higher F1 of the retroflex lateral as compared to the alveolar lateral may be attributed to the relatively narrow tongue blade and the bunching of the tongue to allow the underside to contact the hard palate creating more distance between the roof of the mouth and the sides of the tongue thus consequently increasing the width of the lateral opening. The lower F2 may be due to the relative darkness of the retroflex lateral as opposed to the higher F2 and clearness of the alveolar lateral. The difference in their F3 values is indicative of their place of articulation difference, alveolar being by definition more fronted and thereby creating a smaller front cavity consequently exhibiting the higher F3 values than the more retracted retroflex lateral which has the larger front cavity. Menon (1973) in the only other spectrographic study of Malayalam laterals also found the same results as those of the present study. He points out that the lower F2 frequency of the retroflex lateral could be due to the increased narrowing of the pharyngeal region or the retroflexion of the tongue since retroflexion, pharyngealization and lip-rounding are all known to produce the same acoustic effects of a decrease in the high formant frequencies. Due to the relatively large gap between F2 and F1 for both laterals in Malayalam, Menon suggests that the laterals are perhaps produced with a wide pharyngeal cavity in the language.

Tamil, the parent language of Malayalam, also has two laterals in its inventory, a retroflex lateral and one that has been variously called laminal denti-alveolar lateral (McDonough & Jackson, 1997) and apical dental lateral (Narayanan et al, 1999). The retroflex lateral in Tamil was found to have its F2 and F3 close together (F2=1460Hz, F3=1800Hz) whereas the apical dental lateral had a lower F2 than the retroflex lateral (F2=1200Hz) but a higher F3 (2400Hz) (Narayanan et al, 1999). The retroflex laterals in Malayalam in the present study seem to differ from those described in Tamil in that the F3 values are higher in Malayalam (2356Hz) than in Tamil (1800Hz) while the F2 values seem to be in the same range (1309Hz for Malayalam and 1460 reported for Tamil). This might imply that retroflexion is perhaps stronger in the Tamil lateral than in its

Malayalam counterpart. Phonetic realisations of retroflexion are known to vary across languages and language families (Hamann, 2002; Ladefoged & Maddieson, 1996; Simonsen et al, 2008 etc.). The difference between the two laterals in Tamil seems to be one of retroflex versus non retroflex and back versus front. It is not certain whether there is a sub-apical versus laminal contrast since there is no consensus on the nature of tongue contact of the second lateral (apical or laminal). McDonough & Johnson have provided no mean F2 or F3 values for the laterals in their study and the values mentioned in Narayanan et al (1999) of low F2, high F3 seem to be more consistent with their MRI evidence that suggests a more apical rather than laminal dental lateral. In Malayalam, the difference between the two laterals seems to be based on the following oppositions: retroflex versus non-retroflex (alveolar in this case), dark versus clear, sub-apical versus laminal respectively. The difference in resonance between the laterals could be a direct consequence of the difference in place of articulation of the laterals. It has to be noted that the degree of retroflexion of the retroflex lateral varies with respect to the surrounding vowel environment, i.e. darker and stronger retroflexion surrounding back and open vowels as opposed to front and close vowels, and also with respect to speech rate. Nevertheless auditorily, irrespective of the degree of retroflexion or nature of surrounding sounds, minimal pairs could be differentiated based on resonance characteristics: The target words containing the retroflex lateral sounded darker as a whole than those containing the alveolar lateral.

Albanian laterals are also characterised by resonance differences as in Malayalam. Albanian has two laterals, a clear alveolar lateral and a dark dental lateral characterised by a high F2 in the former and a low F2 in the latter and maximally different during the lateral approximant (Simpson, 1996). The rhotics in Albanian also showed similar resonance differences as their laterals: clear lamino-alveolar tap versus dark apico-alveolar trill (cf. Ch. 1, pg. 21) similar to the rhotics and laterals in Malayalam as shown in the present study. Resonance effects and their significance in phonetic and phonological contrast maintenance will be dealt with in greater detail in Chapter 7.

<u>Preceding vowels</u>

The realisation of the place of articulation of the laterals and quality of the preceding vowel were both found to have significant effects on the formant patterns of the vowels preceding laterals. In general, vowels preceding alveolar laterals were found to have higher F2 and higher F3 values than those preceding retroflex laterals. This would suggest that the vowels preceding alveolar laterals were raised and more advanced than those surrounding retroflex laterals. These results are largely consistent with the auditory impressions of the differences between the vowels surrounding the two laterals.

Apart from the extrinsic effects of the place of articulation of the laterals on their preceding vowels, there were intrinsic effects of vowel quality i.e., their height and front/back dimension, on their formant patterns. On conducting a MANOVA on a more specific data set split according to preceding vowel type, none of the vowel types were found to differ in their F1 or F3 mid-point and offset values. F2 appeared to be the most robust acoustic correlate of differences between vowels surrounding the two laterals. /a/, /aa/, /oo/, /u/ preceding alveolar laterals had significantly higher F2 values at mid-point and offset than when preceding retroflex laterals. /i/ preceding alveolar laterals had significantly higher F2 values compared to /i/ preceding retroflex laterals only at offset. This might imply the most consistent difference between the vowels preceding the two laterals is based on a clear (before alveolar laterals) versus dark (before retroflex laterals) distinction and/or a raised versus retracted distinction respectively.

Unlike the present study, Menon in his study of VCV sequences produced by five native Malayali speakers did not find a consistent effect of the laterals on their surrounding vowels. He notes that the retroflex lateral generally has a F2 lowering effect on its surrounding vowels but this effect was found to be a small one. He however claims that the effect of the retroflex lateral was greater on the preceding front vowels whereas the present study found that both the laterals had significant effects on the F2 values of all the preceding vowels. The pattern in the present study seems to suggest that the preceding front vowel, i.e., /i/ was only affected significantly at the offset by the following laterals unlike what Menon's results claimed. The significance only at F2 offset of /i/ preceding alveolar versus retroflex lateral in this study may be attributed to the opposing nature of articulatory conditions required to produce /i/ immediately followed by a retroflex lateral. The opposite requirements for the production of /i/ and /ɭ/ perhaps inhibit the coarticulatory effects of the retroflex lateral to the offset of /i/ thus making the difference between /i/ preceding alveolar laterals versus /i/ preceding retroflex lateral strongest at the offset.

In Menon's study, nevertheless, F2 and F3 transitions in vowels surrounding the laterals have been reported to be a distinguishing cue between the two laterals in

Malayalam. The F2 and F3 terminal frequencies of vowels surrounding the retroflex lateral were lower than those surrounding the alveolar lateral. These results are partially similar to those of the present study in which F2 values of the vowels surrounding the retroflex lateral were found to be lower than those surrounding the alveolar lateral.

In Albanian, vowels preceding the lamino-alveolar lateral versus apico-dental lateral were found to differ based on the former being clearer versus the latter sounding darker characterized by higher versus lower F2 values respectively (Simpson, 1996). A similar effect of the resonance differences of the laterals on their preceding vowels has also been found in the present study as mentioned earlier in this section. Open vowels preceding dark words in Albanian were found to be more retracted than their clear counterparts whereas the close vowels preceding dark words were found to be more open but further forward than their clear counterparts. These findings were unlike Simpson's auditory impressions of close and open vowels surrounding the dark lateral being retracted and more open than their clear counterparts. In the present study, however, both close and open vowels in the data set, i.e., /i/ and /a/, when preceding the dark lateral (retroflex lateral) were found to be more open and retracted than when preceding the clear lateral (alveolar lateral).

Following vowels

Realisation of the place of articulation of the lateral, and vowel quality, were found to have a significant effect on the formant frequencies of the vowels following the laterals in Malayalam. Vowels following alveolar laterals were found to have lower F1, higher F2 and higher F3 vowels than vowels following retroflex laterals. /i/ and /a/ were the only following vowels common to the alveolar and retroflex laterals and both had lower F1, higher F2, and higher F3 when following alveolar laterals as opposed to when following retroflex laterals. This result might be implying that the vowels following alveolar laterals tend to be closer and more advanced than vowels following retroflex laterals whereas the latter tend to be more open and retracted than the former. Interestingly, /a/ preceding alveolar laterals differed from /a/ preceding retroflex laterals only in its F2 values, the former being higher than the latter whereas /a/ following alveolar laterals had lower F1, higher F2 and higher F3 than /a/ following retroflex laterals. Below is a table that shows the F1, F2, F3 values of /a/ and /i/ preceding alveolar versus retroflex laterals and /a/ and /i/ following alveolar versus retroflex laterals.

		V1 MID-POINT		V2 MID-POINT	
		ALV.LAT	**RTF.LAT**	**ALV.LAT**	**RTF.LAT**
/i/	**F1**	385	383	380	407
	F2	2013	**1665**	2087	**1901**
	F3	**2609**	**2393**	**2836**	**2614**
/a/	**F1**	696	707	622	675
	F2	**1501**	**1319**	**1702**	**1405**
	F3	2454	2415	2543	2502

Table 20. F1, F2 and F3 mid-point values of /i/ and /a/ preceding (V1) and following (V2) alveolar vs. retroflex laterals. The values in bold highlight the more prominent differences.

From the above table, it seems to be that the F2 mid-point values of /i/ were considerably lower when preceding the retroflex lateral than when following it which could be suggesting that the anticipatory effects of the retroflex lateral on /i/ were stronger than its carry-over effects. The same was true for /a/: F2 mid-point values were lower when preceding the alveolar and retroflex lateral than when following them. But with respect to the alveolar lateral, the opposite seems to be true. The effects of the clear resonance of the alveolar lateral appear to be stronger when /a/ follows it than when /a/ precedes it since F2 of /a/ was higher when it followed alveolar laterals than when it preceded them. In general, F2 frequencies of /a/ were higher when following the two laterals than when preceding them which is similar to the results found by Menon (1973). He also found an increase in the F2 frequencies of all the back vowels in his data /a/, /o/, /u/ when following the laterals in Malayalam than when preceding them. He attributes this pattern of the back vowels to the adjacent laterals being produced with a relatively wide pharyngeal ‘pass’. The present author is in agreement with Menon since narrow pharyngeal constrictions is correlated to a decrease in F2 and therefore when back vowels are preceded by sounds produced with a relatively wide pharyngeal pass, the carry-over effects of the latter should cause an increase in the F2 of the back vowels. F3 values of /i/ were also considerably lower when preceding alveolar and retroflex laterals than when following them. Similar patterns were found in Menon (1973) for /i/ and other front vowels: lower F3 values when preceding the laterals than when following them. However, the results of the present study differed from Menon’s study in that while the latter found F2 frequencies of vowels surrounding alveolar versus retroflex laterals to differ only very slightly, the present study found F2 differences between the vowels surrounding the two laterals in Malayalam to be robust.

In Albanian, the following vowel portions were clearly demarcated acoustically depending on whether they followed the lamino-alveolar versus apico-dental lateral, i.e., clearer after the former versus darker after the latter; raised and advanced after the former versus retracted and more open after the latter (Simpson, 1996). These results are similar to those of the present study in which the vowels following alveolar laterals versus those following retroflex laterals were acoustically distinct (cf. Fig. 42, 43, pg.167), particularly with respect to the F2 values, i.e. the acoustic correlate of clearness and darkness.

Lateral Fragments

Auditory analyses

Results of the auditory analysis revealed that the alveolar lateral fragments sounded like the alveolar laterals, only less clear in resonance than the latter. Retroflex lateral fragments on the other hand sounded darker in resonance than the retroflex laterals in Malayalam. These differences between the laterals and their corresponding lateral fragments were more prominent auditorily when the latter occurred word-medially. This may be because of the phonotactic environment of word-medial lateral fragments, i.e., post-vocalic and pre-consonantal and the lateral fragment marks the end of the first syllable in such cases. In languages like English which have several dialects known to have dark laterals, it is most commonly found at the end of syllables or syllable finally. Word-final lateral fragments in Malayalam occur post-vocalically. Although in citation forms they may be produced as syllabic l's, due to the presence of the carrier phrase in the present study and the immediately adjacent sound of the following word also being a vowel (/e/ in /en̺n̺ə/), speakers produced them largely as they did their intervocalic non-fragment laterals. Between the two lateral fragments, the relationship was the same as that between the two laterals, i.e., the alveolar lateral and alveolar lateral fragments sounded clearer than their respective retroflex counterparts.

Acoustic analyses

Duration

With respect to the acoustic characteristics of the lateral fragments in comparison to those of the laterals, duration did not appear to be a significant factor in general. Only retroflex lateral fragments were significantly different in duration from their non-fragment counterparts, the former being longer than the latter. Alveolar laterals and alveolar lateral fragments were not found to differ significantly in their duration measures. The magnitude of the duration difference between the alveolar and retroflex lateral fragments was also found to be small. Word-position was found to have a significant effect on the duration of the lateral fragments. Word-final lateral fragments were found to be significantly longer than their word-medial counterparts. The presence of a word boundary in the case of the word-final lateral fragments may also be allowing for increased lengthening of the segments rather than when they occur word-medially and pre-consonantly. This difference may also be attributed to the difference in the nature of the surrounding sounds in both word-positions: For word-medial lateral fragments, preceding sounds are vowels and following sounds are plosives whereas word-final lateral fragments are preceded by a vowel and due to the particular carrier phrase used in the present study / avaroɖə __ en̪n̪ə parajuka / were always followed by the /e/ of the adjacent word /en̪n̪ə/ making it an intervocalic environment in effect. With respect to the preceding vowel duration, vowels preceding alveolar lateral fragments were found to be significantly shorter than those preceding retroflex lateral fragments but the mean durational difference was 40ms and SD values for both were at least 50ms or greater suggesting there was considerable overlap in duration measures across speakers and within categories.

Formant Frequencies

With respect to formant frequency differences between the two lateral fragments and between the lateral fragments and the laterals, results indicated that differences in F1 and F3 values between the alveolar and retroflex lateral fragments were small while differences in their F2 values were larger and more robust. Alveolar lateral fragments were found to have higher F2 values than retroflex lateral fragments. These patterns are consistent with auditory impressions of the alveolar lateral fragments being clearer and retroflex lateral fragments being darker in resonance. This is similar to the difference between the alveolar and retroflex laterals, the former being clearer and the latter darker. The alveolar laterals were found to have lower F1 and higher F2 values than their fragment counterparts. The difference in F2 values with alveolar laterals having the higher F2 values than alveolar lateral fragments is consistent with the author's auditory impressions of the latter as being less clear in resonance than the former. It has to be noted that since non-fragment and fragment laterals commonly occur only in the word-medial position, word-final lateral fragments were not directly compared with the laterals here. The difference in F2 values implying perhaps a difference in resonance between alveolar laterals (clearer) and alveolar lateral fragments (less clear) may be attributed to their surrounding sounds. In the data set, most of the examples of word-medial alveolar lateral fragments had velar plosives following the alveolar lateral fragment and hence they could have reduced the perceptual and acoustic effects of the clear resonance otherwise associated with alveolar laterals in Malayalam. However, the auditory impression of the retroflex lateral fragments sounding darker than their non-fragment counterparts was not found to be reflected in their acoustic features with both not significantly differing in any of the three formant frequency measures.

The only preceding vowel context common to alveolar lateral fragments and retroflex lateral fragments were /a/ and /aa/ and of these only /aa/ preceding alveolar lateral fragments had significantly higher F2 mid-point and offset values than /aa/ preceding retroflex lateral fragments. Similarly the only common preceding vowel contexts in the data set for alveolar laterals and alveolar lateral fragments were /a/ and /aa/ and of these only /a/ preceding alveolar laterals had significantly higher F2 offset values than /a/ preceding alveolar lateral fragments. There were too few vowel types in the data set to be able to draw a more general conclusion regarding their behaviour in the environment of the two lateral fragments or between the fragment and non-fragment laterals. /a/, /aa/ and /u/ were the preceding vowels common to retroflex laterals and retroflex lateral fragments and none of these vowels differed in their F1, F2 or F3 measures based on whether they preceded retroflex laterals versus retroflex lateral fragments. In general, it appears to be the case that apart from intrinsic differences between different vowel types, there were little or no consistent systematic differences in the formant patterns of vowels preceding the alveolar versus retroflex lateral fragments and vowels preceding the two lateral fragments versus the two laterals. More data is needed before any further speculations can be made regarding the vowels surrounding the lateral fragments and how they differ from their counterparts surrounding the laterals.

With respect to the following vowel patterns, vowel type was found to have a significant effect on the formant patterns of vowels following alveolar lateral fragments versus retroflex lateral fragments. /a/, /aa/ and /e/ were the common vowel types following alveolar lateral fragments and retroflex lateral fragments. While /e/ had significantly lower F1, higher F2 and higher F3 when following alveolar lateral fragments as opposed to following retroflex lateral fragments, /a/ differed only in its F2 and F3 onset values: higher when following alveolar lateral fragments as opposed to following retroflex lateral fragments. /aa/ did not differ in any of its formant frequencies based on whether it followed either of the two lateral fragments. /aa/ being a long vowel may be less influenced by the effects of the adjacent lateral fragments. With the short vowels /a/ and /e/, F2 differences appear to be the most common effect of the adjacent lateral fragments: higher surrounding an alveolar lateral fragment and lower surrounding a retroflex lateral fragment. This then suggests that at least in the case of the short vowels, the co-articulatory effects of the alveolar versus retroflex lateral fragments or their respective clear versus dark resonance effects were uninhibited by the presence of the stop in between the lateral fragment and the following vowel. Such long-domain coarticulatory effects of laterals and even rhotics have been found in recent studies on English data (Heid and Hawkins, 2000; West, 2000). /a/, /aa/ and /ee/ following alveolar laterals had significantly higher F2 onset values than /a/, /aa/ and /ee/ following alveolar lateral fragments. The only vowel type in the data set that was common to retroflex laterals and retroflex lateral fragments was /a/. /a/ following retroflex laterals had significantly higher F1 onset values than /a/ following retroflex lateral fragments.

Relationship with rhotics

Target taps and alveolar laterals were found to have lower F1, higher F2 and higher F3 values compared to the target trills and retroflex laterals. These results seem to imply that rather than there being two distinct categories of laterals versus rhotics, acoustically there seems to be a lot of interaction between these two sound groups based on their resonance, place of articulation and/or tongue configuration. Target taps and alveolar laterals have a clear resonance and relatively fronter place of articulation combined with a convex tongue configuration associated with laminal (tongue-blade) articulations. On the other hand, target trills and retroflex laterals have a darker resonance and relatively retracted place of articulation combined with a concave tongue configuration associated with apical/sub-apical articulations (cf. chapter 4, pgs. 126-127).

With respect to the differences between laterals and rhotics, two of the most prominent factors reported in the general literature are the presence versus absence of anti-formants in laterals versus rhotics respectively (Kent & Reed, 1992; Johnson, 2003) and a lowered F3 to indicate rhoticity (Lindau, 1985) based mainly on data from English (e.g. Delattre and Freeman, 1968; Espy-Wilson, 1992). There are, however, claims that some rhotics, like laterals, also exhibit acoustic zeroes in their spectrograms (Stevens, 1998:540-542) and also in the present study, the author only made informal measurements of anti-formants, which showed no consistent differences between the laterals and the rhotics. Therefore the role of anti-formants in distinguishing between rhotics and laterals does not appear to be as straightforward as generally suggested. More formal measurements of anti-formants as described in Johnson (2003) are beyond the scope of this study but an area of research that future scholars should take up in order to gain a better understanding of the acoustic differences between laterals and rhotics and the nature of their interactions within the same language. Future work can also use articulatory techniques like the EPG to shed light on the precise nature and extent of the occlusion in these various liquids.

With respect to lowered F3 values indicating rhoticity, the present study found no clear acoustic demarcations between laterals and rhotics based on their F3 values. The grouping appears to be based on place of articulation and/or tongue configuration than rhotics versus laterals. Lamino-alveolar laterals were found to have the highest F3 values[5] (2556 Hz) followed by lamino-alveolar taps (2492 Hz), the difference between the two not statistically significant. Trills and retroflex laterals were found to have the lowest F3 values among the four liquids. Trills (2296 Hz) had lower F3 values than the retroflex laterals (2355 Hz) but the difference was not found to be significant. These results seem to suggest that a low F3 may not always be an indicator of rhoticity. Examples of exceptions from other languages have also been noted by Ladefoged and Maddieson (1996). In languages like Malayalam that have a large liquid inventory constituting more than one rhotic and more than one lateral, there is bound to be interaction between the liquids and the rhotic-lateral division may be more secondary to the clear-dark division,

[5]Although measurements were made at onset, mid-point and offsets for the consonants in the study, only the mid-point is mentioned here for ease of comparison.

laminal-apical/sub-apical and front-back division. The rhotic-lateral division in multiple liquid inventories may perhaps be prominently an auditory and articulatory distinction based not merely on segmental features like nature of the occlusion and tongue configuration but also suprasegmental or prosodic features like relative intensity and amplitude etc. In Narayanan et al's study of Tamil liquids (1999), the researchers found that the postulation of a separate class of rhotics and a separate class of laterals was justified mainly by the results of their articulatory data. Narayanan et al suggests that evidence for a larger class of liquids has a largely acoustic basis. These results from Tamil are consistent with the speculations of the present study for Malayalam in that the liquid group in general appears to have an acoustic basis. Unlike the recent studies on Tamil, however, the present study did not use any articulatory techniques, and therefore it is impossible to comment conclusively on the articulatory-acoustic relations among the liquids in Malayalam. Nevertheless, from the acoustic results in the present study, the picture regarding the acoustic consequences of the articulatory differences that presumably exist between rhotics and laterals does not appear to be a clear one. Note also that the present study only measured the first three formant frequencies and higher frequencies particularly F4 values have been claimed to provide valuable acoustic information to distinguish between liquid members or indicate rhoticity in recent studies (e.g. Narayanan et al, 1999 and Waltmunson, J. 2005). The rather elusive picture regarding an acoustic basis that justifies the rhotic-lateral division may perhaps be attributed to the absence of F4 measurements in the present study's results. Also, due to the lack of articulatory data in the present study, the author can only speculate inconclusively regarding what forms the basis of a rhotic-lateral distinction. Future research based on extensive articulatory data using EPG and/or MRI data seems inevitable in enabling a better understanding of the relationship between rhotics and laterals and their distinctive characteristics that justify their separate classifications.

<u>Summary</u>

The two laterals in Malayalam differed from each other in their place of articulation, resonance characteristics and their subsequent effect on their surrounding vowels. The alveolar lateral, as per its definition, was realised further forward than the retroflex lateral and is clearer in resonance than the retroflex lateral. The alveolar lateral was produced with a laminal place of articulation while the retroflex lateral was produced with a sub-apical place of articulation. As a result of these consonantal differences, there appear to be systematic differences between the vowels surrounding alveolar versus retroflex laterals. Vowels surrounding the alveolar lateral were more advanced and raised while those surrounding the retroflex lateral were more retracted and open (see figures below)

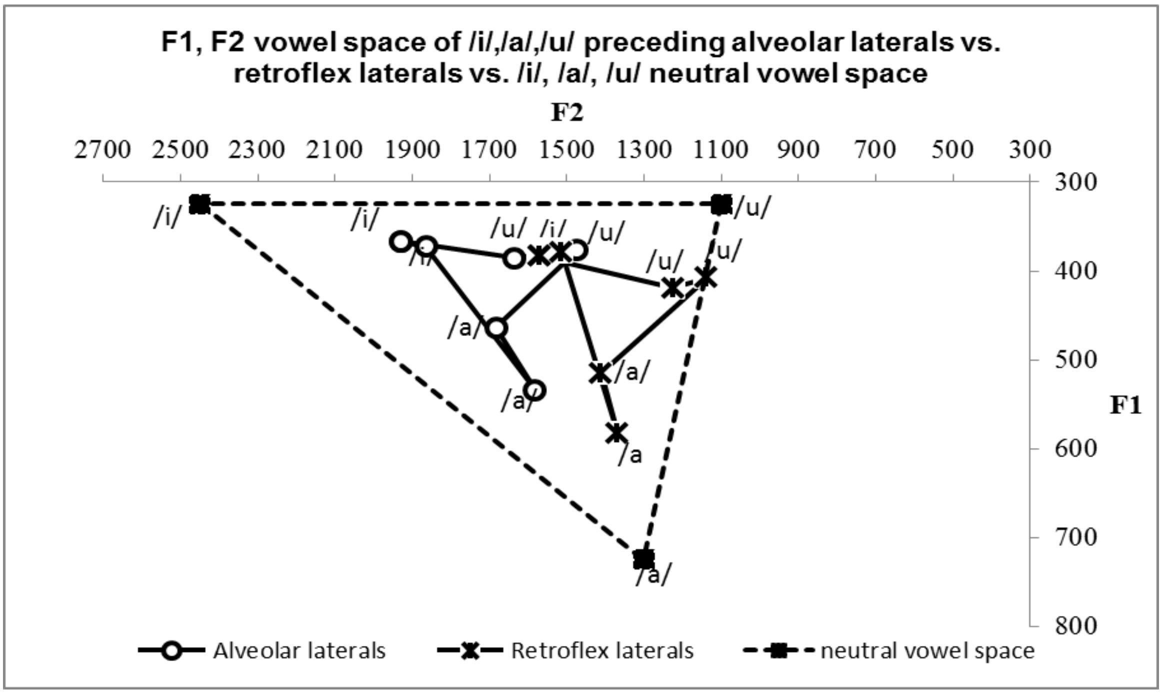


Fig. 46 F1, F2 Vowel space of /i/,/a,/u/ preceding alveolar laterals versus retroflex laterals in Malayalam. Also, F1, F2 vowel space of /i/, /a/, /u/ in non-liquid/neutral environment (fig. 34, pg. 148) is superimposed on the figure above.

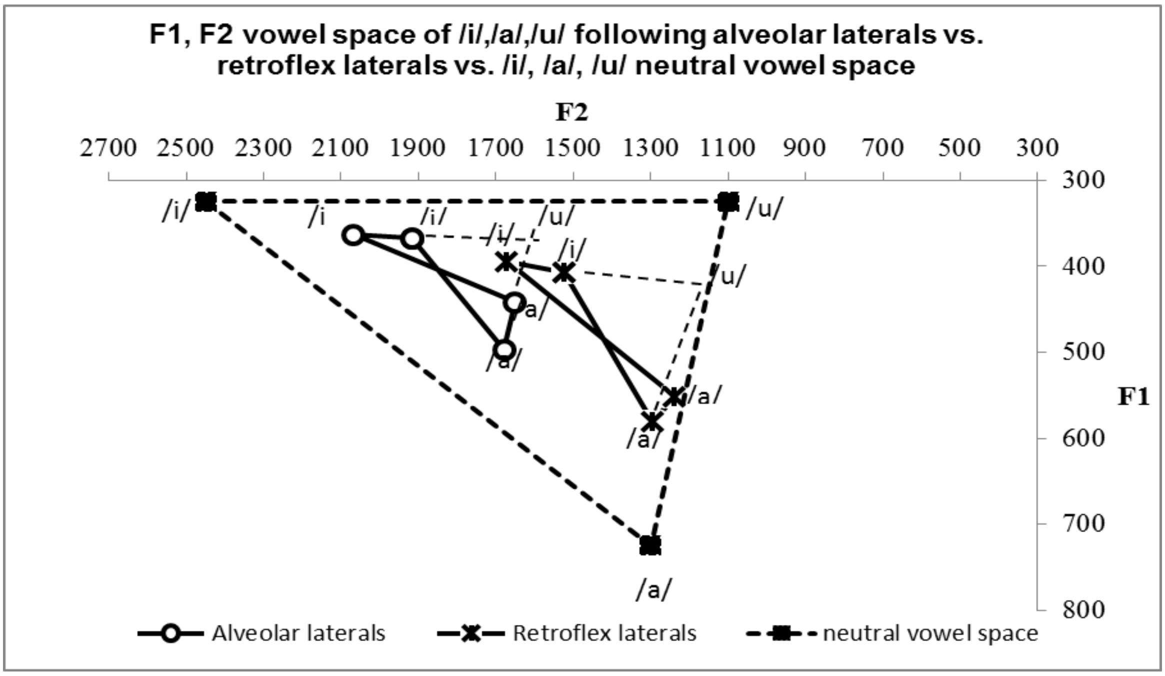


Fig. 47. F1,F2 vowel space of /i/,/a/,/u/ following alveolar laterals versus retroflex laterals in Malayalam. Also, F1, F2 vowel space of /i/, /a/, /u/ in non-liquid/neutral environment (fig. 34, pg. 148) is superimposed on the figure above.

From the above two figures, there does not seem to be a large difference between the vowel spaces of /i/,/a/,/u/ preceding alveolar laterals, retroflex laterals versus /i/,/a/,/u/ following alveolar laterals, retroflex laterals. /a/ appears to have a lower F2 following the retroflex lateral than when preceding it and /i/ appears to have a higher F2 when following the alveolar lateral than when preceding it. This particular patterning may be due to the compatibility between the articulatory requirements for /a/ and a retroflex lateral (both back articulations) and for /i/ and an alveolar lateral (both fronted articulations involving tongue raising). Also, the greater effect of the laterals on their following vowels than on their preceding vowels might be suggesting that the laterals, like the rhotics, may be exerting more carry over coarticulatory effects than anticipatory effects (although the difference does not seem to be as large as that in the case between vowels following the rhotics and vowels preceding the rhotics, cf pgs. 145-147). In each of the above two figures, comparing the vowel space surrounding the laterals with the superimposed plot of the F1, F2 vowel space of /i/,/a/ and /u/ in a non-/liquid or neutral environment shows that the laterals have a great effect in general on their surrounding vowels reducing the vowel space area.

In general, the lateral fragments sound similar to the regular non-fragmental laterals and the contrasts between alveolar and retroflex lateral fragments was similar to those between alveolar and retroflex (non-fragmental/regular) laterals.

The relationship of the laterals with the rhotics in Malayalam was found to be more interactive and less categorical, In other words, the relationship appears to be based more on resonance characteristics than manner of articulation groupings like rhotic versus lateral, i.e. clear versus dark and therefore lamino-alveolar tap, lamino-alveolar lateral on the one hand versus apico-alveolar trill, sub-apical retroflex lateral on the other. Low F3, often claimed to be an indicator of rhoticity, was not found to be exclusive to only the rhotics in Malayalam. Results obtained in recent studies on Tamil described in the previous subsection and those of the present study suggest that articulatory differences that exist among liquids may not always share a one-to-one correspondence with the acoustic structure of the various liquid members.

This chapter described the auditory and acoustic results obtained for the laterals in the present study as produced by eight male native speakers of Malayalam and discussed the patterns observed in the context of similar work in other languages and previous work on Malayalam. The next chapter will report the auditory and acoustic results of the fifth liquid productions in this study.

CHAPTER 6
RESULTS AND DISCUSSION III: Fifth Liquid

This chapter describes the results of the auditory and acoustic analyses of the fifth liquid tokens in comparison and contrast to the results of the rhotics and laterals as produced by eight male speakers of Malayalam and interprets the findings in relation to recent work on Tamil that is reported to have a similar sound. The results and the discussion sections have two main subsections: results/discussion from the auditory analysis and results/discussion from the acoustic analyses. The auditory analysis sections describe and interpret findings from the author's auditory impressions of the target tokens and their surrounding sounds. The acoustic analysis section describes and interprets findings based on two sets of measurements, duration and formant frequencies of the target tokens and their surrounding vowels. This section includes results from the statistical analyses conducted on the data using SPSS with significance measured at the 0.001 level.

6.1Results

6.1.1 Auditory analyses

All tokens of the fifth liquid produced by all speakers sounded like an approximant with a place of articulation that sounded further back than the alveolar ridge but not 'retroflex'. The production of the fifth liquid tokens do not seem to involve the *under-side of the tongue tip* moving towards the post-alveolar region in a back-to-front movement like the other retroflex consonants in the language. The speakers' productions instead gave the impression of tongue tip/blade being raised towards the post-alveolar region. It also seemed to have a clear resonance which ties in with the above mentioned impression of tongue tip/blade raising. Therefore its narrow phonetic transcription has been assigned as [ɹ̠ʲ]. Auditorily therefore it can best be described as a clear post-alveolar approximant. The vowels surrounding the fifth liquid, irrespective of whether they are front or back, sound fronted and raised, unlike vowels surrounding a typical 'retroflex' sound.

6.1.2 Acoustic analyses

This section is further divided into two: Spectrographic analysis results and Acoustic measurements, i.e. duration and formant frequencies.

6.1.2.1 Spectrographic analysis

Comparison to rhotics

Comparing Figs. 48 and 49 (next page), it seems that the fifth liquid and the tap have F2, F3 values in approximately the same range. Their surrounding vowels show relatively the same pattern too: high F2 values around 2000 Hz and F3 values below 3000Hz. Although the slope of the formant transitions was not measured in the present study, it looks steeper and larger during the vowels preceding and following the fifth liquid than the tap. The rise in F2 of the preceding vowel starts earlier in the tap sequence than it does for the fifth liquid and is more gradual in the case of the former than the latter and remains steady through the tap and rises further into the following /i/. In the latter's case, F2 is steady till mid-point after which there is a marked rise till the consonant and remains steady through the consonant and rises further into the following vowel since the following vowel is /i/. In the word containing the tap, there is a gradual yet steady rise in F3 during the preceding vowel /a/ until the tap itself during which F3 remains steady between 2500 and 3000Hz and further increases into the following /i/. In the fifth liquid counterpart, however, there is a slight lowering of F3 during the preceding vowel /a/ but at the offset there appears to be a sudden rise in F3 which then remains steady during the consonant between 2500-3000Hz and increases slightly in the following /i/.

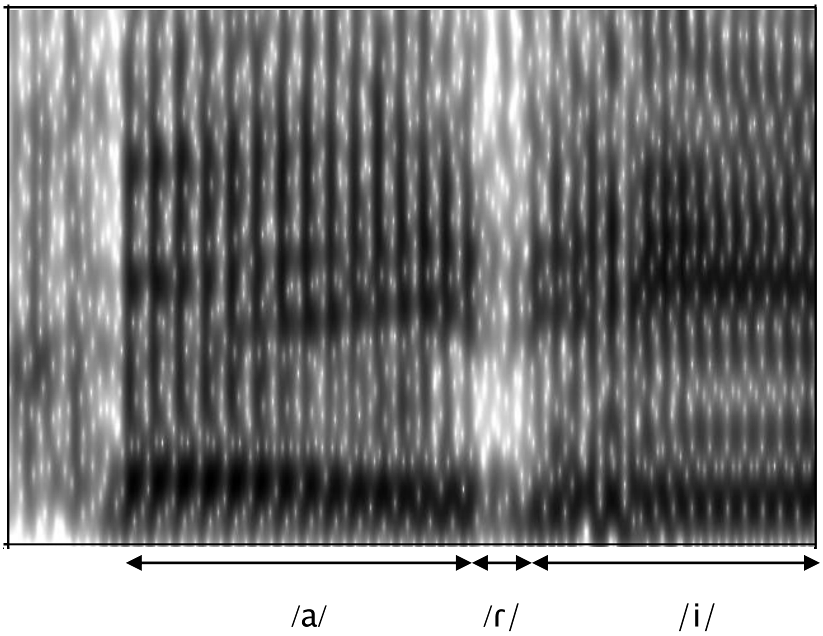


Fig. 48. Spectrogram of the word /kaɾi/. The double arrows indicate the segmental boundaries of the preceding vowel (/a/), rhotic (/ɾ/) and following vowel (/i/) in the word /kaɾi/.

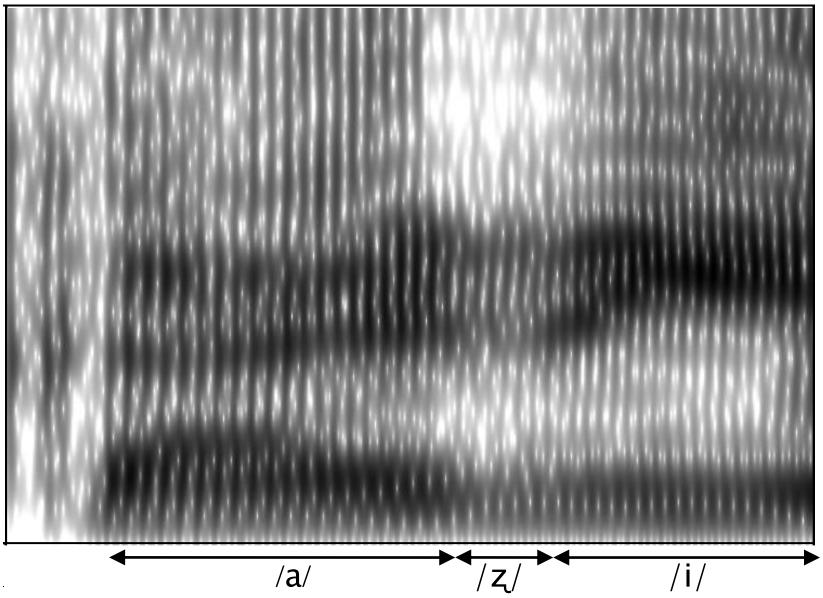


Fig. 49. Spectrogram of the word /kaʐi/. The double arrows indicate the segmental boundaries of the preceding vowel (/a/), fifth liquid (/ʐ/) and following vowel (/i/) in the word /kaʐi/.

Comparing the fifth liquid in Fig. 49 above to the trill counterpart in fig. 50 (next page), it is clear that the difference in F2 is the most prominent, with the fifth liquid having a higher F2 than the trill. F3 is lower for the trill and higher for the fifth liquid. The formant transition patterns of the /a/ preceding the fifth liquid versus trill sequences appear to be more different than that of their following vowel /i/. The following vowel/i/

in both the figures has similar transition patterns though the values particularly F2 were higher in /kaɻi/. As for the /a/ preceding /kaɻi versus /kari/, there is a gradual rise in F2 during /a/ of /kaɻi/ as opposed to a steady low F2 throughout /a/ in /kari/. There is also a slight gradual drop in F3 of /a/in /kaɻi/ followed by what appears to be a sudden rise at the offset as opposed to a steady lower F3 throughout the /a/ in /kari/. F1 values appear to be higher before and during the trill than the fifth liquid.

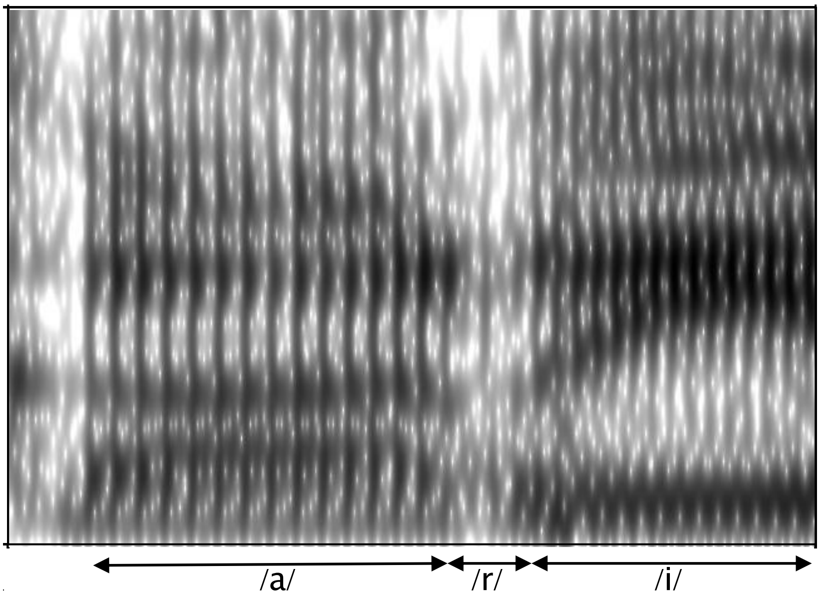


Fig. 50. Spectrogram of the word /kari/. The double arrows indicate the segmental boundaries of the preceding vowel (/a/), trill (/r/) and the following vowel (/i/) in the word / kari /.

Comparison to laterals

The spectrogram of /kali/ (see figure 51 next page) bears several similarities and differences to that of /kaɻi/. With respect to /l/ and /ɻ/, F1 seems lower for /l/ than /ɻ/ and F2 is in the same range for both although the F2 of /l/ is not clearly visible possibly due to the presence of an anti-formant between the F1 and F2 dampening the amplitude of F2. F3 too appears to be in the same range for the alveolar lateral and the fifth liquid. The formant transition patterns of the surrounding vowels also seem to be different, particularly, that of the preceding vowel /a/. /a/ before /ɻ/ has a second formant that rises markedly after the mid-point and until the beginning of /ɻ/ after which it remains steady throughout the consonant and further increases into the following /i/ whereas /a/ before /l/ has a gradually rising F2 from the onset and till the beginning of the consonant. The F3 of /a/ before /ɻ/ drops slightly from onset to mid-point and appears to rise suddenly at offset whereas F3 of /a/ before /l/ rises gradually from mid-point through to the offset.

With respect to the following /i/, both in /kaɻi/ and / kali/, the F2 and F3 values fall between 2000 and 3000 Hz but the formant trajectories appear to be different in the two. Although the slope of the formant transitions was not measured in the present study, from the figs.49 and 51, it seems that the F2 slope is larger for the /i/ in /kaɻi/ than in /kali/.

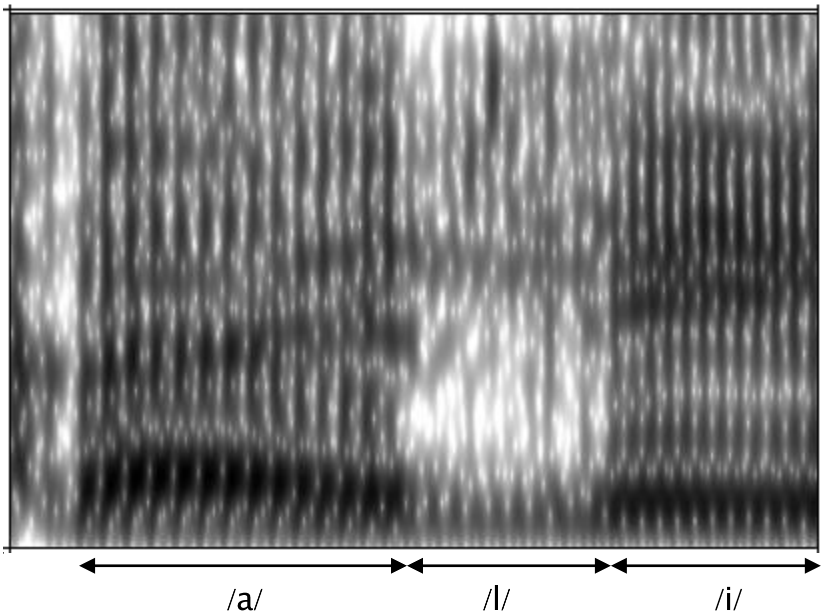


Fig. 51. Spectrogram of the word /kali/. The double arrows indicate the segmental boundaries of the preceding vowel (/a/), alveolar lateral (/l/) and following vowel (/i/) in the word /kali/.

The retroflex lateral in /kaɭi/ as shown in fig. 52 (next page) differs mainly from the post-alveolar approximant/fifth liquid in /kaɻi/ (fig. 49, pg. 189 above) mainly in its F2 values. The retroflex lateral appears to have lower F2 than the fifth liquid. The F3 values seem to be in the same range for both. With respect to the /a/ before /ɭ/ and /ɻ/, F2 is steady and lower in /a/ before the retroflex lateral whereas it is steady and higher and rises gradually from mid-point through to offset in /a/ before the fifth liquid. The F3 trajectory in /a/ before /ɭ/ and /ɻ/ appear to be similar in that there is an initial drop in F3 values from onset through to mid-point following which there seems to be a sudden rise towards the offset. The F2 and F3 trajectories in the /i/ following / kaɭi/ and /kaɻi/ seem to be similar from figures.

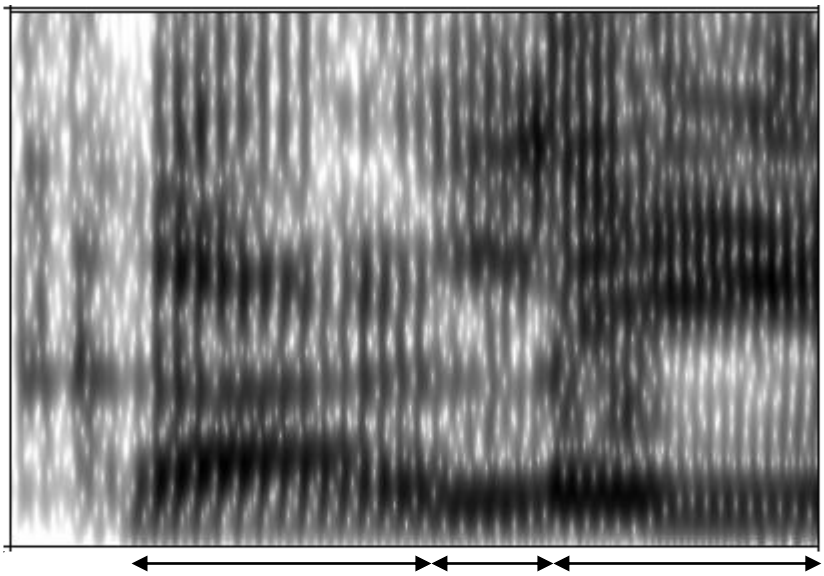


Fig. 52. Spectrogram of the word /kaɭi/. The double arrows indicate the segmental boundaries of the preceding vowel (/a/), retroflex lateral (/ɭ/) and the following vowel (/i/) in the word /kaɭi/.

Fifth liquid in different vowel environments

Given below are spectrograms of one speaker's productions of the fifth liquid in different vowel environments. All the examples below have the same following vowel /a/. The data set had only /a/ and /i/ as following vowel contexts for the fifth liquid. In /piɻa/, the /ɻ/ has a higher F2 and F3 than it does in /paɻam / and both F2 and F3 occur between 1500-3000Hz. In the environment of the back vowel /u/, the F2 and the F3 of /ɻ/ appear to merge or are very close together during the consonant with both F2 and F3 occurring between 1500-2200Hz.

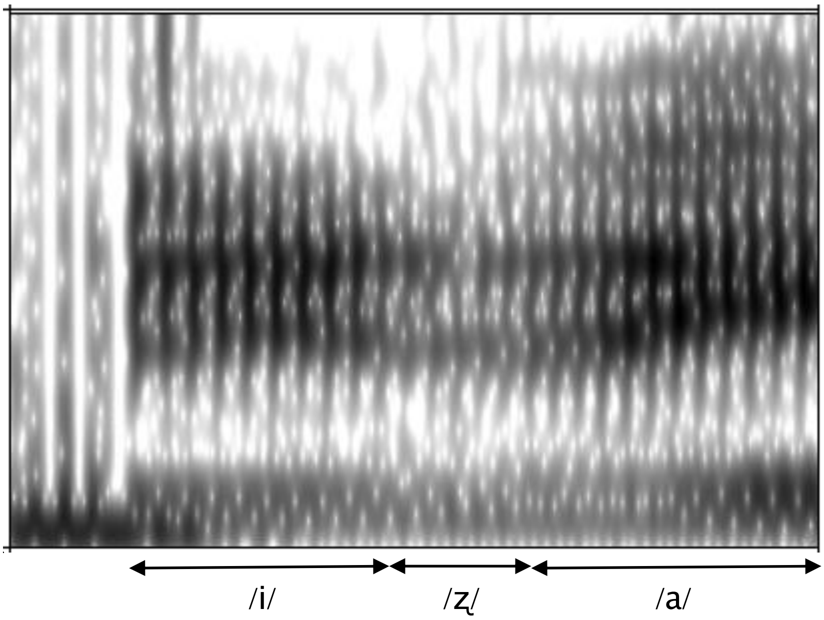


Fig. 53. Spectrogram of the word /piɻa /. The double arrows indicate the segmental boundaries of the preceding vowel (/i/), fifth liquid (/ɻ/) and following vowel (/a/) in the word /piɻa /.

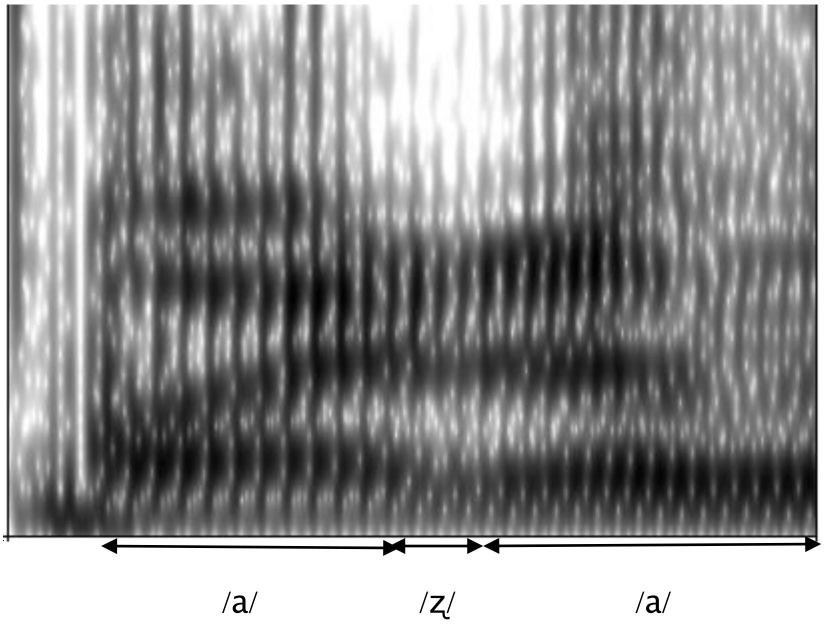


Fig. 54. Spectrogram of the word /paɻam/. The double arrows indicate the segmental boundaries of the preceding vowel (/a/), fifth liquid (/ɻ/) and following vowel (/a/) in the word /paɻam/.

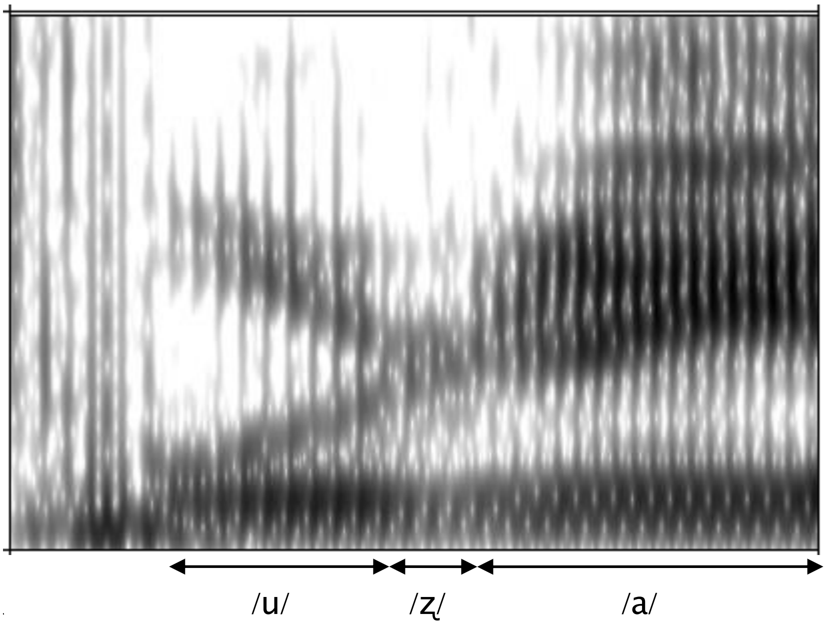


Fig. 55. Spectrogram of the word /puʐa/. The double arrows indicate the segmental boundaries of the preceding vowel (/u/), fifth liquid (/ʐ/) and following vowel (/a/) in the word /puʐa/.

The F1, F2 and F3 of /i/ before /ʐ/ appears to remain fairly steady throughout whereas the F2 of /a/ rises steadily until the beginning of /ʐ/ and F3 drops slightly. F2 of /u/ before /ʐ/ rises exponentially with the onset around 800-900Hz approximately and offset around 1400-1500 Hz approximately and the F3 drops markedly from around 2600-2700 Hz at onset to around 2100-2300Hz at offset approximately.

Summary

From the spectrograms of the five way contrast among the liquids in Malayalam, it seems that the fifth liquid and its surrounding vowels were most similar to the taps and alveolar laterals and most different from the trills and retroflex laterals. Apart from similarities and differences between the consonant segments, the preceding and following vowels and the nature of the formant transitions from the preceding vowel into the consonant and from consonant into the following vowels all appear to be factors that distinguish among the five liquids in Malayalam. For instance, vowels preceding the tap, alveolar lateral and fifth liquid generally exhibit a rise in F2 but the point at which the rise begins varies for the three liquids and the degree of the rise also varies. The slope of the formant transitions was not measured in the present study and therefore no conclusive remarks can be made in this regard.

Spectrograms of the fifth liquid in different vowel environments seem to suggest that the F2, F3 values of /ʐ/ not only vary depending on its surrounding vowels but the different vowel types also appear to be affected differently by the adjacent fifth liquid.

The next subsection on the results of the acoustic measurements made in the present study will point out the similarities and/or differences among the five liquids based on two measures, duration and formant frequencies, and assess the magnitude of those similarities or differences based on statistical significance and effect size measures.

6.1.2.2 Duration

Consonant duration

One univariate ANOVA was run on word-medial liquid consonants' subset with one independent variable: realization of manner of articulation of the consonant. This factor was found to have a significant effect on the duration of the consonants in the subset, $F(10, 1139) = 43.94$, $p<0.001$ and $\omega^2 = 0.265$ indicating that realization of manner of articulation of a consonant had a large effect on its duration. All the liquids in the word-medial position were included in the subset selected for the ANOVA since in the case of the fifth liquid, the aim is to find any pattern that may or may not exist between the fifth liquid and the rhotics (taps and trills) and between the fifth liquid and the laterals (alveolar and retroflex) in terms of duration.

The post-hoc results of only the fifth liquid, i.e. the approximant are mentioned here since this section is concerned only with its durational similarity or difference with the other liquids. The post-hoc tests, i.e. Bonferroni and Tukey tests, revealed that the fifth liquid (M=43.18, SD=14.81) was significantly longer than taps realized as taps (M=31.21, SD= 10.26), d=0.95 indicating that the strength of this difference was 'large'. The approximant was also found to be significantly longer than trills realized as taps (M=24.53, SD=8.2), d=1.54, also indicating a large effect size, and the approximant was significantly shorter than alveolar laterals realized as laterals (M=50.39, SD=10.19), d=-0.6, also indicating a medium sized effect for this difference. The approximant (M=43.18, SD=14.81) was also found to be significantly shorter than the alveolar and retroflex lateral fragments realized as alveolar and retroflex laterals respectively (M=50.39, SD=10.19 and M=52.26, SD=23.86). The duration of approximants realized as approximants (they had no other realizations) were found to be non-significant ($p>0.001$)

to the duration of trills realized as trills (M=37.49, SD=16.35), retroflex laterals realized as retroflex laterals (M=40.83, SD=12.29) and trill fragments realized as taps and trills. Considering the fifth liquid, i.e. the approximant occurs only intervocalically, and trill fragments by definition occur non-intervocalically (preceded by a vowel and followed by a consonant), these can be left out of the comparisons. Therefore the duration of the fifth liquid was found to be closest in range to the duration of trill *realizations* and retroflex laterals.

Preceding vowel duration

Two separate univariate ANOVA's were run on the duration of short and long vowels preceding the liquid consonants with one independent variable: realization of manner of articulation of the consonant it precedes. This factor was found to have a significant effect on the duration of the vowels preceding liquids irrespective of whether they were short or long vowels: F (9, 784) =11.19, $p<0.001$ for short vowels and ω^2 =0.102 which indicated a medium sized effect and F (8, 328) =11.37, $p<0.001$ for long vowels and ω^2 =0.193 which indicated a large effect size. The post-hoc tests showed that both short and long vowels preceding the approximant or fifth liquid (M=106.66, SD=31.67 for short vowels and M=221.29, SD=39.41) were significantly longer than short and long vowels preceding the alveolar lateral fragments realized as alveolar laterals (M=78.58, SD=21.22 for short vowels and M=156.67, SD=38.46 for long vowels). The duration of the vowels preceding the approximants was found to be non-significant to the duration to all the other types of realization of manner of articulation. In other words, the duration of vowels preceding the fifth liquid or approximant was similar to the duration of vowels preceding all the rhotic realizations and all the lateral realizations except the alveolar lateral fragments realized as alveolar laterals.

Summary

The fifth liquid was found to be significant longer than the tap realisations and significantly shorter than the alveolar laterals and was closest in the range of duration measures to trill realisations and retroflex laterals (see table 21 summarising results on the next page). The duration of the vowels preceding the fifth liquid was not significantly different from the duration of the vowels preceding the rhotics or the laterals.

	DURATION	
	Mean	SD
FIFTH LIQUID	43.18	14.81
TP-TP	31.21	10.26
TR-TP	24.53	8.2
TR-TR	37.49	16.35
ALV.LAT	50.39	10.19
RTF.LAT	40.83	12.29

Table 21. Mean and SD of duration of the five liquid segments

6.1.2.3 Formant frequency

Consonant formant patterns

A MANOVA was conducted on all the word-medial consonants in the data set with realization of manner of articulation as the only independent variable. This MANOVA was conducted in order to infer which of the other four liquids; the fifth liquid shared common formant patterns with. So only those results are reported from the MANOVA and subsequent ANOVA's that showed the relationship of the formant patterns of the fifth liquid with those of the other four liquids in Malayalam[6], i.e., lamino-alveolar tap, apico-alveolar trill, lamino-alveolar lateral and sub-apical retroflex lateral. Realization of manner of articulation of the consonant was found to have a significant effect on the F1, F2 and F3 onset, mid-point and offset values of the consonants: λ=0.34, F(30,3338)=49.21, p<0.001, ω^2 =0.65 at onset, λ=0.34, F(30,3338)=49.78, p<0.001, ω^2 =0.65 at mid-point and λ=0.38, F(3,3338)=43.09, p<0.001, ω^2 = 0.61 at offset. The ω^2 measures of effect size at all three points of measurements indicate a large effect of realization of manner of articulation of the liquid on the liquid's formant patterns.

The fifth liquid realized as approximants were found to have significantly lower F1 values, higher F2 values than trills realized as trills but F3 values although slightly lower in the latter's case were not significantly different from those of the fifth liquid (see

[6]Word-medially, the trill fragments and the lateral fragments also occur and these were also included but results comparing the fifth liquid's patterns with these are not reported here since the fragments when in medial position are not intervocalic unlike the rest of the liquids. Also the fifth liquid occurs only in the intervocalic position.

table below). Cohen's d values of effect size indicated that the difference in F1 and F2 values between the two groups was large (F1: d=-1.42 at onset, d=-1.4 at mid-point and d=-1.23 at offset; F2: d=2.36 at onset, d=2.6 at mid-point and d=2.65 at offset) whereas F3 differences were small (d=0.3, d=0.48, d=0.23) (see Table 22 below, Figs. 56, 57 pg. 199). The differences between the fifth liquid realized as approximants and trills realized as taps were similar to those between the fifth liquid and trills realized as trills: the fifth liquid realized as approximants had significantly lower F1 (except at onset), higher F2 values than trills realized as taps but both groups had similar F3 values. Effect size measures indicated that the differences in F1 between the two groups were small-to-moderate (d=-0.53at onset, d=-0.58 at mid-point and offset) and so were the F3 differences (d=0.46 at onset, d=0.5 at mid-point and d=0.35 at offset). F2 differences between the fifth liquid and trills realized as taps were large (d=2.53 at onset, d=2.59 at mid-point and offset). The fifth liquid realized as approximants was however NOT found to have significantly different F1, F2 or F3 values than taps realized as taps, i.e. the two groups were found to have F1, F2 and F3 values in the same range (see table 22, Figs. 56 and 57 pg. 199). The effect size measures also reflected the similarity between the formant patterns of the fifth liquid and the taps realized as taps in that Cohen's d values were small at onset, mid-point and offset (F1: d=-1.4, -1.4 and -1.23; F2: -0.2, -0.12, -0.15; F3: d=-0.18, -0.3, -0.0003).

		Fifth Liquid realized as approximant		Taps realized as taps		Trills realized as taps		Trills realized as trills	
		Mean	SD	Mean	SD	Mean	SD	Mean	SD
F1	onset	409	59	383	60	442	68	517	140
	mid	406	59	380	51	443	69	493	73
	offset	421	63	396	54	458	65	498	62
F2	onset	1689	207	1731	217	1218	157	1230	147
	mid	1725	200	1750	214	1249	159	1235	138
	offset	1741	202	1772	209	1269	151	1238	142
F3	onset	2403	260	2462	376	2292	214	2324	276
	mid	2418	260	2492	236	2296	219	2294	252
	offset	2508	795	2507	289	2313	214	2317	222

Table 22: Means and SD values of F1, F2, F3 onset, mid-point and offset of the fifth liquid versus tap and trill realizations.

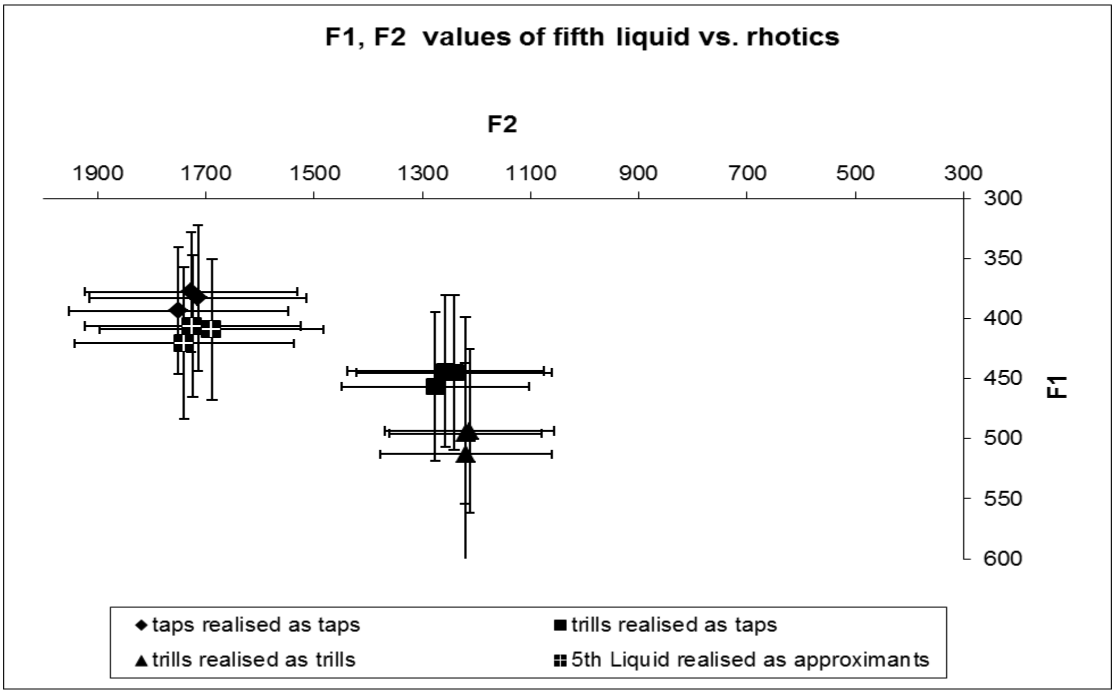


Fig.56. Average F1and F2 values of the fifth liquid versus rhotics (taps and trills). 3 points each are marked for every category on the fig. indicating the onset, mid-point and offset measurements for each category. Error bars = ± 1SD.

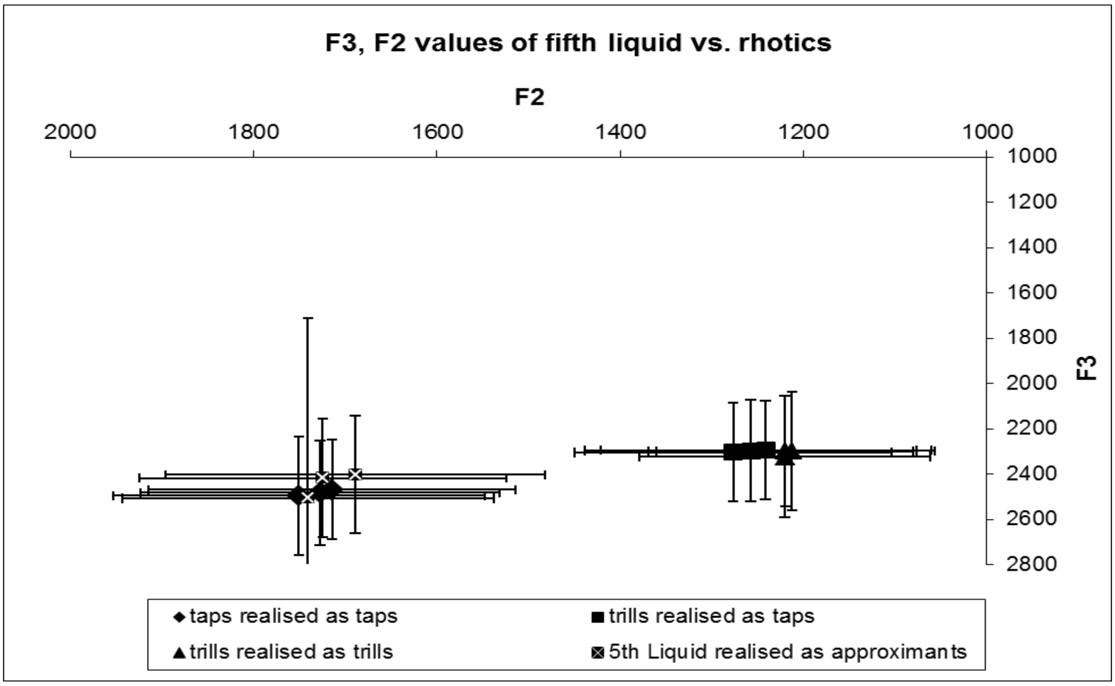


Fig. 57. Average F3 and F2 onset, mid-point and offset values of the fifth liquid versus rhotics (taps and trills). Error bars = ± 1SD.

As shown in Table 23 and Figs. 58 and 59 below, the fifth liquid realized as approximants was found to have significantly different F3 values at onset and mid-point but NOT at offset than the alveolar laterals. Cohen's d values indicated that even at the onset and mid-point the F3 differences were only small-to-moderate (d=-0.5, d=0.54 respectively) and were very small at offset (d=-0.11). Also, the two groups were found to have a similar range of F2 values that were not significantly different and Cohen's d values indicated that the F2 differences between the two groups were very small (d=0.11 at onset and mid-point, d=0.22 at offset). F1 values were significantly lower for the alveolar laterals than the fifth liquid and these differences were either moderate or moderate-to-large in terms of their effect size (d=0.55 at onset, d=0.78 at mid-point, d=0.6 at offset). The fifth liquid however had significantly higher F2 values than retroflex laterals and a similar range of F1 and F3 values as the latter. Effect sizes of the F1 and F3 differences between the two groups were very small (F1: d=-0.46, -0.44, -0.4; F3: d=0.23, 0.24, 0.26, at onset, mid-point and offset respectively) while effect size of their F2 differences was large (d=2.03, 1.99, 1.9 at onset, mid-point and offset respectively).

		Fifth Liquid realized as approximant		alv.lat realized as alv.lat		rtf.lat realized as rtf.lat	
		Mean	SD	Mean	SD	Mean	SD
F1	onset	409	59	381	48	442	84
	mid	406	59	369	40	436	78
	offset	421	63	389	47	449	80
F2	onset	1689	207	1666	215	1277	198
	mid	1725	200	1698	253	1309	219
	offset	1741	202	1695	215	1338	223
F3	onset	2403	260	2529	243	2341	265
	mid	2418	260	2556	257	2356	259
	offset	2508	795	2562	253	2362	253

Table 23. Mean and SD of F1, F2, F3 onset, mid-point and offset values of the fifth liquid versus the laterals (alveolar and retroflex).

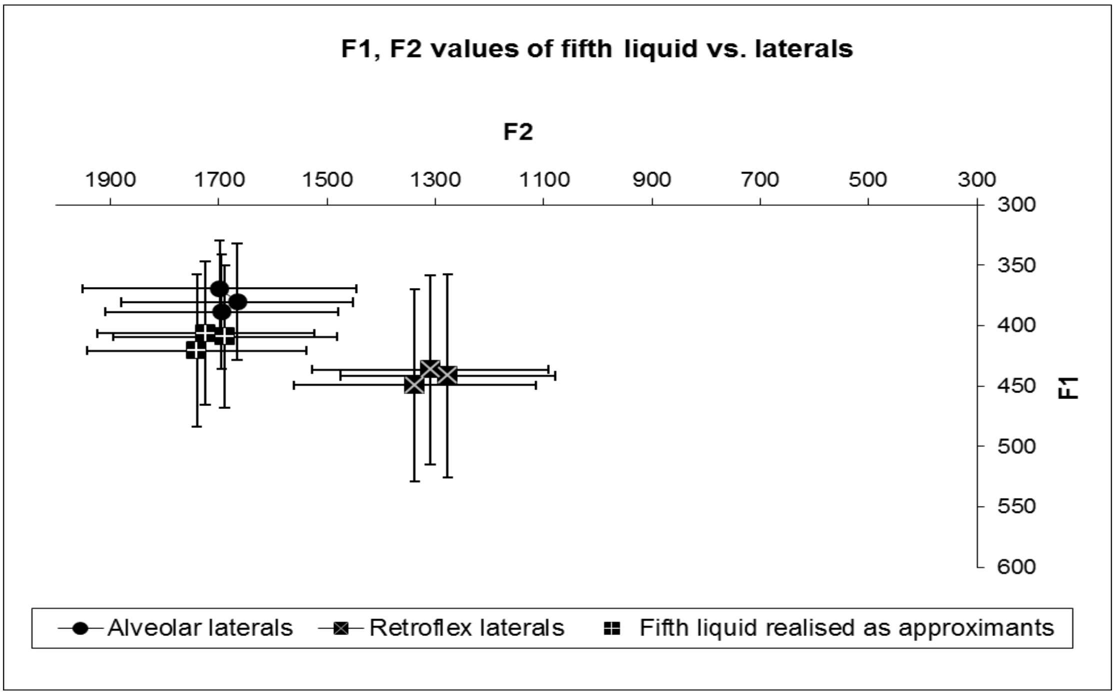


Fig. 58. Average F1 and F2 onset, mid-point and offset values of the fifth liquid versus the laterals in Malayalam. Error bars = ± 1SD.

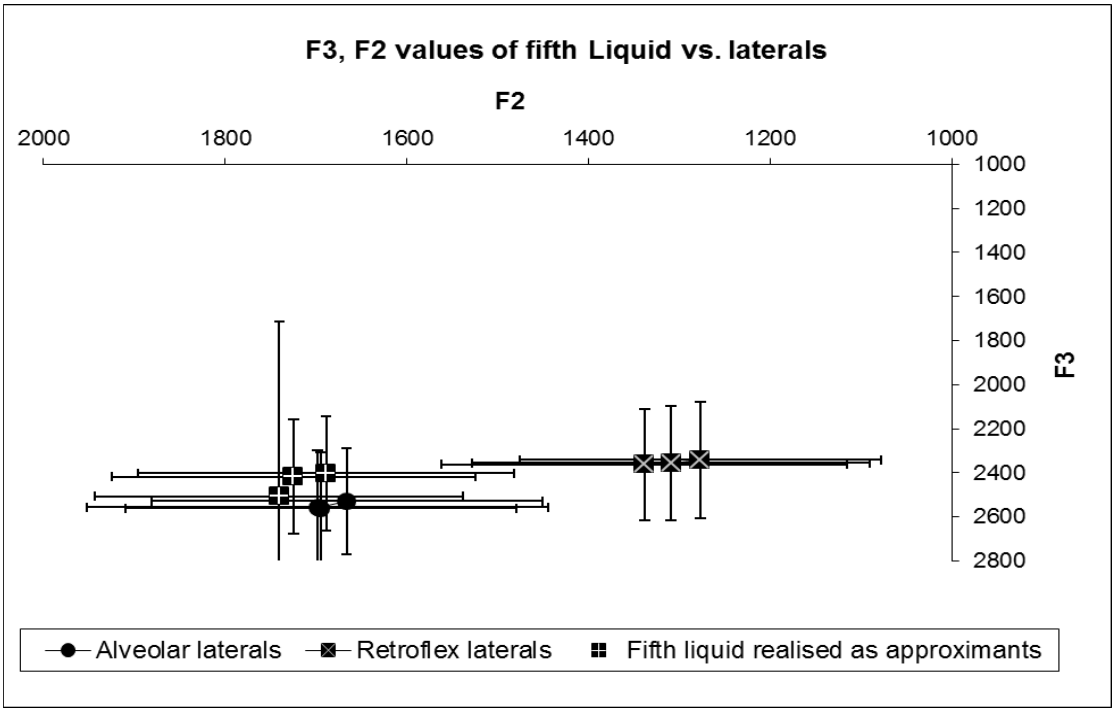


Fig.59. Average F3 and F2 onset, mid-point and offset values of the fifth liquid versus the laterals in Malayalam. Error bars = ± 1SD.

Preceding vowels

A MANOVA was conducted on all vowels, short and long, preceding word-medial rhotics, laterals and the fifth liquid at mid-point and offset with two independent variables: realization of manner of articulation of the consonant and vowel quality. Realization of manner of articulation of following liquid: λ=0.81, $F(30, 3170.69) = 7.95$, $p<0.001$, $\omega^2 = 0.17$ at mid-point and λ=0.49, $F(30, 3170) = 29.33$, $p<0.001$, $\omega^2 = 0.51$ at offset. The ω^2 measures of effect size indicated a large effect of the factor on the formant patterns of the vowels preceding liquids in medial position. Vowel type: λ=0.11, $F(24, 3132.93) = 149.83$, $p<0.001$, $\omega^2 = 0.89$ at mid-point and λ=0.45, $F(24, 3132.93) = 41.08$, $p<0.001$, $\omega^2 = 0.54$ at offset. Here too, the ω^2 measures showed that vowel type had a large effect on the formant patterns of the vowels preceding the liquids. The interaction of realization of manner of articulation of the following liquid and the vowel type was found to have a significant effect on the formant patterns of the vowels preceding liquids: λ=0.78, $F(90, 3232.91) = 3.12$, $p<0.001$, and $\omega^2 = 0.15$ at mid-point indicating a large effect size and λ=0.86, $F(90, 3232.91) = 1.85$, $p<0.001$, $\omega^2 = 0.06$ indicating a moderate effect size.

As shown in table 24, the ANOVA's revealed that the vowels preceding the fifth liquid had similar range of F1 values that were NOT significantly different from those of the vowels preceding taps realized as taps but the vowels preceding the fifth liquid had significantly lower F2 and F3 values than vowels preceding taps realized as taps. Effect size of the F1 differences between the two groups was very small (d=0.1 at mid-point and offset), that of the F2 differences was large at mid-point and moderate at offset (d=-0.88 and d=-0.65 respectively) and effect size of the F3 differences were large at both mid-point and offset (d=-0.83, d=-0.96 respectively). Vowels preceding the fifth liquid were found to have significantly lower F1 offset values and higher F2 offset values than vowels preceding trills realized as taps. The two groups did not differ significantly in their F3 values. Effect size of the F1 differences were very small at mid-point but moderate-to-large at offset (d=-0.08, d=-0.69 respectively), that of F2 differences was very small at mid-point and large at offset (d=-0.29, d=1.35 respectively) and effect size of the F3 differences was very small in conjunction with their non-significant p value (d=-0.33, d=-0.28). Vowels preceding the fifth liquid seemed to have significantly lower F1 mid-point and offset values and higher F2 offset values than vowels preceding trills realized as trills but the two groups did not differ significantly in their F3 values. Effect sizes of F1 differences, despite p <0.001, was small at mid-point (d=-0.32) but large at offset (d=-1.26), that of F2 differences was very small at mid-point (d=0.004) but large at offset (d1.58) and effects of F3 differences was small at mid-point and offset (d=-0.49, d=-0.47 respectively).

	PRECEDING VOWELS							
	Fifth Liquid		Taps realized as taps		Trills realized as taps		Trills realized as trills	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
F1 mid	536	145	521	171	547	145	583	148
F1 offset	453	82	444	87	512	90	559	92
F2 mid	1327	298	1650	433	1413	304	1325	282
F2 offset	1620	236	1780	258	1314	213	1261	199
F3 mid	2359	222	2558	255	2431	222	2469	245
F3 offset	2300	253	2535	238	2368	217	2418	250

Table 24. Mean and SD of F1, F2, F3 mid-point and offset values of vowels preceding the fifth liquid versus rhotics.

The vowels preceding the fifth liquid were found to have significantly lower F2 mid-point values and lower F3 mid-point and offset values than vowels preceding alveolar laterals. The two groups did not differ from each other in their F1 values (see Table 25 next page). Effect size of their F1 differences was very small at mid-point and offset (d=-0.01, -0.31 respectively), that of F2 differences was small-to-moderate at mid-point and small at offset (d=-0.44, d=-0.2 respectively) and effects of F3 differences was small-to-moderate at mid-point and large at offset (d=-0.49, d=-0.87 respectively). Vowels preceding the fifth liquid had significantly higher F2 values than vowels preceding retroflex laterals but the two groups had a similar range of F1 and F3 values. F1 differences between the two groups had a small effect at both mid-point and offset (d=0.01, d=-0.31 respectively) while F2 differences had a moderate effect at mid-point (d=0.54) and a large effect at offset (d=1.56). F3 differences had a very small effect size (d=-0.07 and d=-0.03 at mid-point and offset respectively).

	PRECEDING VOWELS					
	Fifth liquid		Alveolar laterals		Retroflex laterals	
	Mean	SD	Mean	SD	Mean	SD
F1 mid	536	145	538	145	534	149
F1 offset	453	82	480	89	482	104
F2 mid	1327	298	1486	408	1173	261
F2 offset	1620	236	1668	240	1270	211
F3 mid	2359	222	2482	266	2376	255
F3 offset	2300	253	2496	205	2309	238

Table 25. Mean and SD of F1, F2, F3 mid-point and offset values of the vowels preceding the fifth liquid versus the laterals.

With respect to the second factor in the MANOVA, vowel quality, the formant patterns were affected thus:

F1 mid-point: /uu/, /ii/, /u/, /i/ < /ee/, /o/, /oo/ < /a/, /aa/

F1 offset: (/u/, /i/, /ii/, /uu/) < (/ii/, /uu/, /ee/) < (/ee/, /o/) < (/oo/, /a/, /aa/)

F2 mid-point: /uu/ < /oo/, /u/, /o/ < /aa/, /a/ < /i/, /ee/ < /ee/, /ii/

F2 offset: /u/, /uu/, /oo/ < /uu/, /oo/, /aa/, /a/, /o/ < /i/, /ii/, /ee/

F3 mid-point: /oo/, /u/, /o/, /uu/, /aa/ /a/ < /uu/, /aa/, /a/, /i/ < /i/, /ee/, /ii/

F3 offset: /u/, /o/, /oo/, /uu/, /a/, /aa/ < /uu/, /a/, /aa/, /i/, /ii/ < /i/, /ii/, /ee/

As expected, the F1 values correspond with the height of the vowel, i.e., the higher the vowel or the closer the tongue is to the roof of the mouth during its production, the lower the F1 values and similarly, the lower and the more open the tongue is during production of the vowel, the higher its F1 values. F2 values, on the other hand, corresponded to front versus back dimension of vowels, i.e., the more advanced or fronter the tongue configuration for the vowel, the higher its F2 and similarly, the more retracted and backer its tongue configuration, the lower its F2 values. F3 values seem to correspond with the shape of the tongue during vowel production, i.e. lip rounding in vowels like /u/, /o/ and to a certain extent in /a/ showed relatively lower F3 values than those that involved lip spreading like /i/, and /e/. For all three formant frequencies, particularly for F1 and F2 frequencies, the vowel categories were more distinct at the mid-point but overlapped more at the offset.

The interaction effect of the two factors, i.e., realization of the manner of articulation of the consonant and vowel type, was found have a significant effect on the formant patterns of the preceding vowels as mentioned earlier. To determine which vowel types in which combinations with different manner of articulation types were specifically significant, a further MANOVA was conducted with the data set split by preceding vowel type and with realization of manner of articulation of the following consonant as the only independent variable. F1 and F3 values of most of the preceding vowel types were largely unaffected by the realization of the manner of articulation of the following consonant (see figs. 60, 61, 62 and 63). As shown in Fig. 60, /a/ preceding the fifth liquid tokens had significantly lower F1 values than /a/ preceding trills realized as taps and trills realized as trills only at offset. /o/ preceding the fifth liquid tokens had significantly higher F1 values than /o/ preceding taps realized as taps and alveolar laterals at offset (see fig.60, 61). All the vowel types in the data set preceding the fifth liquid, i.e., /i/, /a/, /aa/, /u/, /o/, /oo/[7] , had significantly higher F2 mid-point and offset values than the same vowels preceding trills realized as taps, trills realized as trills and retroflex laterals. The F2 mid-point and offset values of all vowels preceding the fifth liquid tokens were NOT significantly different, i.e., were in the same range as those preceding taps realized as taps and alveolar laterals (see fig. 60 and 61).

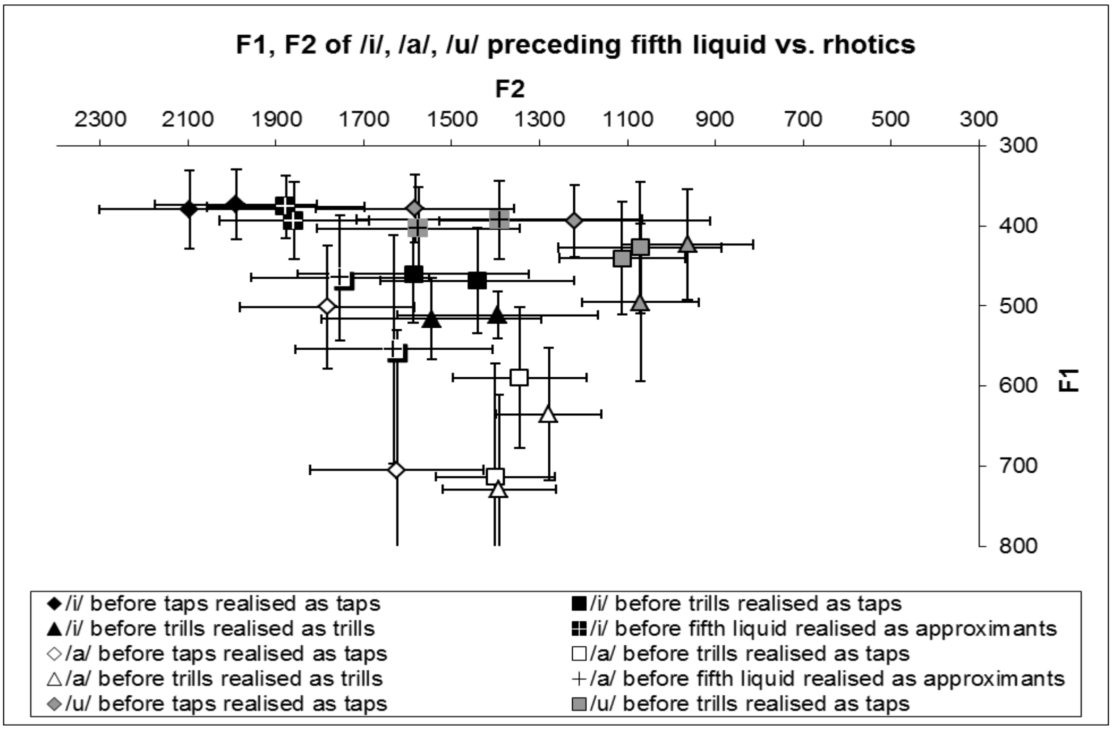


Fig.60. Average F1 and F2 values of /i/, /a/, /u/ preceding the fifth liquid versus the rhotics. The different colours indicate the different vowel types: /i/ in black, /a/ in white with black border/patterns and /u/ in grey with black border/patterns. The different patterns indicate the different manners of articulation. There are two data points each for every category indicating mid-point and offset measurements. Error bars = ± 1SD.

[7] /oo/ and /o/ were not common vowels preceding all five liquids. These two vowels appeared in the data set only in cases where they preceded the fifth liquid, the alveolar lateral and the retroflex lateral.

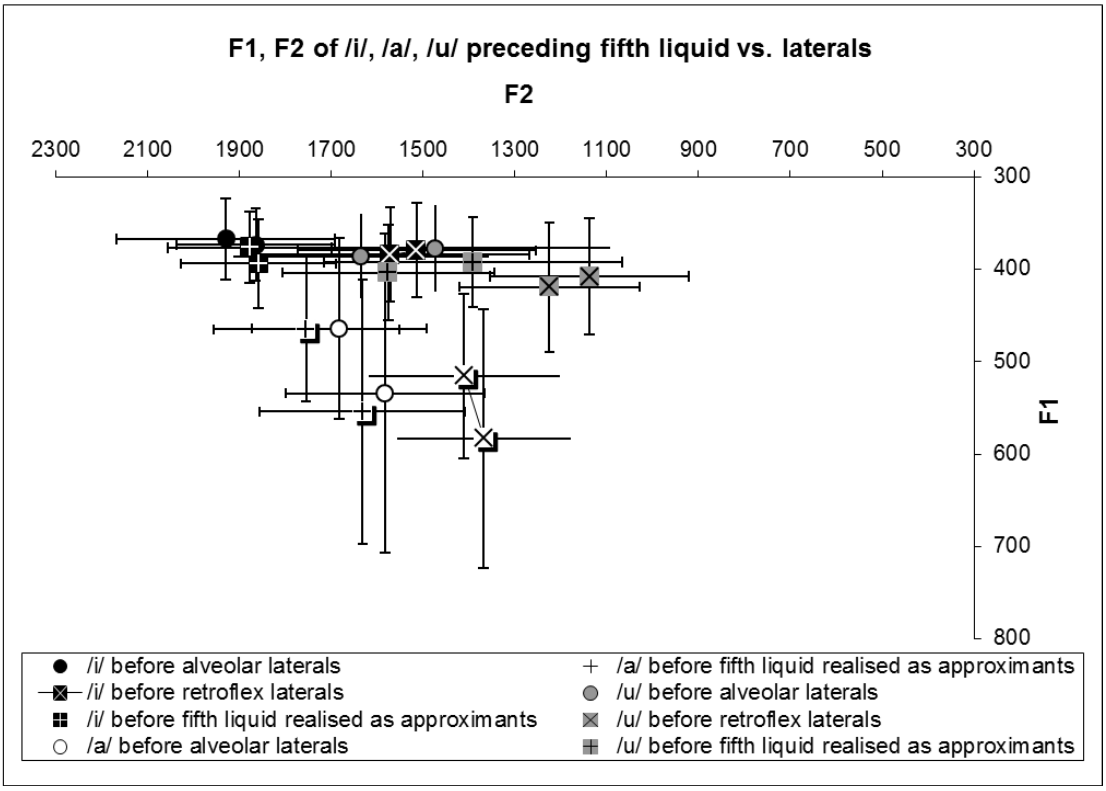


Fig.61. Average F1 and F2 values of /i/, /a/, /u/ preceding the fifth liquid versus the laterals. The different colours indicate the different vowel types: /i/ in black, /a/ in white with black border/patterns and /u/ in grey with black border/patterns. The different patterns indicate the different manners of articulation. There are two data points each for every category indicating mid-point and offset measurements. Error bars = ± 1SD.

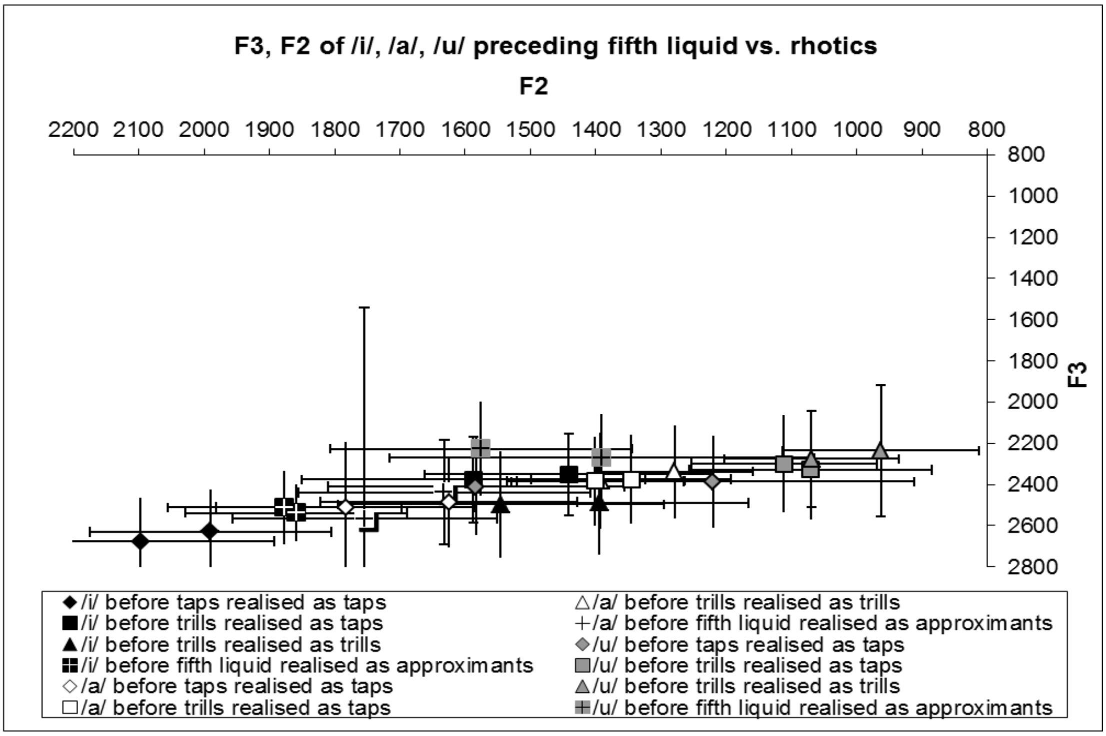


Fig.62. Average F3 and F2 values of /i/, /a/, /u/ preceding the fifth liquid versus the rhotics. The different colours indicate the different vowel types: /i/ in black, /a/ in white with black border/patterns and /u/ in grey with black border/patterns. The different shapes indicate the different manners of articulation. There are two data points each for every category indicating mid-point and offset measurements. Error bars = ± 1SD.

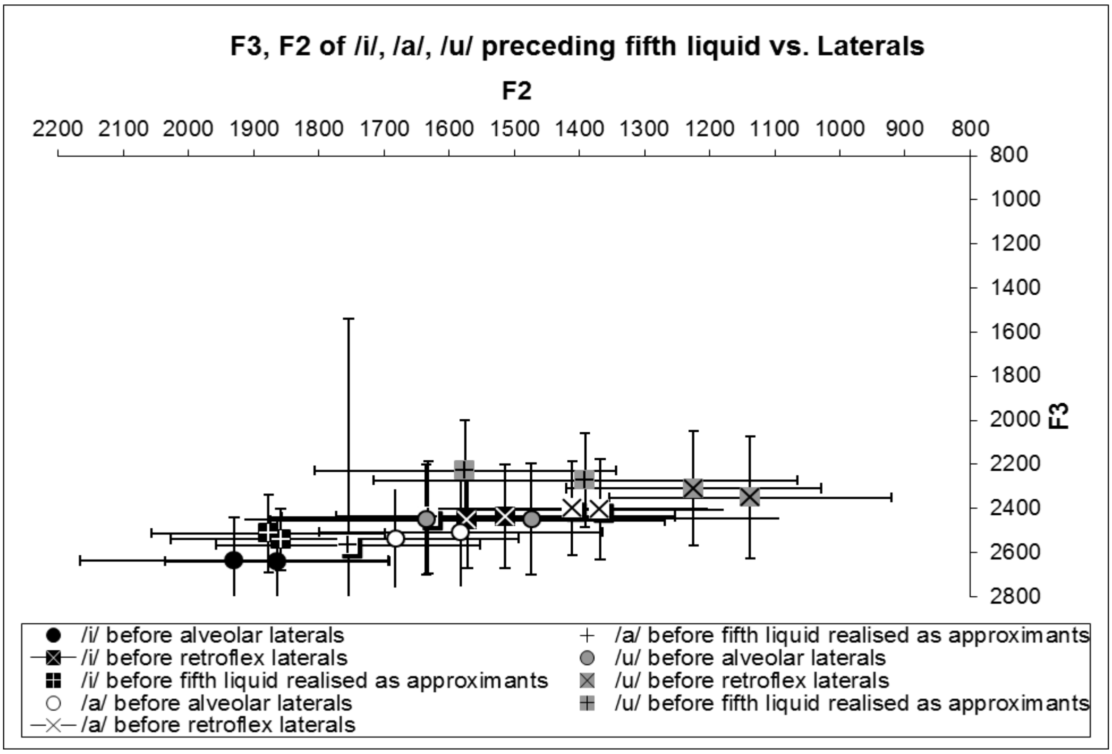


Fig. 63. Average F3 and F2 mid-point and offset values of /i/, /a/, /u/ preceding the fifth liquid versus the laterals. The different colours indicate the different vowel types: /i/ in black, /a/ in white with black border/patterns and /u/ in grey with black border/patterns. The different shapes indicate the different manners of articulation. There are two data points each for every category indicating mid-point and offset measurements. Error bars = ± 1SD.

Following vowels

One MANOVA was conducted on all vowels following word-medial liquids in the data set with realization of manner of articulation of the preceding liquid and vowel type as the two independent variables. Using Wilk's statistic, both factors were found to have significant effects on the formant patterns of the vowels following word-medial liquids. Realization of manner of articulation of the preceding liquid: λ=0.64, F (30, 3179.5) =17.26, p<0.001, ω^2 =0.34 at onset and λ=0.84, F (30, 3179.5) =6.44, p<0.001, ω^2 =0.14 at mid-point. The ω^2 measures indicate that the factor had a large effect on the following vowels' formant patterns. Vowel type: λ=0.68, F (18, 3063.67) =24.46, p<0.001, ω^2 =0.31 at onset and λ=0.56, F (18, 3063.67) =39.24, p<0.001, ω^2 =0.43 at mid-point. The ω^2 measures indicate that vowel type had a large effect on their formant patterns. The interaction of the two factors, i.e., realization of manner of articulation of the preceding liquid and vowel type was found to have a significant effect on the formant patterns of the vowels following medial liquids, λ=0.9, $F(45,3218)=2.5$, $p<0.001$, $\omega^2=0.06$ at onset and λ=0.9, $F(45,3218)=2.67$, $p<0.001$, $\omega^2=0.06$ at mid-point. The ω^2 measures indicate that the interaction of the two factors had a moderate effect on the formant patterns of the vowels following medial liquids.

The subsequent ANOVA's showed that the vowels following the fifth liquid were not significantly different from vowels following taps realized as taps in their F1, F2 or F3 values (see table 26). Effect sizes in each of these cases was small (F1: d=0.05, 0.1; F2: -0.17, 0.1; F3: d=-0.23,-0.05), thereby strengthening the notion that the vowels following the fifth liquid versus those following taps realized as taps were not different in their formant patterns. As shown in fig. 64, the vowels following the fifth liquid had significantly lower F1 onset values and higher F2 onset and mid-point values than vowels following trills realized as taps. The vowels following the fifth liquid did not differ significantly from vowels following trills realized as taps in their F3 values (see fig. 66, pg. 212). Effect size of F1 differences was large at onset (d=-0.82) and small at mid-point (d=0.18) and that of F2 differences was large at onset (d=1.6) and moderate at mid-point (d=0.68). F3 differences had a moderate effect at onset and a small-to-moderate effect at mid-point (d=0.5 and d=0.48 respectively). Vowels following the fifth liquid had significantly lower F1 onset values, higher F2 onset and mid-point values and higher F3 mid-point values than vowels following trills realized as trills. Effect size of F1 differences was large at onset (d=-1.05) and small at mid-point (d=-0.36), that of F2 differences was large at onset and mid-point (d=2.13, d=0.96 respectively) and F3 differences had a moderate-to-large effect at onset and mid-point (d=0.65, d=0.7 respectively) (see figs. 64, 66, pgs. 211,212).

	FOLLOWING VOWELS							
	Fifth Liquid		Taps realized as taps		Trills realized as taps		Trills realized as trills	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
F1 onset	448	75	452	79	514	88	525	64
F1 mid	545	136	558	130	570	129	593	123
F2 onset	1749	225	1789	230	1393	220	1289	183
F2 mid	1798	294	1769	308	1588	326	1513	310
F3 onset	2490	219	2542	232	2380	224	2348	213
F3 mid	2563	229	2575	269	2452	229	2406	203

Table 26. Mean and SD of F1, F2, F3 onset and mid-point values of the vowels following the fifth liquid versus the rhotics.

Vowels following the fifth liquid had significantly lower F1 values than vowels following alveolar laterals but the two groups did not differ significantly in their F2 and F3 values (see Table 27 below, fig.65, 67 on pgs. 211,213). Effect size of the F1 differences was small-to-moderate at onset (d=-0.42) and small at mid-point (d=-0.25), that of F2 differences was very small at onset and mid-point (d=0.1, d=0.09 respectively) and F3 differences also had a very small effect (d=-0.28, d=-0.14 respectively). Vowels following the fifth liquid had significantly lower F1 onset values and higher F2 onset and mid-point values than vowels following retroflex laterals but the two groups did not differ significantly in their F3 values (see figs. 65, 67). Effect size of the F1 differences was large (d=-0.79) at onset and very small at mid-point (d=0.005), that of F2 differences was large at onset (d=1.11) and small-to-moderate at mid-point (d=0.46) and F3 differences had a very small effect (d=0.22 at onset and d=0.03 at mid-point)

	FOLLOWING VOWELS					
	Fifth liquid		Alveolar laterals		Retroflex laterals	
	Mean	SD	Mean	SD	Mean	SD
F1 onset	448	75	476	62	521	112
F1 mid	545	136	578	127	544	149
F2 onset	1749	225	1727	230	1477	271
F2 mid	1798	294	1773	290	1648	367
F3 onset	2490	219	2551	218	2444	194
F3 mid	2563	229	2596	244	2556	219

Table 27. Mean and SD values of F1, F2, F3 onset and mid-point values of vowels following the fifth liquid versus the laterals.

With respect to the second factor in the MANOVA conducted on vowels following medial liquids, i.e., vowel type, the ANOVA's revealed the following patterns:

F1 onset: /u/, /i/, /uu/ < /e/, /ee/, /a/ < /ee/, /a/, /aa/

F1 mid-point: /i/, /u/, /uu/ < /e/, /ee/ < /ee/, /a/ < /a/, /aa/

F2 onset: /uu/ < /aa/, /u/, /a/, /ee/, /e/ < /i/

F2 mid-point: /uu/ < /u/, /aa/, /a/ < /aa/, /a/, /e/ < /a/, /e/, /ee/ < /i/

F3 onset: /ee/, /u/, /aa/, /uu/, /a/, /e/ < /u/, /aa/, /uu/, /a/, /e/, /i/

F3 mid-point: /u/, /uu/, /aa/, /a/, /e/, /ee/ < /a/, /e/, /ee/, /i/

As expected, the F1 values correspond with the height of the vowel, i.e., the higher the vowel or the closer the tongue is to the roof of the mouth during its production, the lower the F1 values and similarly, the lower and the more open the tongue is during production of the vowel, the higher its F1 values. F2 values, on the other hand, corresponded to front versus back dimension of vowels, i.e., the more advanced or fronter the tongue configuration for the vowel, the higher its F2 and similarly, the more retracted and backer its tongue configuration, the lower its F2 values. F3 values seem to correspond with the shape of the tongue during vowel production, i.e. lip rounding in vowels like /u/, /o/ and to a certain extent in /a/ showed relatively lower F3 values than those that involved lip spreading like /i/, and /e/.

The interaction effect of the two factors, i.e., realization of the manner of articulation of the consonant and vowel type, was found have a significant effect on the formant patterns of the following vowels as mentioned earlier. To determine which vowel types in which combinations with different manner of articulation types were specifically significant, a further MANOVA was conducted with the data set split by following vowel type and with realization of manner of articulation of the preceding consonant as the only independent variable. /i/ and /a/ were the only vowel types in the data set following the fifth liquid tokens. As shown in figs. 64 and 65, /i/ and /a/ following the fifth liquid tokens had the same range of F1 onset and mid-point values as /i/ and /a/ following taps realized as taps and alveolar laterals. /i/ and /a/ following the fifth liquid tokens had significantly lower F1 values than /i/ and /a/ following retroflex laterals. /i/ and /a/ following the fifth liquid tokens had significantly lower F1 onset, mid-point and lower F1 onset respectively than /i/ and /a/ following trills realized as taps and trills realized as trills.

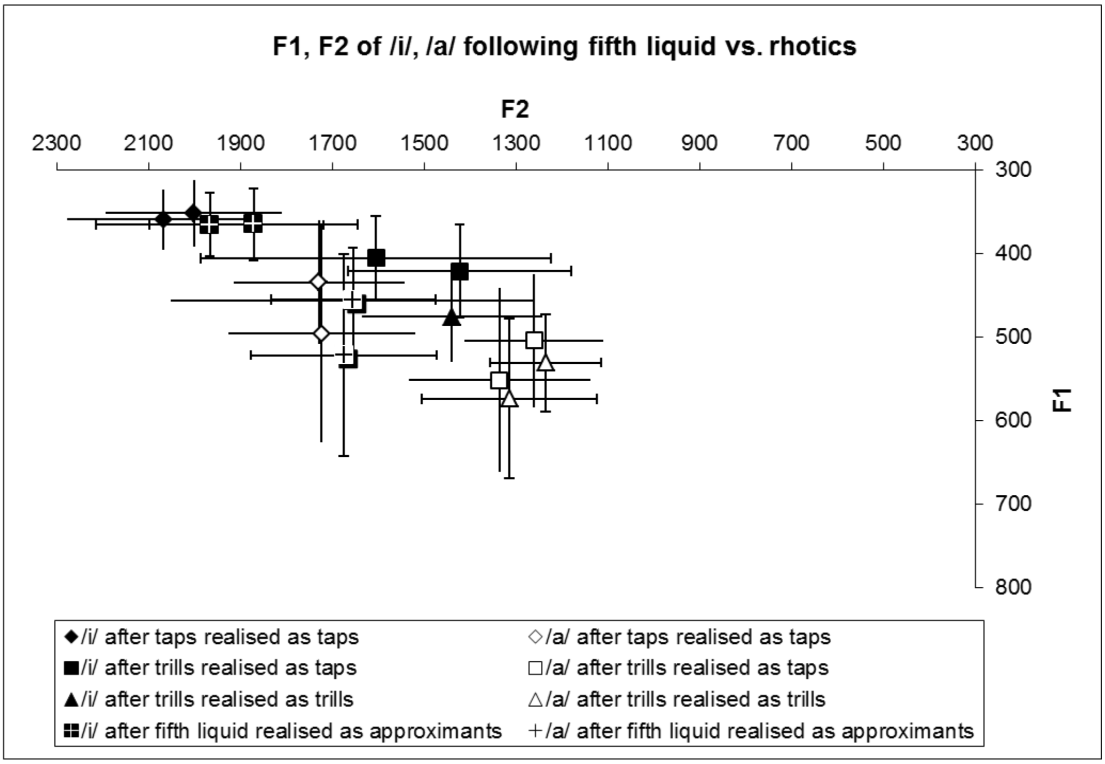
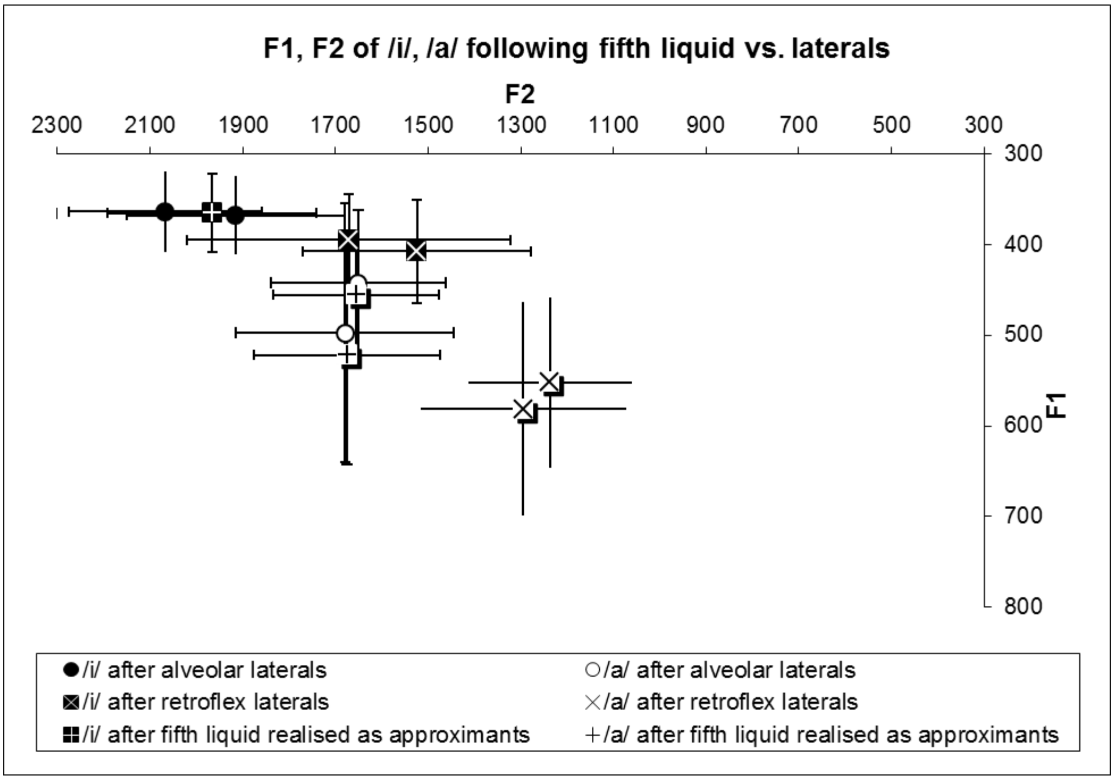


Fig.64. Average F1 and F2 values of /i/, /a/ following the fifth liquid versus the rhotics. The different colours indicate the different vowel types: /i/ in black, /a/ in white with black border/patterns. The different shapes indicate the different manners of articulation. There are two data points each for every category indicating onset and mid-point measurements. Error bars = ± 1SD.



.Fig.65. Average F1 and F2 onset and mid-point values of /i/, /a/ following the fifth liquid versus the laterals. The different colours indicate the different vowel types: /i/ in black, /a/ in white with black border/patterns. The different shapes indicate the different manners of articulation. There are two data points each for every category indicating onset and mid-point measurements. Error bars = ± 1SD.

/i/ and /a/ following the fifth liquid tokens had significantly higher F2 onset and mid-point values than /i/ and /a/ following trills realized as taps, trills realized as trills and retroflex laterals whereas the F2 values of /i/ and /a/ following the fifth liquid tokens were in the same range as those following taps realized as taps and alveolar laterals (see figs. 64, 65 above).

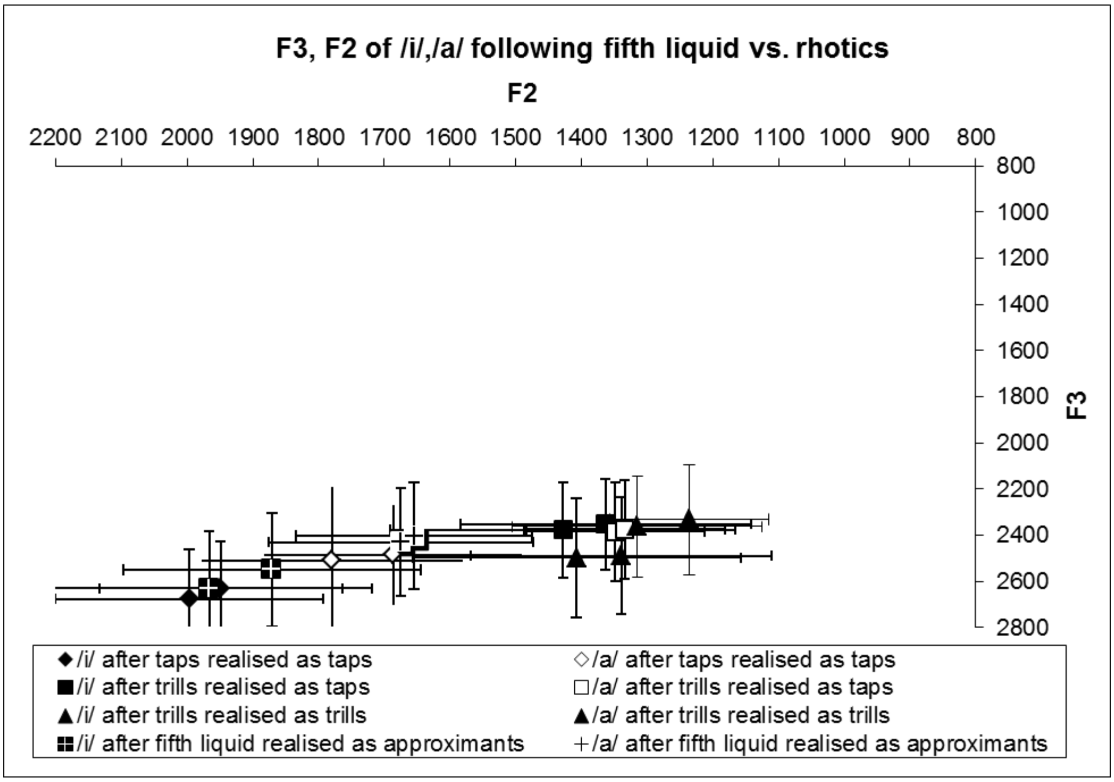


Fig.66. Average F3 and F2 onset and mid-point values of /i/, /a/ following the fifth liquid versus the rhotics. The different colours indicate the different vowel types: /i/ in black, /a/ in white with black border/patterns. The different shapes indicate the different manners of articulation. There are two data points each for every category indicating onset and mid-point measurements. Error bars = ± 1SD.

As shown in fig.66 (above) and fig. 67 (next page), F3 values of /i/ and /a/ following the fifth liquid were in the same range and NOT significantly different from those of /i/ and /a/ following taps realized as taps, trills realized as trills and retroflex laterals. /i/ and /a/ following the fifth liquid tokens had significantly lower F3 values than /i/ following trills realized as taps and /a/ following alveolar laterals respectively.

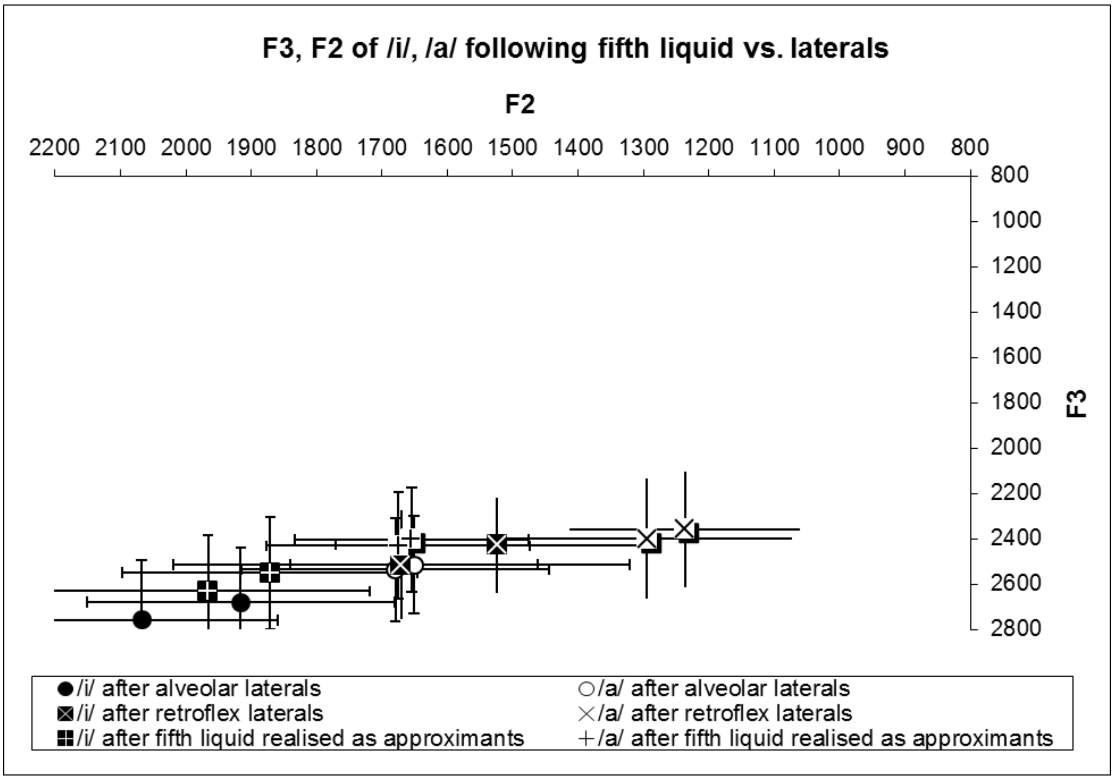


Fig.67. Average F3 and F2 onset and mid-point values of /i/, /a/ following the fifth liquid versus the laterals. The different colours indicate the different vowel types: /i/ in black, /a/ in white with black border/patterns. The different shapes indicate the different manners of articulation. There are two data points each for every category indicating onset and mid-point measurements. Error bars = ± 1SD.

Coarticulatory effects of the fifth liquid on preceding versus following vowels

/i/ and /a/ were the only two vowel types that occurred in the data set in both preceding and following vowel contexts to the fifth liquid. F1 values of /a/ (at mid-point) were higher when it preceded rather than when it followed the fifth liquid (680Hz and 618Hz respectively). F2 values of /a/ were higher when it followed rather when it preceded the fifth liquid (1496Hz and 1680Hz respectively). Also, anticipatory effects of the fifth liquid appear to have a late onset in /a/ (F2 rises from 1496Hz at mid-point to 1723Hz at offset) whereas the carry over effects of the fifth liquid appear to have a late offset in /a/ (F2 remains relatively high and steady throughout the onset and mid-point of the following /a/ at 1668Hz and 1679Hz respectively). The F1 values of /i/ do not appear to vary significantly depending on whether it preceded or followed the fifth liquid whereas the F2 values were higher when /i/ followed rather than when it preceded the fifth liquid (2070Hz and 1932Hz respectively) as was the case with /a/. Unlike /a/ however, the F2 values of /i/ were relatively high and steady throughout when it preceded the fifth liquid while there was a rise in F2 from onset to mid-point when /i/ followed the fifth liquid. Carry-over effects of the fifth liquid if any also appear to have an early offset in /i/ which explains the further rise in F2 of /i/ at mid-point as compared to the onset (2070Hz and 1936Hz respectively).

Summary

The fifth liquid was produced as an approximant by all speakers in all tokens. The place of articulation sounded further back than the alveolar ridge but not ‘retroflex’ since there was no percept of the *underside of the tongue tip* contacting the hard palate or the back-to-front tongue movement typical of other retroflexes in the language. It has been suggested that it is perhaps better to categorize the fifth liquid as ‘post-alveolar’ rather than retroflex.

The fifth liquid realised as approximants had significantly lower F1, higher F2 values than the target trills. F3 differences between the groups were not significant. The fifth liquid was NOT significantly different from the target taps in their F1, F2 or F3 values. The alveolar laterals did not differ from the fifth liquid in their F2 values but differed in their F3 onset and mid-point values (small-to-moderate effect size) and in their F1 values. The fifth liquid had higher F1 and lower F3 values than the alveolar laterals. The retroflex laterals differed from the fifth liquid only in their F2 values: F2 values of the fifth liquid were higher than those of the retroflex laterals.

The formant patterns of the vowels preceding and following the five intervocalic liquids were affected by the realisation of manner of articulation of the liquids and vowel quality. With respect to the preceding vowel context, all the vowel types in the data set, preceding the fifth liquid had significantly higher F2 values than the same vowels preceding target trills and retroflex laterals. However, all the vowels preceding the fifth liquid had a similar range of F2 values as those preceding target taps and alveolar laterals. /a/ preceding target trills had significantly higher F1 offset values than /a/ preceding the fifth liquid. /o/ preceding target taps and alveolar laterals had significantly lower F1 offset values than /o/ preceding the fifth liquid.

With respect to the following vowel context, only two vowel types occurred in the data set that followed the fifth liquid, /i/ and /a/. /i/, /a/ following the fifth liquid had similar F1, F2, F3 values as /i/, /a/ following target taps, similar F2 values as /i/, /a/ following alveolar laterals and similar F3 values as /i/, /a/ following retroflex laterals. /i/, /a/ following the fifth liquid had significantly lower F1 and higher F2 values than /i/, /a/

following target trills and retroflex laterals. /i/, /a/ following the fifth liquid had significantly lower F3 values than /i/, /a/ following alveolar laterals.

Acoustically out of the two rhotics, the fifth liquid appears be most similar to the target taps since the two groups do not differ significantly in F1, F2 or F3 values. Out of the two laterals, the fifth liquid seems most similar to the retroflex lateral which only differs from the former in its F2 values whereas it differs from the alveolar laterals in F1 and F3 values. Comparing its patterns with the rhotics and with the laterals, the fifth liquid appears to be most similar acoustically to the target taps.

This section described the auditory and acoustic results for the fifth liquid in Malayalam with respect to the other four liquids in the language, i.e., the taps, trills, alveolar laterals and retroflex laterals. The next section will discuss these findings in the context of recent work on the fifth liquid in Tamil and other relevant literature.

6.2 Discussion

This section aims to interpret the results obtained from the auditory and acoustic analyses of the fifth liquid tokens in the present study described in the first half of this chapter.

6.2.1 Auditory analyses

Productions of all tokens of the fifth liquid by all speakers sounded like approximants. The place of articulation of the approximant sounded back, almost as back as retroflex but they also sounded 'clear' which contradicts with the perception of retroflexion since a clear resonance is associated with a front and raised articulation whereas retroflexion by definition involves tongue body retraction (Hamann, 2002). The present author notes however that although the approximant sounds as back as retroflex sounds, it does not sound like it involves the use of the underside of the tongue tip unlike in the production of the other retroflexes in the language. The other retroflex sounds in the language involve the contact of the underside of the tip of the tongue against the hard palate and is a back-to-front unfolding of the tongue tip whereas the fifth liquid does not give the impression of a back-to-front movement of the tongue tip, rather a close approximation or sometimes slight contact of the tongue blade against the hard palate. Therefore it might be best to describe the fifth liquid in Malayalam as a post-alveolar approximant based on the author's auditory impressions. Vowels surrounding the fifth liquid, irrespective of whether they were front or back vowels, or close or open vowels, all sounded raised and more advanced than those surrounding the target trills and retroflex lateral. On the other hand, vowels surrounding the fifth liquid sounded similar to the vowels surrounding the target taps and alveolar laterals. This auditory percept of the vowels being fronted and raised may be attributed to the impression of the fifth liquid itself sounding clear in terms of resonance.

To the best of the author's knowledge there has been no previous research on the auditory or acoustic characteristics of the fifth liquid in Malayalam. There have been a few recent studies on a similar fifth liquid in Tamil (Narayanan et al, 1999; McDonough & Johnson, 1997) that allegedly occurs in lexical items common to the two languages (Zvelebil, 1970). These however were mainly acoustic and articulatory studies and no mention of any auditory impressions of the liquids in Tamil have been made. The acoustic results of the fifth liquid in Malayalam as found in the present study and those found in the studies on Tamil will be compared in the next section on acoustics.

6.2.2 Spectrographic analysis

Spectrograms of the five liquids in Malayalam seem to suggest that the spectrograms of the fifth liquid looked most similar to those of the tap and alveolar lateral in Malayalam and most different from the trills and retroflex lateral. These were based mainly on their respective second formant patterns and those of their surrounding vowels which appear to be the most robust cue. The fifth liquid tokens, however, also appeared to vary from the tap and alveolar lateral tokens in the F3 patterns of its preceding vowels. There seemed to be at least an initial slight drop in F3 of the vowel preceding the fifth liquid as opposed to the slight rise in F3 visible for vowels preceding both the tap and alveolar lateral. Whether or not these differences observed in the spectrograms are significant will become clearer in the next section on the acoustic measurements in which the magnitude of these differences will be assessed. These observations also suggest that the acoustic distinction of the fifth liquid among the other liquids in the language should not be viewed as merely based on the consonantal similarities or differences but also as based on the formant frequencies and their transitions from and to the surrounding vowels. The F2 and F3 transitions in the preceding vowels differ based on which of the five liquids they precede. For example, the rise in F2 of the preceding vowel starts earlier for the tap sequence than the fifth liquid sequence and appears more gradual in the former whereas the rise in F2 is more marked and appears to begin at the mid-point of the vowel preceding the fifth liquid. This could be suggesting that the fifth liquid has less coarticulatory effects of its resonance on its surrounding vowels than the tap since the consonantal effects extend only to the mid-point in the fifth liquid sequence as opposed to between the onset and mid-point for the tap sequence. Or in other words, the anticipatory effects of the tap may perhaps be stronger than that of the fifth liquid. Since the present study did not measure the slope of the formant transitions or any other measures of coarticulation, these observations are only tentative and it would be premature to make any further conclusive remarks in this regard.

Apart from the effects of the manner of articulation of the adjacent liquid and/or their resonance characteristics on the formant frequencies and formant transitions of their surrounding vowels, the quality of the vowel also seems to be a significant factor that determines the extent and nature of formant transitions to and from the liquid. Examples of spectrograms of /piɻa/, /paɻam/ and /puɻa/ as produced by one of the eight speakers in the present study (cf. Figs. 53, 54, 55; pgs. 193-194) showed that /i/ had steady formants when preceding /ɻ/ whereas /a/ had a rising F2 and fairly low but steady F3. /u/ on the other hand had a marked rise of F2 and lowering of F3 when preceding the fifth liquid. These results may be seen as an indirect indicator of the tongue configuration involved in the production of the fifth liquid i.e. raising of the tongue tip or blade as also suggested by the results of the auditory analysis since /u/ is a close back vowel and /a/ an open centre-back vowel[8] and both in the presence of the fifth liquid showed a rise in F2 whereas /i/ does not as it is a front vowel. Therefore there is a rise in F2 of the back or centre-back vowels in anticipation of the tongue tip/blade raising involved in the fifth liquid whereas a front vowel like /i/ does not require preparation for the following 'raised' fifth liquid. Or in other words, the back vowels are produced more advanced in anticipation for the following 'raised' fifth liquid. Interestingly, the F3 of /u/ is also considerably lowered when preceding the fifth liquid whereas the F3 of /a/ and /i/ remain fairly steady. Decrease of the higher formants is often associated with a greater degree of lip rounding. Ladefoged (2001) points out that the effect of lip rounding is greater in the third formant for front vowels and in the second formant for back vowels. Since /u/

[8]Velayudhan (1971) classifies /a/ in Malayalam as a central open vowel. Based on her own productions of /a/and those of the speakers in this study, the present author prefers a back-central classification for /a/. This may be true only for the central Travancore dialect of Malayalam that speakers of this study speak.

becomes [ʉ̟] before /ɻ/, the lowering of F3 may be attributed to a greater degree of lip rounding in production of [ʉ̟] before /ɻ/.

Differences and similarities of the fifth liquid to the other four liquids based mainly on the F2 patterns appears consistent with the auditory analysis results that indicated the impressionistic similarity of the fifth liquid to the taps and alveolar laterals in terms of a clearer resonance and its difference from trills and retroflex laterals due to the darker resonance of the latter.

The next section on the acoustic measurements, i.e. duration and formant frequencies will quantitatively assess the significance of the trends observed during the spectrographic analysis and auditory analysis.

6.2.3Acoustic Analyses

6.2.3.1 Duration

Consonant Duration

The fifth liquid was found to be significantly longer than tap realisations and shorter than alveolar laterals. Its duration was most similar to that of trill realisations and retroflex laterals. The patterning of the fifth liquid, which was realised by all speakers as an approximant, with trills and retroflex laterals with respect to duration may be attributed to their relatively retracted place of articulations compared to the taps and alveolar laterals. Also, the fifth liquid and the retroflex lateral are both approximant articulations although of course the place of the occlusion is not fully certain in the case of the fifth liquid, i.e. whether it is central or lateral. Auditorily, it sounds central but no definite conclusions can be made in this regard without articulatory evidence for the same. Therefore the durational patterning of the fifth liquid with the retroflex lateral but not the alveolar lateral, all three of which have an approximant manner of articulation, might be reaffirming that the fifth liquid has a 'post-alveolar' place of articulation. However, it must also be noted that although these results were based on statistical significance or non-significance, the actual difference in duration between these categories was not that large. For instance, the mean duration of the fifth liquid was 43ms and that of alveolar laterals was 50ms, the difference between which was found to be statistically significant with a medium effect size. SD values were also considerably high implying an overlap in durational measures across categories and speakers (Table 28 below).

	DURATION	
	Mean	SD
TR-TP	24.53	8.2
TP-TP	31.21	10.26
TR-TR	37.49	16.35
RTF.LAT	40.83	12.29
FIFTH LIQUID	43.18	14.81
ALV.LAT	50.39	10.19

Table.28. Average duration (ms) and SD of the five liquids in intervocalic position[9]. TR-TP=Trills realised as taps, TR-TR=Trills realised as trills, TP-TP=Taps realised as taps, RTF.LAT=Retroflex lateral and ALV.LAT= Alveolar lateral.

Mc Donough & Johnson (1997) report that the average duration of the fifth liquid in Tamil based on their two speakers reading out words in a carrier phrase was 84ms and that this was comparable to durations of the retroflex lateral and the denti-alveolar lateral in Tamil. This might suggest that the fifth liquid in Malayalam had a shorter average duration than that in Tamil (half of that in Tamil) although this could be due to the rate of speech in both the studies being different since it was not specifically controlled for in either study.

6.2.3.2 Formant Frequency

Consonant

In this section, the results for the fifth liquid will first be compared with the two rhotics and then with the two laterals. The fifth liquid was found to have significantly lower F1 and higher F2 values than trills (trills realised as taps and trills realised as trills). This suggests that the fifth liquid tends to involve more tongue tip/blade raising compared to the more retracted tongue-tip trills in Malayalam. F1 differences between consonants are generally correlated with the size of the constriction or size of the pharyngeal cavity

[9] The intervocalic position is the only word-position in which all five liquids commonly occur.

or both (Stevens, 1998:533, Mady and Beer, 2004). An increase in F1 signals either a smaller constriction length or a smaller pharyngeal cavity or both. Due to the apicality of the target trills, the degree of tongue tip-alveolar ridge contact is shorter in trills than the degree of tongue blade-hard palate contact or approximation in the laminal post-alveolar approximant, i.e. the fifth liquid. The shorter constriction length for the target trills as compared to the fifth liquid gives rise to a higher F1 in the former. The F1 differences were of a small-to-moderate effect size while the F2 differences were large. The high F2 of the fifth liquid is consistent with auditory impressions of its clear resonance. The fifth liquid was found to have F1, F2 and F3 values in the same range as that of the taps. The two appear to have their clear resonance in common which is reflected in their high F2 values. F3 was slightly lower for the trills than the fifth liquid but this difference was small. In chapter 4, results for the rhotics showed that the taps differed from the trills in Malayalam in their F3 values along with their F1 and F2 values. F3 values were significantly lower for the trills than the taps perhaps indicative of the former's retracted place of articulation as compared to the latter. The fifth liquid's F3 values were only slightly different from that of the trills and similar to that of the taps perhaps reflecting the retracted tongue tip and/or tongue body involved in trill production in Malayalam as opposed to the raised tongue blade in taps and arguably the fifth liquid too. In general, these results seem to suggest that the fifth liquid is acoustically closest to the taps among both the rhotics.

The fifth liquid had significantly lower F3 and higher F1 values than alveolar laterals and the magnitude of the F3 differences was small-to-moderate while that of the F1 differences were moderate-to-large. The lower F3 values of the fifth liquid may be reflective of its post-alveolar place of articulation as observed in the auditory analyses and perhaps even suggestive of its rhoticity. Considering F1 is inversely proportional to size of constriction, the higher F1 values of the fifth liquid suggest that it has a smaller constriction length than the alveolar lateral. This may be due to the differences in tongue configuration between the two. While the lamino-alveolar lateral is frontal in place of articulation than the lamino-postalveolar, the former also has a flat tongue body with a lateral opening and the latter may have its tongue blade raised towards the hard palate but has a grooved tongue body like the post-alveolar fricative /ʃ/. The groove formation of the tongue body would imply that a smaller area of the tongue, i.e. only the raised tongue blade, is in approximation with the roof of the mouth for the fifth liquid giving rise to a higher F1 whereas the flat, front tongue body of the alveolar lateral implies that a larger tongue body area is in closer approximation with the roof of the mouth leading to a higher F1. The fifth liquid and the alveolar lateral did not differ in their F2 values which is consistent with the auditory percept of both sounds being clear in resonance. On the other hand, the fifth liquid had significantly higher F2 values than retroflex laterals but similar range of F1 and F3 values. This implies that acoustically, the fifth liquid mainly differs from the retroflex lateral in their opposing resonance effects, clear in the former versus dark in the latter, which is most likely a consequence of difference in tongue configuration for both articulations. The cavity created by the lateral release in the retroflex lateral may also be creating a different resonance from that of the fifth liquid. The fifth liquid appears to involve raising the tongue blade towards the hard palate whereas the retroflex lateral appears to involve retraction of the tongue body and contact of the underside of the tongue-tip against the hard palate. Interestingly their F3 values were not found to be significantly different which further suggests that there may not be a significant difference between the fifth liquid and retroflex lateral in terms of their places of articulation. This would be consistent with the auditory impression of the former as being post-alveolar.

Certain dialects of Tamil have five liquids in their inventory like Malayalam and among them the fifth liquid is allegedly a common sound in both the languages (Zvelebil, 1970). Both languages also have a retroflex lateral. The acoustic relationship between the retroflex lateral and the fifth liquid in Malayalam as mentioned in the previous paragraph appears to be based mainly on a difference in their F2 values which indicates a dark versus clear resonance respectively. In Tamil, however, the retroflex lateral and the fifth liquid which they claim is a retroflex approximant are said to be different in that the F3 values of the latter are low before and after the consonant closure (pg.22). The latter is also described as having a low F3 throughout its duration (McDonough & Johnson, 1997). Although no direct comparisons are made between the 'retroflex' approximant and retroflex lateral in the article by McDonough & Johnson, the spectrograms of the two show that their F2 values may be considerably different. The F2 looks higher in the case of the 'retroflex' approximant than for the retroflex lateral which is similar to the pattern observed between the fifth liquid and retroflex lateral in Malayalam. In another study on Tamil liquids by Narayanan et al (1999), however, both the retroflex approximant and retroflex lateral were found to share the same low frequency acoustic characteristics , low F2 and low F3, F2 and F3 close together (F2=1460Hz, F3=1800Hz for retroflex lateral versus F2=1500Hz, F3=1850Hz for retroflex approximant). The researchers also found that the F4 values were higher for the retroflex approximant than the retroflex lateral by about 500 Hz). If the present author's observations about the spectrograms in McDonough & Johnson are correct, then their results and those of Narayanan et al appear to vary with respect to the F2, F3 measures of the fifth liquid. One reason for the difference in results obtained could be due to the background of the participants involved. While both studies were based on either one or two speakers of the Brahmin dialect of Tamil, the single speaker in Narayanan et al's study had been residing in the U.S for around 5-10 years at the time of the experiment and there may have been an influence of the American English bunched 'r' on the speaker's productions of the retroflex approximant and hence the lower F2, F3 than what was observed in McDonough & Johnson (1997). No detailed background information of the two speakers in terms of length of stay in the U.S etc. have been given in McDonough & Johnson's study and so it is difficult to determine with more certainty whether there was more or less influence of American English on the speakers in one study versus those of the other.

To summarize, both Malayalam and Tamil have the fifth liquid and the retroflex lateral in common in their five member liquid inventory. While the fifth liquid has similar low frequency acoustic characteristics as the retroflex lateral in Tamil, it appears to be the most acoustically similar to the lamino-alveolar taps in Malayalam with respect to the F1, F2 and F3 frequencies and differs from the retroflex lateral mainly in F2 values. Could the allegedly similar fifth liquid have different phonetic realisations in Malayalam and Tamil? In order to allow for a more detailed and direct comparison with the studies on Tamil mentioned above, more articulatory data is needed for the liquids in Malayalam.

Preceding vowels

Realisation of manner of articulation of the adjacent liquid and the quality of the vowel were both found to be significant factors determining the formant patterns of the vowels preceding the liquids. The interaction of the two factors also had a significant effect on the formant patterns of the preceding vowels. F2 was the most robust acoustic correlate of the differences or similarities between vowels preceding the fifth liquid and those preceding the rhotics, laterals. F1 and F3 values of the vowels were largely unaffected by the realisation of the manner of articulation of the adjacent liquid. All vowel types in the data set had significantly higher F2 mid-point and offset values when preceding the fifth liquid as opposed to when preceding the trills or retroflex laterals. All vowel types preceding the fifth liquid and those preceding the taps and alveolar laterals all had F2 values in the same range. These results seem to suggest that vowels preceding the fifth liquid were produced more advanced and raised than those preceding the trills or retroflex laterals whereas the vowels preceding the fifth liquid were not significantly different in quality from their counterparts preceding the taps or alveolar laterals (see figs. 60-63, pgs. 205-207, also see figs. 68, 69 on next page). These extrinsic differences in vowel quality appear to be an effect of the resonance characteristics of the adjacent liquid consonant: more advanced and raised when preceding the *clear* fifth liquid, taps, alveolar laterals versus more retracted and open when preceding the *dark* trills, retroflex laterals. Apart from the extrinsic differences, there were also intrinsic differences in the formant patterns of the vowels preceding the five liquids. Irrespective of realisation of manner of articulation of the adjacent liquid, preceding vowels had high versus low F1 based on whether they were close or open vowels respectively and high versus low F2 based on whether they were front or back vowels respectively.

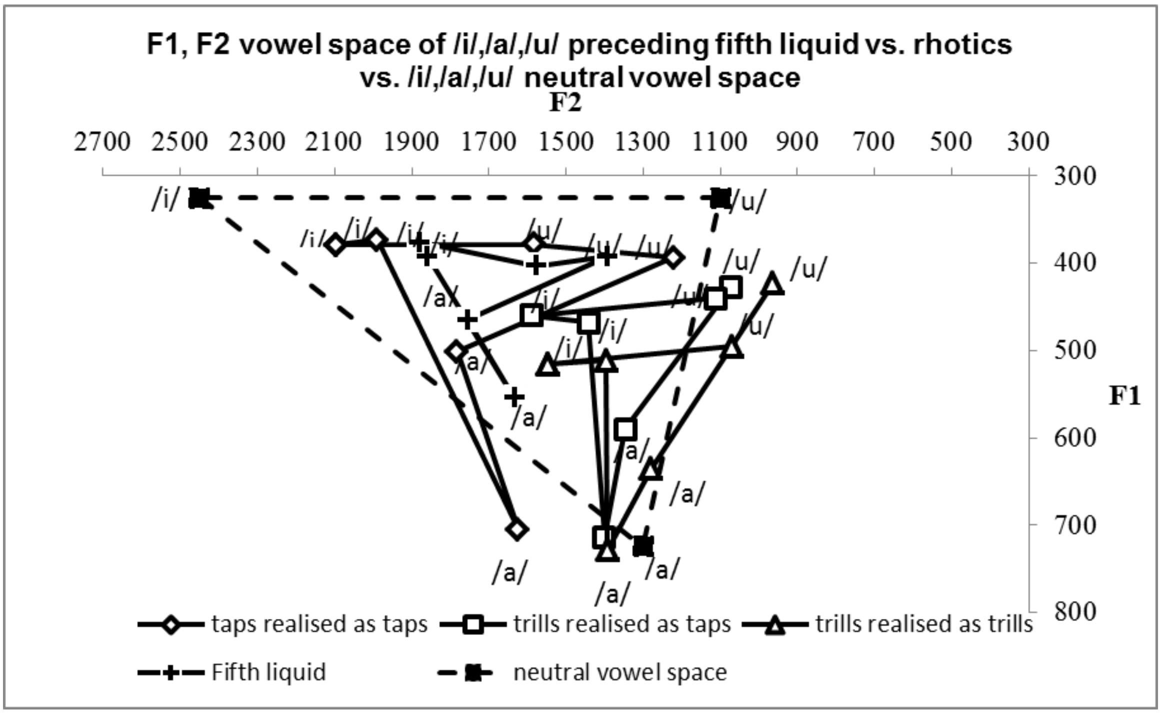


Fig.68. F1, F2 vowel space of /i/, /a/, /u/ preceding the fifth liquid versus rhotics. Also, F1, F2 vowel space of /i/, /a/, /u/ in non-liquid/neutral environment (fig. 34, pg.148) is superimposed on the above figure.

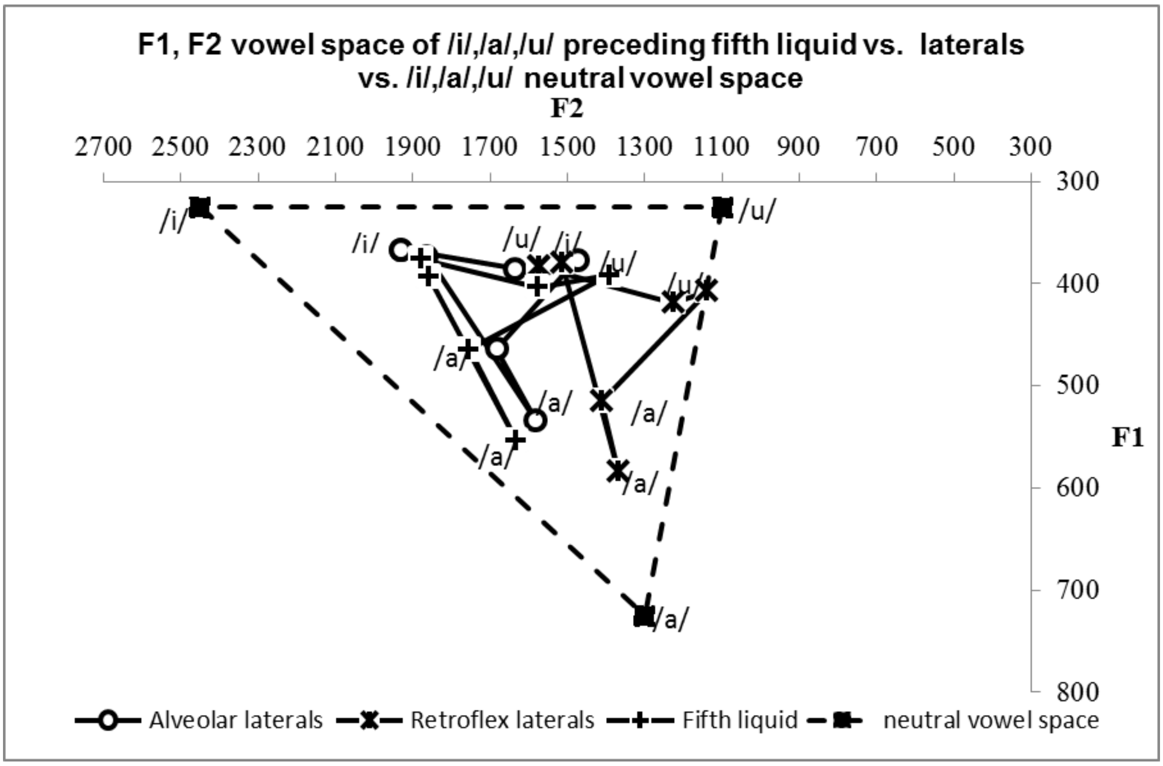


Fig.69. F1,F2 vowel space of /i/,/a/,/u/ preceding the fifth liquid versus laterals. Also, F1, F2 vowel space of /i/, /a/, /u/ in non-liquid/neutral environment (fig. 34, pg.148) is superimposed on the above figure.

From figs. 68 and 69, the vowel space preceding the fifth liquid appears most similar to the vowel space preceding the alveolar lateral and then to the vowel space preceding the target taps. In figs. 68, 69 above, comparing the vowel space preceding rhotics, laterals and fifth liquid with the neutral vowel space in Malayalam (for details of neutral vowel space in Malayalam modified from Radhakrishnan (2009: 64), see Ch.2, pg. 38 and Ch. 4, fig. 34, pg. 147) shows that the vowel space preceding all the five liquids is much smaller than the neutral vowel space in Malayalam reflecting the large overall effect of the liquids on their preceding vowel space.

In both the studies on Tamil liquids by Narayanan et al (1999) and McDonough & Johnson (1997), there is no description or measurements given of the formant frequencies of the surrounding vowels and hence no comparison is possible between the data on Tamil and the data on Malayalam in the present study.

Following vowels

Realisation of manner of articulation of the adjacent liquid and vowel quality were both found to have significant effects on the formant patterns of vowels following liquids in Malayalam. The interaction between the two factors also had a significant effect on the formant frequencies of the following vowels. /i/ and /a/ were the only vowel types in the data set of the present study following the liquid tokens. Apart from extrinsic differences in vowel quality which will be described below, i.e. those based on which of the five liquids they followed, there were also intrinsic vowel quality differences. In other words, formant frequency values of /i/ and /a/ varied irrespective of the adjacent liquid environment since /i/ is a close and front vowel characterised by low F1, high F2 and /a/ is a low and back-central vowel in Malayalam characterised by a high F1, low F2.

/i/ and /a/ following the fifth liquid had F1 and F2 onset and mid-point values in the same range and not significantly different from that of /i/ and /a/ following target taps and alveolar laterals. /i/ and /a/ following the fifth liquid had lower F1 values and higher F2 values than /i/ and /a/ following the target trills (trills realised as taps and trills realised as trills) and retroflex laterals. These results suggest that the vowels following the fifth liquid pattern acoustically with those following target taps and alveolar laterals and appear to be maximally different from those following target trills and retroflex laterals. Therefore the similarities or differences between vowels following the fifth liquid versus those following the other four liquids do not appear to be based on whether the other four liquids are rhotics versus laterals but rather on whether they were fronted or back and clear or dark respectively. The vowels following the fifth liquid patterned most with those following the clearer and fronter of the other four liquids, i.e., taps and alveolar laterals.

Unlike the vowels preceding the liquids, the vowels following them appear to have been affected by the realisation of manner of articulation of the adjacent liquid in their F1 and F2 values. Only the F2 values of the preceding vowels were affected by the realisation of manner of articulation of the adjacent liquid. There are two possible ways to address these patterns: Firstly, that F2 appears to be the most robust acoustic cue determining whether vowels preceding or following the fifth liquid pattern with those preceding and following the taps and/or trills and/or alveolar laterals and/or retroflex laterals. Secondly, the difference in the effects of the adjacent liquids on the preceding versus following vowels might be suggesting that the height of the vowel which is associated with the first formant frequency is affected more by the carry-over effects of the adjacent liquid than its anticipatory effects.

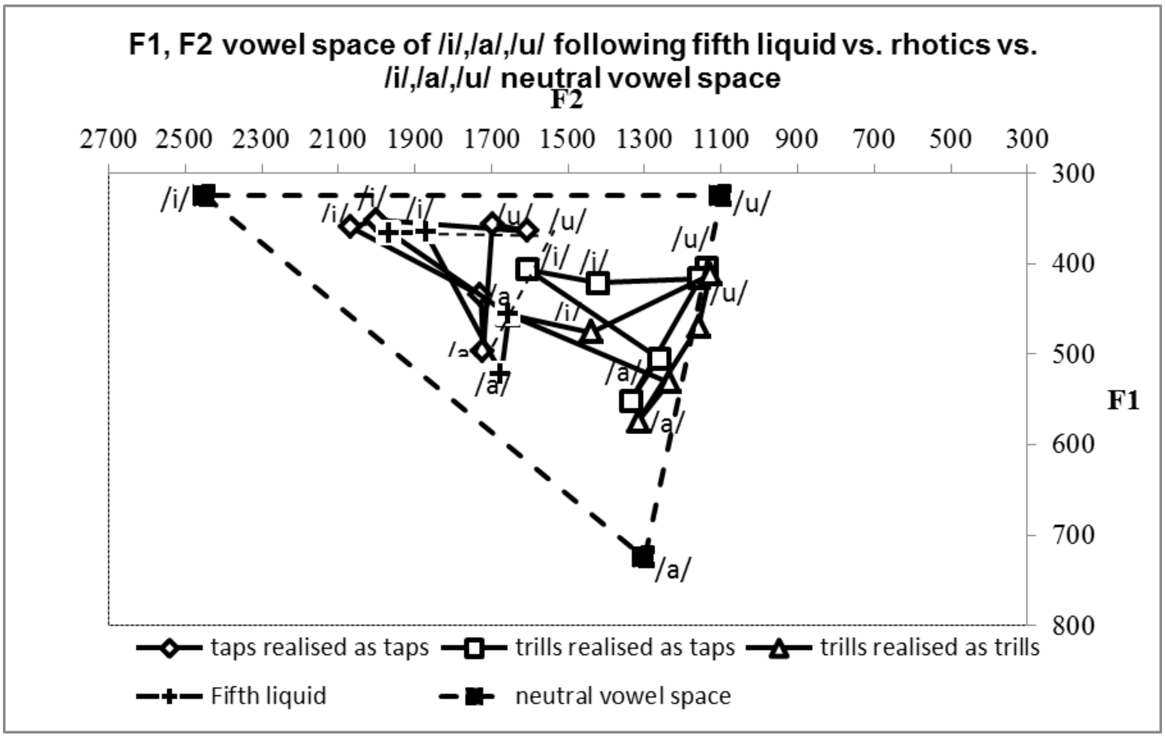


Fig. 70. F1, F2 vowel space of /i/, /a/, /u/ following fifth liquid versus rhotics. Also, F1, F2 vowel space of /i/, /a/, /u/ in non-liquid/neutral environment (fig. 34, pg.148) is superimposed on the above figure.

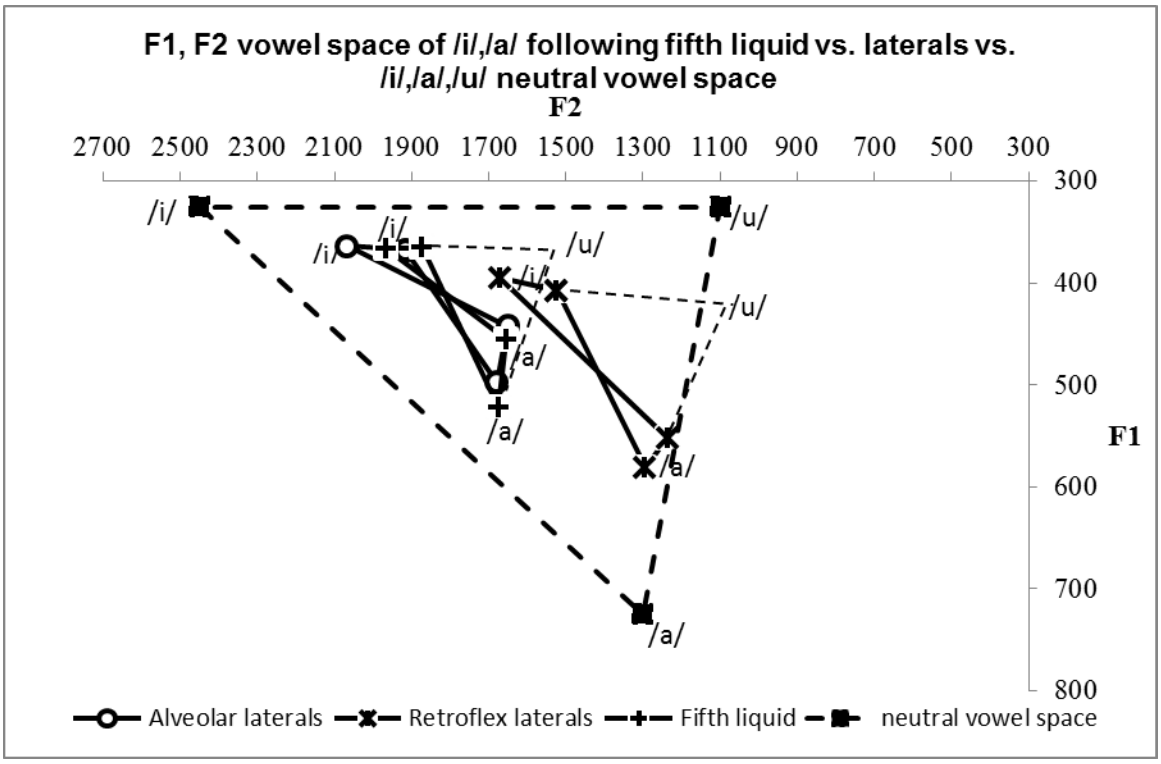


Fig. 71. F1,F2 vowel space of /i/,/a/,/u/ following the fifth liquid versus laterals. Also, F1, F2 vowel space of /i/, /a/, /u/ in non-liquid/neutral environment (fig. 34, pg.148) is superimposed on the above figure.

Comparing the two figs. above, it seems that the vowels following the fifth liquid share the same vowel space as the vowels following alveolar lateral and the taps. In figs

70, 71 above and figs. 68, 69 (on pg. 224), comparing the vowel space following rhotics, laterals and fifth liquid with the superimposed neutral vowel space in Malayalam (for details of neutral vowel space in Malayalam modified from Radhakrishnan (2009: 64), see Ch.2, pg. 38 and Ch. 4, fig. 34, pg. 147) shows that the vowel space following all the five liquids is much smaller than the neutral vowel space in Malayalam reflecting the large overall effect of the liquids on their surrounding vowel space. The fifth liquid like the rhotics and the laterals has a huge co-articulatory effect on its surrounding vowels in general which reduces their vowel space area in comparison to the neutral vowel space.

/i/ and /a/ were the only vowel types in the data set that occurred as preceding and following vowel contexts to the fifth liquid. Their F2 values revealed that the coarticulatory effects of the adjacent fifth liquid may be different for the two vowel types and also different depending on whether they preceded or followed the fifth liquid. a/ was affected more than /i/ by the coarticulatory effects of /ʐ/. Since the auditory and acoustic results suggest the fifth liquid to have a clear resonance, it follows that high close vowel /i/ and /ʐ/ are not in articulatory conflict due to the similarity in the articulatory constraints required for the two and therefore the anticipatory effects of the fifth liquid are much lesser on /i/ than on /a/. Previous research on V-to-C and V-to-V coarticulation on Spanish and Catalan has also suggested that /i/ is in general more resistant to coarticulation than /a/ (Recasens, 1987; Farnetani & Recasens, 1993 etc.). F2 values of /a/ were higher when it followed rather when it preceded the fifth liquid. Also, anticipatory effects of the fifth liquid appear to have a late onset in /a/ (F2 rises from mid-point to offset) whereas the carry over effects of the fifth liquid appear to have a late offset in /a/ (F2 remains relatively high and steady throughout the onset and mid-point of the following /a/). The F2 values were higher when /i/ followed rather than when it preceded the fifth liquid as was the case with /a/. Unlike /a/ however, the F2 values of /i/ were relatively high and steady throughout when it preceded the fifth liquid while there was a rise in F2 from onset to mid-point when /i/ followed the fifth liquid. Carry-over effects of the fifth liquid if any also appear to have an early offset in /i/ which explains the further rise in F2 of /i/ at mid-point as compared to the onset. Since no formal measurements of coarticulation have been made in this study, the above observations are only tentative and therefore should be interpreted with caution. A more detailed account of the coarticulatory effects of /ʐ/ on surrounding vowels or those of the surrounding vowels on /zh/ is beyond the scope of the thesis.

To summarize, the fifth liquid in Malayalam appears to be a post-alveolar approximant with a clear resonance. Acoustically, the fifth liquid and its surrounding vowels pattern most with the taps and alveolar laterals and their surrounding vowels and are most different from the trills and the retroflex laterals. The next chapter will address the recurrent phonetic and phonological themes emerging from the results outlined in this chapter and the previous two chapters in the light of the research questions of this thesis.

CHAPTER 7
GENERAL DISCUSSION

This chapter aims to interpret the auditory and acoustic analyses results obtained for productions of the rhotics, laterals and a fifth liquid by eight male native speakers of Malayalam with respect to the research questions addressed in this thesis. Recurrent phonetic phenomena emerging from these results and the relationship between the phonetics and phonology of the liquids in Malayalam will be discussed in the context of two main principles: Principle of Maximal Differentiation and Extrinsic Phonetic Interpretation (EPI), and the phonological analysis proposed here is the Firthian Prosodic Analysis.

The present study had two main objectives. The first objective was to describe the phonetic characteristics of the two uncontested rhotics in Malayalam and the nature of the contrast maintenance between them. The second objective was to shed light on the phonetic and phonological features of the fifth liquid in Malayalam which has been variously referred to in the literature as an 'r-sound', a 'voiced retroflex palatal fricativised lateral' (Kumari, 1972:27-28), 'a voiced sublamino palatal approximant' (Asher & Kumari, 1997: 419), a 'frictionless continuant' (Namboothiri, 2002) and more recently a 'retroflex approximant' (Krishnamurti, 2003).

7.1 Contrast maintenance between the two rhotics

7.1.1 Dimensions of contrast

The results of this study regarding the rhotics in Malayalam outlined in chapter 4 showed that the two rhotics differed from each other in their place of articulation, resonance qualities and their effect on surrounding vowels. One was advanced and clearer in resonance whereas the other was more retracted and darker in resonance. The advanced rhotic was produced as lamino-alveolar whereas the retracted rhotic was produced as apico-alveolar. The advanced rhotic was always realised as a tap by all eight speakers in the study while the other slightly more retracted rhotic had various realisations including tap, trill and approximant realisations[10]. Nevertheless most speakers produced most target trill tokens as taps in both word positions. Surrounding vowels sound advanced and raised in the presence of the target taps while the 'same' vowels sound retracted and more open in the presence of the target trills. Acoustically, the advanced rhotic had lower F1, higher F2 and higher F3 values than the retracted rhotic indicating a more close, raised and fronter articulation for the former than the latter which is consistent with the auditory analysis results. Auditorily, the most prominent difference between the rhotics and their surrounding vowels seemed to be the difference in their resonance qualities (clear advanced tap versus dark retracted trill). Acoustically too, the most robust distinguishing feature was the difference in F2 values (higher F2 for the tap/advanced rhotic versus lower F2 for the trill/retracted rhotic) which is the acoustic correlate of clearness versus darkness respectively. Resonance therefore appears to be a significant aspect of the contrast maintenance between the rhotics in Malayalam and could be an off-shoot of the laminal versus apical difference in tongue configuration between the two. Resonance and its role in maintenance of several other contrasts in Malayalam will be dealt with in section 7.4.

7.1.2 Role of the manner of articulation of rhotics in contrast maintenance

The manner of articulation of the rhotics, although it has been the topic of much disagreement in the limited literature on Malayalam, may not be a primary source of contrast maintenance between the two rhotics. While in the present study one rhotic was always realised as taps, the other had several realisations including taps, trills and approximants as mentioned earlier. Therefore, the realisation of the manner of articulation of the rhotics was not consistently different between the two rhotics. In other words, this study presumed two target manners of articulation for the two rhotics but found in the data more than two pairs of target-realisation combinations of manner of articulations namely target taps realised as taps, target trills realised as taps, target trills realised as trills and target trills realised as approximants. This means that there was no one-on-one correspondence between the presumed target manner of articulation and the actual phonetic realisation of the manner of articulation of the two rhotics. The categorisation at the start of the present study to the advanced rhotic as taps and the retracted rhotic as trills

[10] The retracted rhotic was realised as an approximant in some cases by the speakers only in word-initial position.

with respect to their target manner of articulation is based mainly on the present author's native speaker instincts of the central Travancore dialect. Some Grammarians have also categorised them as one tap/flap and one trill (Kumari, 1972; Asher & Kumari, 1997) while other researchers have categorised both as being trills (Ladefoged & Maddieson, 1996). Some evidence supporting the one tap-one trill notion from the view of phonological patterning of the two rhotics will also be explored in the next sub-section.

The results of this study revealed that there were systematic differences between the two types of rhotics, i.e., *target taps* and *target trill*s in resonance qualities, tongue configuration and place of articulation. However, none of the above mentioned differences can be attributed to be a consequence of the difference in their manner of articulation. The only other known acoustic study of the rhotics in Malayalam, Srikumar and Reddy (1988), categorised the two rhotics as being two trills, nevertheless they too found the relationship between the two rhotics to be similar to that found in this study. Their results also showed that the main dimensions of contrast between the two rhotics were differences in resonance qualities and a slight difference in place of articulation and the subsequent effects on their surrounding vowels. Therefore irrespective of whether the rhotics are perceived as being one tap, one trill (Kumari, 1972; Asher & Kumari, 1997; present study) or two trills (Ladefoged & Maddieson, 1996; Srikumar & Reddy, 1988 etc.), the dimensions of contrast maintenance between the two rhotics appear to be less concerned with their manner of articulation. Nevertheless, in section 7.1.4 below (pgs. 235-237), the clear (palatalized) versus dark (velarized) contrast between the rhotics will be explored as possible evidence for the phonological classification of the former as tap and latter as trill.

7.1.3 Role of duration in contrast maintenance between rhotics: acoustic duration versus articulatory timing

In languages of the world that have tap-trill contrasts, duration is often cited as a dimension of contrast maintenance, like for example in Spanish. Nevertheless the literature on Spanish tap-trills is also divided regarding the role of duration in contrast maintenance. While some studies have reported significant durational differences (Willis and Bradley, 2008), others have found little or no significant durational differences between taps and trills and even claims to tap-trill neutralisation in some dialects (Hammond, 1999). The present study adopted the stance of one rhotic in Malayalam being a target tap and the other being a target trill. Since this study differentiated between target forms and actual phonetic realisations, it was predicted that trill *realisations* would be longer than tap *realisations*. The results were consistent with the predictions in that the durational difference between trill realisations (trills realised as trills in this case) and tap realisations (taps realised as taps and trills realised as taps) were statistically significant. However, trills realised as taps were shorter than taps realised as taps. The reasons for these patterns have been explained in Results and Discussion I (Ch.4, pg.130). The direction of the durational difference between trills realised as trills and taps realised as taps was different from that between trills realised as taps and taps realised as taps. In other words, both realisations of target trills differed in duration from target taps in two opposite ways. Also note that the actual difference in duration among the sound groups is 10-20 ms which is not a big difference and hence the implications of the statistical significance found in this case cannot be generalised and must be interpreted with caution. Duration of the two rhotics or that of their surrounding vowels does not appear to provide a straightforward picture regarding its role in contrast maintenance. In general, nevertheless, it seems to be the case that duration may not be a prominent acoustic cue in distinguishing between the two rhotics in Malayalam.

The duration of liquids in this study was measured based on a set of acoustic cues that are known to help with the segmentation of the acoustic stream and with delineating the boundaries between liquids and their surrounding vowels (e.g. periodicity, amplitude, etc.)(For details of segmentation criteria used in this study, see Chapter 3 pgs. 73-74). From an articulatory perspective, however, gestures are the basic units of speech and according to gestural models of articulatory phonology (Brownman and Goldstein, 1989); duration is seen as an intrinsic property of gestures (Romero, 1996). Given that the articulation of liquids (and consonants in general) involves several gestures with varying degrees of overlap depending on intrinsic and extrinsic factors, the boundaries between them and surrounding vowels can be a lot more blurred and may affect the resulting durations that are reported for the liquids. Based on the above articulatory perspective, a possible interpretation of the duration results obtained in this study for the liquids in Malayalam has been discussed below.

The liquids in Malayalam constitute a complex set of coordinated gestures. The tap and alveolar lateral apart from their primary alveolar constriction also seem to involve a secondary tongue body raising/fronting gesture while the trill and the retroflex lateral apart from their primary retracted-alveolar and sub-apical constriction respectively, also seem to involve a secondary tongue dorsum backing gesture. Results of the present study showed that the among the rhotics, trills realised as taps (apico-alveolar taps) were the shortest in duration followed by taps realised as taps (lamino-alveolar taps) and then by trills realised as trills which had the longest duration (apico-alveolar trill). In other words trill realisations (apical trill) were longer than tap realisations (apical tap and laminal tap). This is expected due to the difference in the nature of gestures that characterise a trill and tap. Production of trills involves an aerodynamically induced movement of a flexible part of the tongue vibrating against the passive articulator more than one time[11]. This makes it longer than the tap, which by definition is a single brief and rapid contact of the active articulator against the passive and is a purely muscular gesture. Also, these are only the primary gestures that are involved in the trill and tap but as mentioned above there are also other secondary gestures that characterise their individual identities in Malayalam, namely the resonance differences. Target trills irrespective of their realisations were realised ‘dark’ (velarized) (trills realised as taps, trills realised as trills) whereas target taps were realised ‘clear’ (palatalized) (taps realised as taps). These too may play a role in determining differences in their respective durations. Within the two types of tap realisations (target taps realised as taps which were advanced lamino-alveolar and target trills realised as taps which were retracted apico-alveolar), apical taps were shorter in duration than laminal taps. The primary articulatory target in both cases is the tongue tip (apical) or blade (laminal) making a brief rapid contact with the alveolar ridge. One of the reasons suggested earlier on (cf Chapter 4, pg. 130), regarding this durational difference between apical and laminal taps, is that the tongue blade is relatively larger in mass than the tongue tip and therefore takes longer to move towards the alveolar ridge than the tongue-tip, making the laminal taps longer than the apical taps. Another reason could be that the differences in the tongue body gesture between the apical and laminal tap (concave versus convex tongue configuration respectively) cause differences in relative timing of the primary and secondary gestures with respect to each other owing to varied patterns of gestural overlap resulting in different durations. Or yet another possibility is that the ‘source’ of the difference between the target tap and target trill duration could be either the approach, closure or release phases of the gestures that are involved in their production. For instance, one could speculate that it is perhaps due to the incomplete closure or weak contact of the tap realisations (which is also why they have also been

[11] One-tap trills are not being dealt with separately here since the literature is not clear regarding how they are different from regular taps in terms of their duration.

more specifically categorised as ‘tap approximants’) and the non-canonical trill realisations (see figs.14, pgs. 91-92) with few contacts that the durational difference between tap realisations and trill realisations for Malayalam in this study, although significant, was not as large as reported for other languages like Spanish (e.g. Willis and Bradley 2008 etc.). In other words, the relative timing of the different phases of approach, closure and release of the tap and trill gestures may play a role in the duration results observed The relatively large standard deviation values in these categories also reflect the large inter- and intra-speaker variation in duration values. This may be due to the individual differences in production owing to different vocal tract shapes and sizes, speech rate, gestural timing and prosodic factors.

Between the laterals, the clear alveolar lateral was found to have a ‘significantly’ longer duration than the retroflex lateral but the average duration difference was only about 10ms. Nevertheless what is interesting is that the laterals show a similar pattern to the rhotics in in that between two rhotics of the same manner of articulation, the clearer one was found to be longer than the darker one, which is also the case with the laterals (even if the difference is slight).Here too, it can be speculated that the relative timing of the primary and secondary gestures involved in the alveolar lateral and retroflex lateral, i.e. the tongue blade constriction along with some degree of tongue raising and possibly fronting for the alveolar lateral versus the constriction involving the underside of the tongue-tip along with some degree of tongue dorsum retraction and possibly lowering for the retroflex lateral may be what is causing the difference in duration (slight difference in this case). SD values were large in the case of the laterals too and it is also important to point out that no specific predictions were made regarding the duration of alveolar versus retroflex lateral, unlike the case with the rhotics, since hardly anything has been discussed in the literature regarding duration as a cue to distinguish between the laterals in Malayalam.

The duration of the vowels preceding the liquids was also measured in this study and in general there were either no significant effects of the liquid type on the duration of its preceding vowel or the effect size of the few statistically significant cases was small and standard deviation values were large (cf chapter 4, pgs. 102-104; chapter 5, pgs. 153-154). Only absolute duration values were measured in this study and perhaps future researchers can also measure V1C and CV2 transitions which will indicate the magnitude, direction and degree of coarticulatory effects and thereby hint at the possible timing of the multiple gestures involved in each liquid. It is possible that the transition measures might provide relevant information regarding any timing differences in gestures associated with taps versus trills, alveolar versus retroflex laterals that may have also have perceptual significance. Apart from measuring duration and formant transitions in vowels surrounding the liquids, it seems imperative that future scholars also focus on articulatory methods like EMA (Electromagnetic Midsagittal Articulography) (e.g. Romero's, (2008) work on gestural timing in Spanish clusters etc.) or a combination of EMA and EPG (Electropalatography) (e.g. Hardcastle et al, 1996 on tongue kinematics in kl clusters and singleton k) for a more precise account of gestural timing. While EPG measures the place and length of constriction (degree of contact), timing of tongue contact with the hard palate, EMA (Perkell et al 1992) enables measurement of tongue movement trajectories and provides valuable information regarding the tongue, jaw and lower lip movements involved in speech sounds and track the movements in an x-y plane. A combination of the two methods has been reported to provide a reasonable representation of the overall tongue shape and configuration and tongue movement (Hoole, 1993; 1996 as reported in Hardcastle et al, 1996). Therefore future work on liquids in Malayalam must focus on such articulatory methods to obtain a detailed account of the timing of the complex gestures involved in the production of liquids and its possible role in distinguishing between the rhotics or among the five liquids in Malayalam.

7.1.4 1 tap, 1 trill or 2 trills? Phonological patterning of the rhotics

The two rhotics contrast in the intervocalic position [V_V], [CV_V] and in word-initial position [_VVCV]. In the word-initial position, trills occur mostly, if not always, in loan words from Sanskrit and are relatively less frequent in the lexicon. Only the retracted rhotic, i.e. what is referred to as the target trill in the present study, occurs in the word-final position [CVCV_] and therefore the rhotic contrast is neutralised in the word-final position. Only the trill occurs as 'fragments', i.e. occurs post-vocalically in the word-final position as mentioned above and word-medially in a pre-consonantal and post-vocalic position, e.g. /pajar/, /marmmam/ etc. Therefore the phonotactic environments of the two rhotics appear to be different. This difference cannot be solely attributed to the place of articulation difference between the two rhotics since both are essentially alveolar articulations and differ only slightly in their place of articulation, one being alveolar and the other being retracted alveolar. The difference may be a consequence of their different tongue configurations, laminal (convex) for the former and apical (concave) for the latter. However, if it was the case that laminality is what prohibits the advanced rhotic forming fragments and occurring word-finally, then one would expect other lamino-alveolars in the language to also show similar trends but the lamino-alveolar lateral for example does not behave in the same way. The lamino-alveolar lateral, unlike the lamino-alveolar rhotic occurs word-finally and forms 'fragments'. Perhaps then it may be the different manners of articulation that causes the two rhotics to behave differently phonotactically.

The disagreement in the literature is regarding whether Malayalam has one tap, one trill or two trills, or in fact, regarding whether the advanced rhotic is a tap or trill since both viewpoints agree that one rhotic, the more retracted of the two, is definitely a trill. Also, Srikumar and Reddy (1988), like the present study, found that the advanced rhotic is clear in resonance or in other words palatalized. Srikumar and Reddy claim Malayalam has one palatalized trill and one velarized trill. Although not impossible, it is highly unlikely this is the case since palatalized trills are a rare occurrence in the languages of the world (Ladefoged & Maddieson, 1996; Kavitskaya et al., 2008). Ladefoged & Maddieson (1996) attribute the markedness of palatalized trills to the conflicting nature of articulatory requirements that characterise palatalization, i.e. raising of the blade and front of the tongue, and the aerodynamic vibrations involved in trill production. Kavitskaya et al. (2008:24) showed in their study that the conflicting constraints on the tongue dorsum for palatalization and trilling led to relative phonetic instability of palatalized trills in many Slavic languages which subsequently had phonological consequences. Therefore the opposing demands on the tongue dorsum exerted by palatalization and trilling was responsible for the depalatalization of the proto-Slavic palatalized trill at least partially in languages like Ukrainian, Upper Sorbian and Bulgarian and fully in languages like Belarusian, Slovak, Serbian/Croatian and Macedonian. Toda, a Dravidian language like Malayalam, is reported to have plain and palatalized trills (Ladefoged & Bhaskararao, 1994) but Hamann (2003) argues that what is transcribed as a palatalized retroflex trill in Toda and Kashmiri is actually realised as a sequence of rhotic and a palatal approximant. Some researchers like Hall (2000) have also argued for the general instability of palatalized rhotics as a whole. There appear to be some amount of cross-linguistic evidence supporting the markedness of palatalized trills in the world's languages. The non-preference for palatalized trills and the different phonotactic behaviour of the palatalized rhotic from that of the velarized second rhotic (a trill) might be hinting that the advanced rhotic could phonologically be a tap.

The present study only had a small sample of data representing one geographical dialect of Malayalam and it could very well be the case in that some other dialect realisation of the advanced rhotic also includes tap variants as well as trill variants as is the case with the retracted rhotic in the present study . More data from different dialects and more research into the historical evolution and possible change of these sounds over time are needed before more concrete inferences regarding the phonetic and phonological patterns of the rhotics can be made.

7.2 The Rhotic-Lateral relationship in Malayalam

7.2.1 Dimensions of phonetic contrasts

As discussed in chapter 5, the phonetic relationship between rhotics and laterals based on the data in the present study on Malayalam appears to involve distinctions based more on resonance qualities and place of articulation and/or tongue configuration rather than a simple two way distinction based on rhotics versus laterals. The lamino-alveolar tap and lamino-alveolar lateral had more in common with each other acoustically and grouped together as opposed to the apico-alveolar trill and retroflex lateral. This grouping is based on several inter-related dimensions of contrast: laminal versus apical/sub-apical, fronted versus back, both contrasts giving rise to a convex versus concave tongue configuration respectively and a third contrast of clear versus dark respectively. Acoustically the lamino-alveolar tap and lateral were characterised by a low F1, high F2, high F3 while the apico-alveolar trill and retroflex lateral were characterised by a high F1, low F2, and low F3. The difference in resonance quality between the two groups may be a consequence of the difference in place of articulation and tongue configuration. Alternatively, the laminal versus apical feature and raised versus retracted tongue body may be strategies used to achieve a difference in resonance quality between the two groups. As we will see in section below, it is the latter view point this thesis adopts and it is argued that differences in resonance quality underlie maintenance of several contrasts in Malayalam and other languages.

It is also important to note however that this study only conducted auditory and acoustic analyses and the above trends are true of the acoustic analyses and the author acknowledges that the rhotic-lateral distinction perhaps has a more articulatory basis while the superclass of ‘liquids’ has more of an acoustic basis as also suggested by recent research on Tamil liquids (Narayanan et al., 1996). However, the present author acknowledges that this study only focussed on the first three formant measures as part of the acoustic study which is not the only acoustic characteristics that could have been tested. F4 measures may provide interesting cues to an acoustic distinction between rhotics and laterals in future studies along with in depth analyses of the nature and location of anti-formants, both of which were beyond the scope of the present study. Nevertheless, results of the acoustic analyses in the present study seem to provide some evidence justifying a super-class of liquids that have sub-groups based on resonance quality and tongue configuration differences rather than merely rhotics versus laterals.

7.2.2 Phonological relationship between rhotics and laterals in Malayalam

Phonologically, the laterals and rhotics in Malayalam share a complex relationship, one that is partly interactive and partly fixed. The sections below will focus on three specific aspects of this relationship: the occurrence versus non-occurrence of gemination, phonotactic patterning where relevant Sandhi rules will be explored and the possible role of resonance quality (palatalization versus velarization) in determining permissible word-internal rhotic-lateral occurrences in Malayalam

7.2.2.1 Gemination

One of the most prominent phonological differences between the rhotics and the laterals in Malayalam is that the laterals can undergo gemination whereas rhotics cannot. All the consonants in Malayalam are allowed to undergo gemination except for the rhotics (Asher & Kumari, 1997; Sadanandan, 1999). The rhotics are therefore unique in this respect.

Malayalam, as has been mentioned before, is said to have originated from a western dialect of Middle Tamil (Zvelebil, 1970) which can then be traced back to Proto-Dravidian. Recent research on Proto-Dravidian (Krishnamurti, 2003) has shown that it had one rhotic and two laterals in its consonant inventory. The rhotic was a flap and the laterals were alveolar and retroflex (pg. 91) and it has been reported that Proto-Dravidian laterals geminated whereas the rhotic and ‘frictionless continuant’ did not. “Single and double consonants contrast in non-initial position with the exception of *r and *z[12] which occur only singly" (Krishnamurti, 2003: 92-93). Therefore the 'non-doubling' of rhotics as opposed to the doubling of the laterals in modern Malayalam seems to have been inherited from Proto-Dravidian.

Laterals in Malayalam, as mentioned above, can undergo gemination. Local & Simpson (1999:595) suggests in their study of geminate laterals and nasals in Malayalam that gemination should be treated as a long domain phonological phenomenon having implications for the articulatory and durational aspects of utterances that extends over a number of syllables They found that the phonetic implementation of gemination is not limited to a particular point in the utterance, i.e. just the consonant, and to only length differences, but that it also involves systematic differences in surrounding vowel quality and resonance in the consonantal portions. Geminate consonants irrespective of place or manner of articulation were found to be clearer in resonance than their non-geminate counterparts and the former's surrounding vowels were fronted and more closed than the latter's. The authors rightly point out that in a singleton-geminate pair like /mula/-/mulla/, both laterals were *clear* in resonance but the lateral in /mulla/ was *clearer*. This suggests that although the difference in resonance is relative and not absolute in such cases, it appears to still be a strong distinguishing cue between singleton and geminate pairs. This clear/clearer versus dark/darker resonance differences to maintain contrasts has been observed in the present study for the two rhotics in Malayalam and also for the dental-alveolar distinction in Malayalam (Dart & Nihalani, 1991).

This section discussed the non-gemination of the rhotics and the fifth liquid in Malayalam as opposed to the gemination of the laterals as an important phonological difference between rhotics and laterals in the language. A previous study on the geminate laterals and nasals in Malayalam by Local & Simpson (1999) was described and it showed the significant role of resonance quality in distinguishing between singleton-geminate minimal pairs. The significant role of resonance in the phonology and phonetics of Malayalam liquids will be dealt with in section below.

[12]Krishnamurti (2003) uses the symbol *r to describe the voiced alveolar tap and *z to describe the 'retroflex approximant' in Proto-Dravidian.

7.2.2.2 Phonological interaction of rhotics and laterals with other sounds

In this section, the phonotactic interactions between rhotics and laterals with other consonant groups are examined via relevant Sandhi rules that exist in Malayalam. 'Sandhi' refers to a wide variety of phonological processes that occur at morpheme or word-boundaries. In this section, only those Sandhi rules that involve any of the five liquids in Malayalam are briefly discussed in order to compare and contrast the phonotactic patterns of the five liquids. A slightly more detailed account of Sandhi in Malayalam has been covered in Chapter 2.

While there are some rules that apply to laterals, rhotics and glides, some others apply only to the laterals and nasals. One Sandhi rule that applies to all liquids and glides when in combination with suffixes beginning with /k,ʧ,t̪,p/ results in the deletion of the final liquid or glide of the first word (Thomas, 1990; Gopinathapillai, 2006). Here the final lateral and rhotic behave similarly as the examples below show (based on examples in Gopinathapillai, 2006).

4) /ʃiʃjar + /kaɭ/= /ʃiʃjakaɭ/

5) /kaʈaɭ + /puram/ = /kaʈappuram/

Another Sandhi rule involving assimilation forming part of what is called 'Aadeshasandhi' applies to only the laterals and nasals as shown below. The initial /t/ of the suffix assimilates to the place of articulation of the word-final lateral. No examples involving consonant groups other than laterals or nasals were found (based on examples in Gopinathapillai, 2006).

5) /akal/ + / t̪iː/= /akatti/

6) /vil/ + /t̪u/ = /vittu/

Given below is an Aadeshasandhi rule that shows the alternation between the laterals and the nasals. It involves assimilation of the word-final alveolar lateral fragment into an alveolar nasal fragment when combining with a word beginning with a nasal. /l/ →/n/ / _/m/ (based on examples in Gopinathapillai, 2006).

5) /kal/ + /maḏam/= /kanmaḏam/

6) /nel/ + /muḻa/ = /nenmuḻa/

Therefore it appears that there is some evidence of phonological alternation between laterals and nasals in Malayalam and certain rules that apply to only laterals and nasals but that do not apply to the rhotics or the fifth liquid. This might then also be seen as an example of how the fifth liquid behaves like the rhotics rather than the laterals in the nature of its interaction with other consonant groups. There seems to be more interaction between laterals and nasals than rhotics and nasals in Malayalam. In other words, the relationship of the laterals with the nasals and that of the rhotics with the nasals is one example of the difference in phonotactic patterning between the rhotics and laterals in Malayalam. There is however at least one rule applying to all liquids and glides which has also been described above. Another example of where rhotics and laterals behave similarly is that both constitute the second element in word-initial clusters with plosives. By exploring some aspects of between each of the two liquid sub-groups with other consonant groups, this section showed the phonological distinctness of the rhotics and laterals as separate groups while also presenting some evidence in favour of shared phonological features between rhotics and laterals.

It has been suggested that there was/is a phonological alternation between /r/ and /l/ in Dravidian (Levitt, 1987) but the present author could not find any examples of the same within present day Malayalam. Most of the examples provided in (Levitt, 1987) do not apply to present day Malayalam and were presented as cases of proto-Dravidian roots involving /l/ e.g. *kal existing in some Dravidian languages for which there exists a comparable proto-Dravidian root involving /r/ e.g. *kar̲- in the same language. “We also find evidence for forms with a phonemic shape *kal- such as Te. Kala, Ta. Kalai, kalvi…beside forms which provide evidence for a phonemic shape *kaṟ̣-, such as Te. Ka**r̲**acu, ka**r̲**apu…Ta. Ka**r̲**kai, ka**r̲**pan-, Ma. Kar̲-**r̲**avar…”[13] (pg.132). There is mention of examples from Malayalam, “kalkka (kar̲r̲), kar̲r̲avar (which) can be explained by euphonic combination” (pg. 141). These examples are non-existent in present day Malayalam and are not recorded in any current dictionaries. It must however be noted that

[13] Levitt used the abbreviations as follows: Te.- Telugu, Ta. –Tamil, Ma. - Malayalam. The meanings of the lexical items were not given.

there is very little work on the phonology of Malayalam and it was beyond the scope of this thesis to explore in more detail the phonological intricacies of the language.

This section focussed on the differences and similarities in the phonotactic relationship that the rhotics and laterals each shared with other consonant groups. The next section will describe the nature of phonotactic interaction between the rhotics and the laterals in Malayalam.

7.2.2.3 Interaction between rhotics and laterals in Malayalam

To the best of the present author's knowledge, there appear to be no reliable sources that describe in detail the phonotactic patterns of the liquids in the lexical items in Malayalam. Therefore a Malayalam dictionary (Warrier et al., 2006) was used to assess all lexical entries involving liquids in order to establish at least some phonotactic patterns of the liquids in interaction. The present author acknowledges that this is by no means an exhaustive description of the lexical phonotactics of the liquids in Malayalam and it is only an initial attempt at finding interesting patterns that may be involved in the phonotactic interaction of liquids in the lexicon. Note that the examples given below are in their transliterated version where r denotes alveolar tap, R-alveolar trill, l-alveolar lateral, L-retroflex lateral and zh- fifth liquid (approximant).

1) It seems that there is a general trend that prohibits laterals and rhotics occurring together in monosyllabic words in Malayalam.
2) There are also very few examples of polysyllabic non-compound words that have two rhotics or two laterals occurring together in the same or adjacent syllables. For example, words like 'ruru, 'loolam', 'viloola', 'peruuR' etc. but these appear to be very infrequent in the lexicon.
3) However compound words or base word + suffix combinations allow all combinations of the five liquids to occur. For example, 'niiRaazhi'('niiR''+'aazhi'), 'perukkallu', 'viLaR'kkuka' ('viLaru'+ 'uka'), 'peerill'' ('peeru' + 'ill''), 'kariveeppila' ('kari veppinte ila'), 'kaalil'' ('kaal'' + 'il'') etc. In some of these examples, note that there is one or more consonants intervening between the two liquids, e.g. /v/ and /pp/ between the /r/ and /l/ in 'kariveeppilla' and 'kk' between /r/ and /ll/ in 'perukkallu'.
4) In polysyllabic non-compound words, the general trend appears to be as follows: either a clear rhotic-dark lateral combination occurs in the same or adjacent syllables

or a dark rhotic-clear lateral combination occurs, i.e. r-L/L-r or l-R/R-l combinations. For instance, ‘kalavaRa’, ‘kaLari’, ‘kaaRal’’, ‘kalaR’’, ‘pooRal’’, ‘poruL’’, ‘piLLeeru’, ‘paaRal’’, ‘pulaR’’, ‘viraLa’, ‘viraLam’, ‘varaaLam’, ‘vaLare’, ‘viiraaLi’ etc.

5) However, there seem to be some exceptions to rule (4) in the lexicon, i.e., *l-r/r-l and *L-R/R-L combinations e.g. ‘vallari’, ‘palalam’, ‘viRaLi’, ‘vaRaLi’, ‘nirooli’. Nevertheless it is important to point out that the all the above words are not very frequently used in common speech.

Therefore the nature of phonological interaction between the liquids within a particular lexical item seems to vary depending on the number of syllables it has (extremely restrictive in monosyllables, less restrictive in disyllables and least restrictive in polysyllables) and also depending on whether the lexical item is a compound word and base word/stem + suffix OR a non-compound word (least restrictive in compound word and most restrictive in non-compound word). Although the author’s observations are only tentative, patterns like those in (4) above are interesting because it seems to suggest that resonance quality of the liquid determines in what combinations it is allowed to pattern together with another liquid in the same or adjacent syllables in the language.

In (4) above, the preference for clear rhotic and dark lateral or dark rhotic and clear lateral combinations within syllables and words has also been observed in British English by Kelly and Local (1986); Carter (1999, 2003) and Olive et al. (1993) in American English. Carter in his study of rhotic and non-rhotic varieties of British English found that resonance characteristics of the liquids played an important role in their phonetics and phonology. Resonance was used as a differentiation strategy between rhotics and laterals in rhotic and non-rhotic varieties, more so in the latter and also between syllable initial rhotics/laterals and syllable final rhotics/laterals respectively in rhotic varieties The need to differentiate between the two syllable positions did not apply to the non-rhotic varieties which by definition is the variety where speakers do not realise their syllable-final rhotics. Speakers of Malayalam also appear to be using resonance as a differentiation strategy between rhotics and laterals phonetically and phonologically but the manner in which this strategy is employed seems to vary between the two languages. Section 7.4 deals with resonance and its role in the phonology and phonetics of Malayalam in more detail.

The rhotic-lateral phonetic relationship in Malayalam appears to be reliant on the levels of consonant resonance, spread of resonance effects on surrounding vowels and the places of articulation and tongue configuration of the liquid. The rhotic.-lateral divide, i.e., the manner of articulation divide appears to have less prominence acoustically than the other dimensions of contrast in this relationship. As for the phonological relationship between rhotics and laterals in Malayalam, three aspects of this relationship were examined: non-occurrence versus occurrence of gemination in rhotics versus laterals respectively, differences and similarities in phonological patterning of rhotics and laterals with other consonants and nature of phonotactic interaction between rhotics and laterals. Resonance characteristics of the liquids appear to be a significant aspect of their phonological interactions with each other. These observations have important implications for the second main research question of this thesis regarding the phonetic and phonological characteristics of the fifth liquid and whether it is a third rhotic or third lateral in Malayalam which will be explored in the next section.

7.3 Fifth Liquid: Rhotic or Lateral?

7.3.1 Phonetic characteristics

The fifth liquid in Malayalam produced by all speakers in this study sounded like an approximant and spectrograms also showed evidence for the same in the form of a vowel-like continuous formant structure. The place of articulation sounded post-alveolar but not ‘retroflex’ in terms of contact of the underside of tongue tip against hard palate. The approximant sounded like it was being produced by a close approximation of the tongue blade or front towards the hard palate and did not involve the back-to-front movement of the underside of the tongue tip against the hard palate that seems typical of retroflex sounds particularly in Dravidian. It also had a clear resonance and vowels surrounding it irrespective of whether they were front or back vowels sounded raised and advanced. Its acoustic characteristics in relation to the other four liquids were as follows: the fifth liquid had lower F1 and higher F2 values than the trill. The magnitude of the F1 differences was only small-to-moderate while that of its F2 differences was large. The trills also had slightly lower F3 values than the fifth liquid but the difference was not significant. The fifth liquid had F1, F2 and F3 values in the same range as the taps. Among the laterals, the fifth liquid had significantly higher F1 and lower F3 values than the alveolar lateral. The magnitude of the F3 differences was small-to-moderate but that of the F1 differences was moderate-to-large. The alveolar lateral and the fifth liquid had similar F2 values. The fifth liquid only differed from the retroflex lateral in its F2 values, i.e., the former had higher F2 values than the latter. Acoustically therefore, the fifth liquid was most similar to the taps followed by the retroflex lateral.

Taps had significantly higher F3 values than trills and alveolar laterals had significantly higher F3 values than the retroflex lateral whereas the F3 values of the fifth liquid was not found to be significantly different from that of the trills, taps and retroflex lateral perhaps indicative of its post-alveolar articulation? In terms of the magnitude of the differences or similarities among the liquids, F2 was found to be the most robust cue. The higher F2 of the fifth liquid, tap, alveolar lateral compared with the lower F2 of the trill and retroflex lateral is reflective of the clearer resonance of the former group versus the darker resonance of the latter group which has also been observed in the auditory analysis.

Vowels preceding and following the fifth liquid, taps and alveolar laterals were advanced and raised while those preceding and following the trills and retroflex laterals were retracted and more open. Although no measurements involving formant transitions were made in the present study, from the analysis of the spectrograms of the target words, it seems to be that the formant transitions of preceding vowel into the liquid and that of the liquid into the following vowel differed based on the manner of articulation and the intrinsic quality of the vowel. For instance, /i/ appeared to be less affected by the clearer liquids than /a/ or /u/ since /i/ itself is a front and raised vowel as opposed to the lower more open vowels like /a/ or a backer vowel like /u/. The same vowel behaved differently when it preceded versus followed a particular liquid consonant. /i/ and /a/ both had higher F2 values when they followed rather than when they preceded the fifth liquid. Therefore apart from the differences or similarities among the five liquid consonants themselves, the behaviour of their surrounding vowels also seem to provide cues as to the phonetic nature of each of the five liquids.

Auditorily, the fifth liquid sounded like a clear post-alveolar approximant. Although the present author is also inclined to comment that it sounded ‘rhotic’ it should also be acknowledged that there is gap in the literature regarding what exactly constitutes one’s auditory percept of rhoticity and non-rhoticity or degrees of rhoticity. Therefore it is difficult to completely justify the auditory impression of the fifth liquid ‘sounding’ like a rhotic since it is unclear at least from the auditory point of view and to some extent even the acoustic point of view as to how to define the feature ‘rhoticity’. Acoustically, the literature often cites lowering of F3 as some indicator of rhoticity but there has also been some research showing that a low F3 need not be exhibited by all rhotics since the rhotics are a diverse and complicated sound group that does not have one single phonetic correlate that unifies all its members.

Recent research on perception of rhoticity, e.g. Heselwood (2009), has suggested the opposite of the traditionally expected view on low F3 as an indicator of rhoticity, that is, low F3 may in fact have an inhibiting effect on rhotic perception. Heselwood (2009) conducted two perception experiments. The first involved forty phonetically trained listeners listening to the rhotic tokens of the words *fort*, *stars* and *hurt* in two conditions, filtered (where F3 and all higher formants were removed) and the unfiltered (where F3 and formants up to 5.5kHz were present). Results revealed that stronger rhoticity was perceived in the filtered condition which Heselwood explains in terms of “the presence in auditory space of a distinct and relatively sharp peak in the region of 9.0-11.5 Bark, i.e. between about 1080-1595Hz” (pg. 62). Perception of rhoticity is seen as a function of the F1-F2 relationship dynamic of the vocalic portions of the syllable. The second experiment involved twenty three phonetically trained listeners (a subset of the first experiment listeners) listening to a non-rhotic token of the word nurse in an unfiltered and filtered condition. Despite the actual absence of the rhotic in this experiment, a majority of the listeners are reported to have heard the filtered token as a rhotic. Based on the results of his study, Heselwood suggests that Lindau’s concerns regarding the importance of a low F3 for the perception of rhoticity in non-approximant rhotics can be generalised to include approximant rhotics also, in the context of central and back vowels at least, since that was the context tested in his study.

In the present study, there was found to be no clear-cut division of rhotic versus non-rhotic based on F3 measures. If a rhotic is defined in terms of its ‘central’ airflow as opposed to the passage of air through the sides of the tongue that characterise a lateral, then only methods that elicit articulatory data including ultrasound and EPG among others can provide a true picture of the nature of production of the fifth liquid. Articulatory work is therefore inevitable in answering the question of whether the fifth liquid in Malayalam is a rhotic or a lateral phonetically.

The next subsection will explore the phonological patterning of the fifth liquid in Malayalam with non-liquid consonants and with the other four liquids in Malayalam and will also briefly describe the history of the sound and the length of its presence in

Malayalam in order to assess the phonological status of the sound in the context of patterning and historical origins.

7.3.2 Phonological identity of the fifth liquid

In section three aspects of the phonological relationship between the rhotics and laterals in Malayalam were explored, namely the presence or absence of gemination, nature of patterning with other non-liquid consonants in the inventory and nature of patterning with other liquids. This section will discuss the phonological identity of the fifth liquid in the light of the above three factors.

7.3.2.1 Gemination

As mentioned in section 7.2.2.1 above, the only consonants that do not undergo gemination in Malayalam are the rhotics (Mohanan, 1989; Mohanan and Mohanan, 1984; Asher and Kumari, 1997) and /ʐ/ (Asher and Kumari, 1997; Sadanandan, 1999). Of the five liquids in Malayalam, only the two uncontested rhotics and the fifth liquid do not geminate, which in itself might suggest that phonologically the fifth liquid seems to be patterning like the rhotics in Malayalam. Historically too, /ʐ/, which traces back to Proto-Dravidian, was prohibited from undergoing gemination (Krishnamurti, 2003). The non-gemination of rhotics versus the gemination of laterals as one of the important phonotactic differences between rhotics and laterals in the language has already been discussed earlier.

7.3.2.2 Phonological patterning with non-liquid consonants

The fifth liquid occurs as the first element in a few word-medial clusters, e.g. ‘aazhcha’ (week), ‘kaaraazhma’ but such cluster formations are word-internal but not syllable internal. It must however be noted that such examples are relatively very few in the lexicon and the fifth liquid mainly occurs intervocalically, i.e. flanked on both sides by vowels. Unlike /r/ and /ɭ/ however, /ʐ/ does not occur as the second element of word-initial clusters with plosives. Although there are few words like ‘paazhu’ in the lexicon where the fifth liquid occurs in an environment similar to that of word-final fragments, the difference is that such words are almost always realised phonetically as an intervocalic /ʐ/ followed by a schwa and not a word-final /ʐ/. The Sandhi rule regarding stem-final lateral deletion, when in combination with suffixes /ti/ and /tu/ does not appear to apply to either of the two rhotics or the fifth liquid but only the laterals and nasals in Malayalam. This might again be suggesting that the fifth liquid tends to pattern with the rhotics phonologically.

There appears to be some evidence that suggests an alternation between /ɻ/ and /j/ (Pillai, 1996) which however does not occur very frequently and is mostly representative of illiterate speech or extremely informal speech in certain dialects. This alternation in some lexical items containing /ɻ/ is also common in baby talk and early learners of the language and young children acquiring the sound. For instance young children often produce 'mazha' as [maja], 'pazham' as [pajam] etc. In Malayalam, if the acquisition of the fifth liquid involves an earlier stage of /j/ productions by children this may be due to the prominent gesture being common to the two sounds namely the raising of the tongue giving rise to a clear resonance or a 'palatalized' effect that the two sounds share. Perhaps then resonance may be a significant part of the phonological and phonetic identity of the liquids in Malayalam?

Research on acquisition of /r/ in children learning American English has claimed that children begin with productions of [w]-like variants for /r/ for a period of time before /r/ is gradually acquired (Kuehn & Tomblin, 1977; Grunwell, 1987; Menyuk & Anderson, 1969 etc.). Young learners of SSBE were found to produce [w] which itself was found to give way to another intermediate variant [ʋ] as initial substitutes before /r/ was acquired (Knight, Dalcher & Jones, 2007). The preference in different varieties of English for [w]-like variants in the early stages of the acquisition of the target apical /r/ productions may be due to the 'velarized' aspect that /w/ and apical /r/'s have in common. /w/ is a labio-velar approximant whereas the apical /r/ productions in American English tend to be bunched /r/ or retroflex /r/ and alveolar approximants in SSBE both of which involve retraction of the tongue tip and thereby producing a relatively 'velarized' effect. The occurrence of /ʋ/ as an intermediate stage between /w/ and /r/ in the process of the acquisition of /r/ may be attributed to the relative increase in percept of rhoticity caused by the decrease in F3-F2 distance in /ʋ/ with respect to /w/ (Knight, Dalcher & Jones, 2007). In syllable onsets, child learners acquiring American English have been found to regularly produce [w] for /r/ and [j] for /l/ (Dinnsen 1992; Smit 1993). The glide /w/ involves a labial protrusion and tongue-dorsum approximation and /j/ involves raising of the tongue, both gestures also forming part of the adult phonology of the bunched /r/ and clear /l/ (Delattre and Freeman, 1968; Gick et al, 2003) in American English syllable onsets and therefore might make good substitutes for /r/ and /l/(Proctor, 2009).

This section described the nature of interaction between the fifth liquid and the other consonants in Malayalam. Since /ɻ/ does not occur in combination with other consonants in the form of clusters barring very cases in the lexicon, and mainly occurs intervocalically, the main focus was on its alternation with /j/ in acquisition of Malayalam by children which seems to be based on their shared palatalized resonance. The next section will present examples illustrating possible patterns emerging from the interaction of /zh/ with the other liquids which might be indicative of its place and/or manner of articulation.

7.3.2.3 Interaction with other liquids

Possible rules governing the interaction of rhotics and laterals at the lexical level laid out in section 7.2.2.3 above may be applied to the fifth liquid also since it is either a rhotic or lateral and the following patterns arise on examination of the dictionary (GopinathaPillai, 2006)

(1) There appear to be no monosyllabic words in Malayalam that contain both the fifth liquid and another liquid in any combination.

(2) There are several polysyllabic words that contain the fifth liquid and another liquid separated by vowels. For instance, nizhal, kuzhal, kazhal, kazhala, kazhaluka, kazhichill, kazhuveeRi , kazhumaram. Note that the last four words are compound words: kazhal + uka, kazhi + chill', kazhukku'+ eeRi, kazhu + maram.

(3) As seen in (2), it seems to be that in compound words, /ɻ/ can occur with any of the other four liquids but in non-compound words the tendency seems to be that /ɻ/ appears mostly in combination with /l/. The absence of /ɻ/ and /ɭ/ in combination in non-compound words is interesting. Should that be seen as evidence for /ɻ/ being

phonologically a ‘retroflex’ sound and hence prohibited from occurring with another retroflex liquid /ɭ/ within the same non-compound word?

Another evidence for the same would be that /ʐ/, like all the other retroflex sounds in Malayalam, does not occur word-initially in Malayalam. Interestingly, there is also some evidence in favour of an alternation between /ɭ/ and /ʐ/ in certain morpho-syntactic contexts (Varma as reported in Pillai, 1996) as shown in the examples below:

1) appoL’ *then* - appoLaaNeh OR appozhaaNeh *it was then that*
2) varumpoL *when(it) comes* -varumpoLaaNeh/ OR varumpozhaaNeh *when (it) will com*
3) karayumpoL *when (it) cries* -karayumpoLaaNeh OR karayumpozhaaNeh *when (it) will cry*

Varma reportedly only mentions the word-final /ɭ/ in the first form changing into /ʐ/ in the second (Pillai, 1996). The present author has observed that both /ɭ/ and /ʐ/ forms are in usage for the second form with /ɭ/ being more commonly used in formal settings and /ʐ/ in more casual informal speech. The preference for /ɭ/ or /ʐ/ may also be dialect-specific but more sociolinguistic work on the dialects of Malayalam will be needed before some of these speculations can be confirmed. Nevertheless, the fact that both /ɭ/ and /ʐ/ forms are used by native speakers for the verb + suffix forms above might be suggesting that the two sounds have a common shared feature allowing speakers to substitute one for the other. Could it then be that /ʐ/ is phonologically retroflex like /ɭ/ and it is their ‘retroflexion’ that they have in common allowing for one to be substituted for the other in the above context?

(4) Regarding the near-categorical occurrence of /ʐ/ with /l/ in non-compound words, there are two remarks to be made here. Firstly, considering rule (4) in section above where rhotics and laterals were found to combine in a clear-dark / dark-clear format within non-compound words, the trend of /ʐ/ to pattern with only /l/ might be suggesting that /ʐ/ is phonologically a rhotic. There are examples of rhotic-rhotic and lateral-lateral

combinations within disyllabic or trisyllabic words but these appear to be extremely infrequent in the lexicon and are therefore more marked. Secondly, since rhotics and laterals have been found to occur in a pattern of opposing resonance qualities that might predict /ɻ/ to be phonologically 'dark' in the examples in (2) where it occurs with /l/ since /l/ tends to be 'clear'. This raises an important question regarding the relationship between the phonetics and phonology of the fifth liquid since it has also been found that phonetically /ɻ/ tends to have a clear resonance. This paradox of what seems like a phonologically 'dark' yet phonetically 'clear' fifth liquid will be addressed in the next subsection based on the theories of EPI, Extrinsic Phonetic Interpretation and Maximal Differentiation Principle.

7.4 Resonance quality and its role in the phonetics and phonology of liquids in Malayalam

7.4.1 Resonance quality and the Principle of Maximal Differentiation

In the present study, resonance is the common underlying theme for both research questions addressed, namely contrast maintenance among the rhotics in Malayalam and the phonetic and phonological characteristics of the fifth liquid. Resonance characteristics of the liquids were found to be more than just a consequence of the nature of their 'secondary' articulations. Like Carter (2003: 238) points out, "what is secondary in a degree of stricture sense may in fact be an important part of the phonetics of any given stretch of speech". This appears to be true for the present study on the liquids in Malayalam.

Resonance appears to play an integral part in the maintenance of contrasts between the two rhotics, between the two laterals and among all five liquids. The two rhotics were produced essentially at the alveolar place of articulation, one slightly more retracted than the other. The advanced rhotic had a 'convex' tongue configuration due to its laminal tongue contact compared with the retracted rhotic which had a 'concave' tongue configuration due to its apical tongue contact, both against the alveolar ridge. The clearness of the advanced rhotic versus the darkness of the retracted rhotic was achieved by their different tongue configurations. These resonance differences between the two rhotics were also found to have systematic effects on their surrounding vowels or 'spread' across the surrounding segments: vowels were closer and raised surrounding the clear advanced rhotic and were open and retracted surrounding the dark retracted rhotic.

A similar difference in resonance was found to underlie the contrast between the two laterals in Malayalam. The alveolar lateral was produced with a laminal contact thereby producing a 'clear' resonance while the retroflex lateral was produced with a 'sub-apical' contact producing the opposing 'dark' resonance effect. 'Retroflex' sounds are by definition 'retracted' (Hamann, 2003) and therefore have a 'dark' resonance. These resonance differences between the two laterals also had effects on their surrounding vowels as was the case with the rhotics: vowels were closer and raised surrounding the clear alveolar lateral and were open and retracted surrounding the dark retroflex lateral.

One might argue that the resonance differences are merely by-products of the differences in place of articulation between the two rhotics and between the two laterals in Malayalam. It is however important to note that the rhotics are both essentially 'alveolar' in terms of place of articulation and the difference seems to be mainly that of tongue configuration which is largely a result of the laminality of one versus the apicality of the other. This subtle difference may be a strategy to create the desired opposing resonance effects of clear versus dark respectively. Even in the case of the two laterals, the alveolar versus retroflex difference does not imply a clear versus dark difference. Retroflex sounds by definition involve tongue retraction (Hamann, 2002; 2003) and in the Dravidian languages contact of the underside of the tip of the tongue i.e., are sub-apical and therefore can be said to be 'dark' phonetically. The same is not true for alveolars since alveolars can involve retraction and apicality on the one hand or laminality and tongue raising on the other. Acoustically too, the second formant seems to be the most reliable and robust cue that distinguishes between the rhotics and between the laterals and generally among the five liquids in the present study. The second formant is also considered to be the correlate of clearness versus darkness of sounds. Therefore out of the possible combination of rhotics and laterals in terms of tongue configuration, the inventory of Malayalam has one apical/sub-apical member and one laminal member each. The fact that Malayalam uses resonance differences apart from a prominent difference in place of articulation in the case of the laterals and also appears to use resonance to differentiate between the two rhotics suggests that resonance may have a significant role in the phonetics and phonology of the liquids in Malayalam. Interestingly, resonance differences have also been found to underlie the maintenance of several other contrasts in the language namely the dental-alveolar distinction (Dart & Nihilani 1991and the singleton-geminate distinction (Local & Simpson, 1999).

Why use consonantal 'resonance' as a differentiation strategy? The use of resonance as a differentiation strategy may be perceptually motivated. Perhaps a clear versus dark difference between sounds and its long domain effects across segments may contribute to an increased perceptual salience of the distinction between two or more sounds. More perception studies are needed before this speculation can be confirmed. Another reason behind the use of consonantal resonance as a differentiation strategy may be in order to 'maximally' differentiate between two or more sounds or sound groups phonetically in order to ensure that the contrasts between sounds are maintained in a language.

Carter's study (1999) showed that resonance categories typically associated with laterals can also be associated with rhotics and showed that in British English dialects, laterals and rhotics were differentiated 'maximally' in the phonetic space using resonance quality as a strategy. He points out that it does not matter which liquid has which resonance quality as long as laterals and rhotics have opposing resonance qualities. The study showed that for British English liquids the factors that determine the implementation of clear/dark alternations depend on whether the dialect is rhotic or non-rhotic. Results of his study echoed that of a previous study on British English liquids by Kelly and Local (1986) and on American English liquids by Olive et al. (1993), both of which found the clear /l/-dark /r/ and dark /r/-clear /l/ patterns. Rhotic dialects by definition mean that speakers realise their syllable final r's and therefore two syllable positions need to be accounted for, syllable initial and syllable final positions since laterals and rhotics occur in both syllable positions in such dialects. The pattern that emerged for such dialects was that the same liquid in different syllable positions had opposing resonance qualities and different liquids in the same syllable position also had opposing resonance qualities. In non-rhotic dialects, however, the factor syllable position does not come into play since the only syllable position common to laterals and rhotics in such dialects is the syllable initial position. So here the only pattern that emerged was that the laterals and rhotics had opposing resonance qualities: clear lateral-dark rhotic or dark lateral-clear rhotic.

The lateral and the rhotic can be clear or dark in different varieties of English (Kelly and Local, 1986; Carter, 1999 on British English and Olive et al., 1993 etc. on American English) provided they are in opposing resonance pairs in any given syllable position and/or provided in different syllable positions; the same liquid has opposing resonance effects. Malayalam, on the other hand, has a larger richer liquid system than British English with five members: two rhotics, two laterals and a fifth liquid and while consonantal resonance quality has been found to play an integral role in contrast maintenance among the liquids, the implementation of resonance quality as a differentiation strategy in Malayalam appears to vary from that in British English.

Due to the fact that Malayalam has a larger liquid system with five members, there is not just one relationship between /l/ and /r/ as is the case in British English but several relationships to take into account namely that between rhotics and laterals, between the two rhotics, between the two laterals and between the fifth liquid and the other liquids. Therefore the nature of phonetic and phonological interaction among these five liquids is naturally more complex. The phonetic relationships among the five liquids have already been discussed in great detail in the last three chapters. There are two examples of a five way contrastive minimal set that the present author knows of in Malayalam and therefore a five way lexical contrast is extremely rare. Within the class of liquids, the two rhotics are lexically contrastive between themselves and so are the two laterals. The fifth liquid forms minimal pairs with each of the other four liquids but there are not that many of such minimal sets in the lexicon. As mentioned earlier, the rhotic-lateral divide in the liquid group does not appear to have as much of an acoustic prominence as the advanced rhotic-retracted rhotic contrast and the alveolar lateral-retroflex lateral contrast.

Consonantal resonance quality was not found to determine the identity of the liquid, i.e. whether it is a rhotic or a lateral but was found to significantly contrast between the two rhotics and between the two laterals in Malayalam. In other words, of the several contrastive relationships within the class of liquids, resonance appears to be used as a strategy to 'maximally differentiate' between the two rhotics and between the two laterals and not so much between the rhotics and the laterals as two groups. In British English, on the other hand, there is essentially only one relationship that exists within the class of liquids, that between the one lateral and the one rhotic in its inventory. This lateral and rhotic have allophones but phonemically there is only one lateral and one rhotic in its inventory. Carter showed that there are clear/dark alternations between the two liquids in British English that are structure-dependent and dialect-specific.

According to the Principle of Maximal Differentiation, sounds/sound groups in a system should be maximally different from each other in the phonetic space and applying this to the liquids in English predicts that the lateral and rhotic would be as different as possible from each other. Carter found that resonance quality is one strategy used to achieve ‘maximum differentiation’ between lateral and rhotic where one is clear and the other dark or vice versa. The same principle, however, does not seem to apply in as straightforward a fashion in Malayalam as it does in English. The rhotic-lateral contrast in Malayalam is not lexically contrastive, i.e. apart from the fifth liquid which forms a few minimal pairs with each of the other four liquids, none of the other rhotics forms minimal pairs with the either of the laterals. The two rhotics, however, are lexically contrastive with each other and so are the two laterals in Malayalam. Therefore, the contrasts between the two rhotics and those between the two laterals appear to have a more prominent functional load in the language than a mere rhotic-lateral divide. It is here then that resonance in Malayalam is used as a differentiation strategy, i.e. to maximally differentiate phonetically between the lexically contrastive advanced and retracted rhotic and also between the alveolar and retroflex laterals. The principle of maximal differentiation perhaps applies only at those levels that involve the heavy functional load of lexical contrasts which in the case of Malayalam is within the sub-group ‘rhotics’ between the advanced and retracted rhotics and within the sub-group ‘laterals between the alveolar and retroflex laterals.

Certain dialects of Tamil, like Malayalam, have a five member liquid inventory and the retroflex lateral and fifth liquid are allegedly common sounds in both languages (Zvelebil, 1970). Like Malayalam, Tamil too has two (uncontested) rhotics, two laterals and in certain dialects as mentioned above a fifth liquid. In some dialects, the fifth liquid has merged with the retroflex lateral (Krishnamurti, 2003). In dialects that contrast among the five liquids, several studies have shown that the rhotics are apical pre-alveolar/dental and apical post-alveolar and the alveolar lateral is apical while the retroflex is sub-apical and the fifth liquid has also been defined by some as being a retroflex approximant (Narayanan et al, 1999; McDonough & Johnson, 1997). Narayanan et al found all five liquids characterised by a low F2 suggesting a relatively darker resonance for all five liquids. The dimensions of contrast that characterise the five liquids in Tamil are static/dynamic (defined with respect to F3 contour during consonant closure), lateral/central (presence or absence of acoustic zeros), retroflex/ non-retroflex (low versus high F3) (McDonough & Johnson, 1997:23).

In the present study, acoustic zeroes were not explicitly noted although casual observations made based on the spectrograms did not appear to reveal a presence versus absence of acoustic zeroes pattern for laterals versus rhotics respectively. Unlike Tamil, retroflex/non-retroflex was not a dimension of contrast among all five liquids in Malayalam and only applied to the laterals. The rhotics were both alveolar and differed only slightly in place of articulation, one being slightly more retracted than the other. F3 was significantly different between the two rhotics and between the two laterals and between the fifth liquid and the alveolar lateral. F2 was found to be an even more robust acoustic cue distinguishing between the two rhotics, between the two laterals and between the fifth liquid and the retracted rhotic, retroflex lateral. F2, the acoustic correlate of clearness versus darkness was found to be a prominent dimension of contrast among the five liquids in Malayalam. The advanced lamino-alveolar rhotic (classified as target taps in the present study), lamino-alveolar lateral and the fifth liquid were all clearer in quality than the retracted rhotic (classified as a target trill in this study) and the retroflex lateral. The other dimensions of contrast among the five liquids in Malayalam apart from clear versus dark include laminal versus apical/sub-apical leading to convex versus concave tongue configurations (high versus low F2) and front versus back (high versus low F3) respectively. This is by no means an exhaustive list of all possible dimensions of contrast. The present study is limited in terms of acoustic measurements made, for instance, more formal observations on acoustic zeros might have yielded similar results to that found in Tamil, i.e. presence versus absence of acoustic zeroes in laterals versus rhotics respectively. Nevertheless this does not take away from the fact that resonance quality is a significant aspect of the contrast maintenance among the five liquids in Malayalam. The dimensions of contrast among liquids appear to be language-specific. Tamil, despite being the parent language of Malayalam and having a very similar liquid inventory constituting five members each, of which two members are allegedly common to both inventories (Zvelebil, 1970), uses different strategies to maintain the contrasts in its liquid inventory as described above.

Another point to note is that unlike Malayalam, not all dialects of Tamil have a five member liquid inventory. Some dialects of Tamil have lost the fifth liquid and replaced it with the retroflex lateral (Krishnamurti, 2003) and a few others are claimed to have lost the rhotic contrast too (Narayanan et al, 1999). In Malayalam the fifth liquid appears to be at least phonologically ‘retroflex’ which means that it has two retroflex liquids in its inventory– the fifth liquid and the lateral. Applying the Principle of Maximal Differentiation to the phonetic realisations of both these sounds using resonance as a strategy may explain the clear resonance of the fifth liquid as opposed to the dark resonance of the retroflex lateral. Also, the presence of the fifth liquid has been traced all the way back to the Proto-Dravidian consonant inventory (Krishnamurti,2003) and some dialects of Modern Tamil and Modern Malayalam are the only present day Dravidian languages known to have retained the sound in their inventories. Not all Dravidian languages that have lost the fifth liquid have replaced it with a retroflex lateral. Most have replaced it with the retroflex lateral but some have a zero variant while other variants include /ɳ/, /ɖ/, /r/, /j/etc. (Krishnamurti, 2003). Could the absence of perceptually salient strategies of maximal differentiation like resonance quality perhaps be the reason behind the loss of the fifth liquid contrast in some dialects of Tamil and all Dravidian languages except Malayalam and it being replaced in most cases by the retroflex lateral? In other words, it seems possible that resonance quality as a differentiation strategy has perhaps been contributing significantly to the long lasting presence and survival of the fifth liquid in all dialects of Malayalam.

Results of the present study seem to suggest that phonetically the fifth liquid is produced as a clear post-alveolar approximant, possibly a central rather than a lateral approximant although it is impossible to be certain about the centrality claim without evidence from articulatory data. Phonologically, there seems to be some evidence suggesting that the fifth liquid is a 'retroflex' approximant and possibly a rhotic considering Malayalam already has a retroflex lateral approximant. The question still remains however regarding how the fifth liquid can be phonologically 'dark' but phonetically 'clear'?

7.4.2 Resonance quality and Extrinsic Phonetic Interpretation (EPI)

Many works on phonology adopt an intrinsic model wherein phonological features are viewed as being essentially phonetic features or in other words, phonological structure is considered to be uniquely associated with or equated to phonetic events. For example, in Bromberger and Halle (1989), phonological representations in the form of binary values are transformed into scalar values in their phonetic implementation. The results of the present study particularly in terms of the fifth liquid do not support an intrinsic model since such a model by definition cannot explain the seemingly contradictory values associated with the phonetic implementation (clearness) and phonological representation of the fifth liquid (darkness and retroflexion). An extrinsic interpretation of phonology (Local, 1995a), however, involves "abstract phonological categories which are related to, but do not equate to, phonetic features" (Carter, 2003: 237). In such a perspective, phonology is not seen as being made up of purely phonetic features but as being made up of abstract relational categories mainly focussed on contrasts. The fifth liquid may be phonologically 'dark' due to its retroflexion, patterning like other retroflexes in the language. In particular, the fifth liquid is phonologically 'darker' in non-compound lexical items when it occurs with another liquid, always an alveolar lateral which is clear (examples in section7.3.2.3, pgs. 249-251 above). An intrinsic model would predict that the fifth liquid would also be phonetically 'dark' since it is phonologically retroflex and therefore 'darker' whereas the results of the present study show that the fifth liquid tends to have a clear resonance and has a post-alveolar rather than a typically retroflex realisation. This phonetic implementation of the fifth liquid as a clear post-alveolar rather than a dark retroflex helps to also 'maximally differentiate', phonetically, between the fifth liquid and the (phonologically and phonetically) 'darker' retroflex lateral in Malayalam.

Therefore in the present study results of the auditory and acoustic analysis of the fifth liquid on the one hand and its phonological patterning and interaction with other liquids on the other hand showed that phonetic detail appears to pattern with phonological categories in a 'partly absolute-partly relative' manner which supports an extrinsic interpretation of phonology

7.4.3 Firthian Prosodic Analysis of the liquids in Malayalam

EPI mechanisms have been used in some contemporary frameworks like versions of Declarative Phonology that are influenced by Firthian Prosodic Analysis (Local, 1995; Simpson, 1996; Local & Simpson, 1999; Ogden 1993 etc.) (Carter, 2003:237). Simpson (1996) applied the framework of Firthian Prosodic Analysis to his data on Albanian liquids the results of which showed the liquids could not only be grouped based on within-rhotics and within-laterals contrasts, i.e. "/r/-/rr/ and /l/-/ll/" but also based on tongue configurations, i.e. "/r/-/l/" (clear) and "/rr/-/ll/" (dark).Simpson moved away from using traditional IPA symbols arguing that their use often either overvalues or undervalues the phonetic and phonological correlates of the sounds in use. The symbols he used related to the following descriptions: /r/- alveolar tap; /rr/-alveolar trill; /l/-clear alveolar lateral and /ll/-dark dental lateral (1996:3). His phonological analysis of his impressionistic and acoustic observations on Albanian liquids was based on Firthian

Prosodic Analysis (Firth, 1948; Henderson, 1949) which involves two main steps: Firstly, a set of phonological abstractions and secondly, a set of 'phonetic exponency statements' relating the phonological abstractions to certain aspects of their phonetic content (Simpson, 1996: 13; 1998: 97). Simpson's analysis of Albanian liquids based on these two steps has been applied to the observations and results of the present study as follows (for more details of Simpson's analysis and the key aspects of Firthian Prosodic Analysis see chapter 1, pgs. 18-22):

Like Albanian, the results of the present study also showed that the liquids in Malayalam not only group as rhotics versus laterals, i.e., /ɾ/,/r/,/ɹ̠/ versus /l/, /ɭ/, but also group based on tongue configuration, i.e., /ɾ/,/ɹ̠/,/l/ versus /r/, /ɭ/. Note however, there are five contrastive liquids in Malayalam as opposed to four in Albanian. Based on these results and applying Simpson's (1996) model of analysis on Albanian liquids, the phonological abstractions in Malayalam liquids are categorised into two systems, R/L and $^{y}/^{w}$ and the exponents of the terms in these two systems are given below:

1) R –coronality and momentary tongue contact (brief and singular for tap, intermittent for trill, slight partial contact or approximation for fifth liquid)
2) L-laterality and coronality
3) ^{y} - clear resonance and convex tongue configuration, laminal articulation
4) ^{w} - dark resonance and concave tongue configuration, apical/sub-apical articulation, apical trill for R and sub-apical retroflex for L.

Coronality is used here as a broad term covering articulations involving the front of the tongue, with respect to both the active (apical vs. laminal) and passive (alveolar, post-alveolar, retroflex).

This is only a partial analysis, however, since the temporal alignment of the liquids in Malayalam has not been addressed in this study. More work is first needed on the suprasegmental features of Malayalam in order to be able to explain temporal alignment of phonological units. Nevertheless, Firthian Prosodic Analysis appears to be an appropriate analysis for the liquids in Malayalam since according to this approach phonetic pattern is not seen as the realisation of features from a universal feature set. Phonetic similarity is not a condition for phonological identity (Honeybone, 2005:83). Such an approach is particularly useful in analysing rhotics and in understanding their phonological unity despite immense phonetic diversity. The tap, trill and approximant (fifth liquid) in Malayalam do not need to have one or more shared phonetic properties in order to validate their status as rhotics phonologically. The opposite is also true, i.e., that their phonological identity as rhotics does not automatically imply that their phonological unity manifest itself phonetically. The phonetic patterns of the three rhotics are not realisations or instantiations of their phonological characteristics. This approach views phonetics and phonology as being essentially separate but relational, the relationship mediated by exponency statements that state how a particular phonological structure maps onto the phonetics (Honeybone, 2005: 82-83). This mapping, however, is not one-on-one or completely 'absolute' and instead the relationship between phonetic detail and phonological structure is 'partly-absolute-partly-relative'. In this study, results showed that resonance quality is a significant aspect of that partly-absolute-partly-relative relationship between phonological structure and phonetic detail.

Regarding the coarticulatory effects of the liquids on their surrounding sounds, Firthian Prosodic Analysis (FPA) takes on a non-segmental approach. The process of coarticulation is traditionally understood and advocated as being one where surrounding sounds are affected by the primary phonetic properties of an adjacent sound to varying degrees like its place or manner of articulation etc. and as a result their phonetic shape changes. FPA views the phonetic exponents of various phonological items as occurring at the same point in time. Manifestations of differences in tongue configuration resulting in differences in vowels and consonants are not seen as examples of coarticulation with a particular consonant. Instead the process is looked upon as a part of the phonetic exponency of one phonological unit having greater temporal effect than the exponency of another phonological unit (Simpson, 1996). So in the present study, if the retracted rhotic was found to cause its surrounding vowels to sound 'darker', more retracted and open, then it should be seen as a part of the phonetic exponency of the phonological unit ^{w} having greater temporal effect than the exponency of the phonological unit 'R'. A more in-depth analysis of 'coarticulatory' effects of the liquids in Malayalam is beyond the scope of this thesis.

This section focussed on the significance of resonance quality in the phonetics and phonology of liquids in Malayalam based on theories of EPI and Maximal Differentiation and a phonological analysis was also proposed to account for the nature of liquids in the language, namely, a partial FPA analysis of the liquids.

Apart from the auditory and acoustic cues for contrast maintenance between the rhotics in Malayalam, the phonetic and phonological relationship between the rhotics and laterals and the phonetic characteristics and phonological identity of the fifth liquid in Malayalam, another aim of this thesis was to examine the notion of a separate consonant category called ‘fragments’ as suggested by traditional Malayali grammarians. The next and last subsection of this chapter will address this notion of ‘fragments’ in the light of the results of the present study.

7.5 ‘Fragments’: Separate consonant category or positional variants?

Malayali grammarians describe certain consonants in the language, i.e. /r, l, ɭ, n, ɳ/ as 'fragments' when they occur in two particular environments: post-vocalic, pre-consonantal position (word-medially) e.g. /va:ɭpajattə/ (*sword fighting)*, /ka:lpa:ɖə/ (*footprint)*, /garbʰam/ (*pregnancy)* and post-vocalic position (word-finally), e.g. /mo:ɭ/ *daughter*, /pa:l/ *milk*, /kajar/ *rope* (Chapter 2, pgs. 40-41). Rajaraja Varma and others argue that the difference between the fragments and their non-fragment counterparts is mainly that fragments have vowel-like qualities and that they can be produced as “isolated entities” which could refer to these consonants in these contexts perhaps being syllabic. It is not very clear from the very limited literature what the exact nature of the syllable structure of Malayalam is and also no detailed remarks have been made by Pillai (1996) with respect to what his usage of the term ‘isolated entities’ means. Their length is described as being calculated using a unit of time called 'maatra' (reported in Pillai, 1996: 36). Their description of this unit of length is not clear and therefore difficult to comprehend (see pg. 41). Also, another characteristic of these ‘fragments’ at word-final position is that adding a schwa to them does not change the meaning of the word. There is also a claim that the phonetic realisations of these fragment consonants are different somehow from their non-fragment counterparts although the limited literature reveals no further details in this regard. It is important to note in this regard that there is no phonemic contrast between these so-called ‘fragments’ and the non-fragments.

Since this thesis focussed on the phonetic and phonological characteristics of liquids in Malayalam, it gave the author the opportunity to also explore the phonetic nature of the *liquid* ‘fragments’ i.e., trill fragments, alveolar lateral fragments and retroflex lateral fragments. One of the aims of the present study therefore was to assess if there were any phonetic evidence that warranted a separate classification for these sounds or if the traditional classification was based mainly on their phonotactic environment.

Trill fragments were realised by speakers either as taps (more specifically taps with weak incomplete closures also referred to as ‘tap approximants’) or trills (trill realisations involved trills + a very short vowel sequences). Auditorily, trill fragments realised as taps sounded no different from the target trills realised as taps. Trill fragment tokens realised as trills, however, differed from target trills realised as trills in that the former was realised as a trill plus a short vowel sequence. The addition of a vocalic element to trill realisations of trill fragments may be perceptually motivated. The vocalic element may be helping to sustain the voicing of the trill for a longer time and thereby strengthen the percept of the trill particularly in the pre-consonantal, post-vocalic environment of the word-medial trill fragment. Also, the number of trill realisations was larger in the word-medial fragment context, that is, in the post-vocalic and pre-consonantal context than any of the regular trill contexts. Acoustically, there were no significant differences in formant patterns depending on whether a token was a regular target trill versus if it was a target trill fragment. The very short vocalic element that forms a part of the trill fragment did not affect the formant measurements because it exhibited the continuation of the same formant patterns of the rhotic so it was treated as part of the fragment segment and measurements were made accordingly. With respect to duration, trills realised as taps had the shortest duration followed by trill fragments realised as taps. Trill fragments realised as taps and trills realised as trills did not differ significantly in their duration values. Trill fragments realised as trills had the longest duration and were longer than all the other three groups which may be due to the fact that these were all realised as trill plus epenthetic vowel sequences as opposed to the non-fragment trills that did not have the vocalic element.

Auditorily, the alveolar lateral and its fragment counterpart sounded similar, the latter sounding less clear in resonance than the former, while the retroflex lateral fragment sounded slightly darker in resonance than the retroflex lateral. Acoustically, the alveolar lateral had significantly lower F1 and higher F2 values than its fragment counterpart confirming the author’s auditory impressions of the alveolar lateral fragment sounding less clear than the non-fragment alveolar lateral but the retroflex lateral and its fragment counterpart had similar formant patterns which are inconsistent with the auditory impressions. With respect to duration, the retroflex lateral fragments were longer in duration than their non-fragment counterpart but the overall mean difference was only about 12ms which does not appear to be a big difference so the result must be interpreted with caution. Alveolar laterals and their fragment counterparts had similar duration measures.

The above patterns for the three types of fragments analysed in this study appears to suggest that there may be no shared phonetic differences between the three types of fragments and their respective non-fragment counterparts. In other words, while trill fragments and to a lesser extent the retroflex lateral fragments, show some degree of durational difference with their non-fragment counterpart, the alveolar lateral fragments show formant frequency differences from its non-fragment counterparts. The two lateral fragments were different from the trill fragment in that they did not constitute a vocalic element whereas the trill fragments were realised always with a vocalic element albeit very short. Also, as mentioned in the beginning, there is no phonemic contrast among the fragment and non-fragment liquids in Malayalam. The few differences that have been observed between fragment and non-fragment liquids could be merely a consequence of comparing liquids in different syllable positions and not because of the unique phonetic characteristics of the so-called fragment liquids claimed in the literature. In fact, the fragments showed similar patterns to their non-fragment counterparts in certain important aspects: the lateral fragments behaved like the non-fragment laterals in that both were different from the rhotics. Also, the alveolar lateral fragments differed from the retroflex lateral fragments just like the alveolar lateral differed from the retroflex lateral. Similarly the trill fragments were more similar to the non-fragment target trills than the target taps and the laterals. Combining all of these observations, there seems to be no concrete evidence that justifies the traditional separate classification of these sounds as 'fragments' and instead these sounds may be viewed as being simply positional variants of the trill, alveolar lateral and retroflex lateral, all of which may merely be reflecting attributes of their phonotactic environment.

The non-liquid fragments have not been analysed in this study and therefore the results of this study cannot be generalised to include the whole set of 'fragment' consonants. Nevertheless, the lack of what appears to be enough phonetic evidence might be suggesting that the notion of 'fragments' as a separate consonant group serves little or no phonetically useful purpose.

Based on the discussions of the auditory and acoustic analyses results obtained for the rhotics, laterals and the fifth liquid in the last three chapters, this chapter has dealt with the major themes that emerged from them in the context of the research questions addressed in this thesis, namely contrast maintenance among the rhotics, the rhotic-lateral relationship in Malayalam and the phonetic-phonological identity of the fifth liquid. Two main principles were drawn, Principle of Maximal Differentiation and Extrinsic Phonetic Interpretation (EPI). The phonological analysis proposed for the patterns and themes observed are based on Firthian Prosodic Analysis. Resonance quality was found to be a significant part of the 'partly-absolute-partly-relative' relationship between the phonetic detail and phonological structure of the liquids in Malayalam. This chapter also addressed the traditional Malayali Grammarians' notion of 'fragments' as a separate consonant category and based on the results of the present study for liquid fragments, no phonetic evidence was found that justifies classifying them as a separate group. The present author has suggested that these so-called trill 'fragments', alveolar lateral 'fragments' and retroflex lateral 'fragments' may be viewed as merely being positional variants of the trill, alveolar lateral and the retroflex lateral respectively, that may reflect attributes of their phonotactic environment.

CONCLUSION

This thesis had two main objectives: Firstly, to define the auditory and acoustic characteristics of the two uncontested rhotics in Malayalam and to describe the contrast maintenance strategies native speakers used to distinguish between the two. The second objective was to identify the phonetic characteristics of the fifth liquid in Malayalam and examine its phonological status in the consonantal system of the language.

Chapter 1 reviewed the general literature on the phonetics and phonology of rhotics and highlighted the importance of using a non-segmental approach to address the paradox of the phonetically diverse yet phonologically unified class of rhotics. The nature of phonological and phonetic interaction between rhotics and laterals was also addressed based on recent studies on English (Carter, 1999, Kelly and Local, 1986) and Albanian (Simpson, 1996) and Catalan (Recasens, 1991) etc. Instead of the traditional segmental approach of Generative Phonology and similar derivational frameworks, a declarative phonology like Firthian Prosodic Analysis was explored as an alternative non-segmental approach to account for the paradox surrounding the class of rhotics and the relationship between rhotics and laterals in a language (as shown by Carter, (1999) for British English dialects).

In chapter 2, the origin of Malayalam and its phonological system were briefly reviewed. The limited literature on the liquids in Malayalam was assessed and findings from these were compared with those from recent studies on Tamil liquids, since Tamil is claimed to be the parent language of Malayalam (Zvelebil, 1970).

Chapter 3 described the methodology of the present study based on participants involved, data collected, methods used and types of analyses conducted. The present study was based on eight male native speakers of the central Travancore dialect of Malayalam reading out words containing at least one of the five liquids in Malayalam in the context of a carrier phrase. The two modes of analyses were auditory and acoustic. The former involved listening to recordings several times and transcribing the target word using IPA symbols while the latter involved observing the waveforms and spectrograms of the sound files and measuring duration and the first three formant frequencies of the target liquid segments and their surrounding vowels. The details of the types of statistical tests carried out on the data were also described and justified.

Chapters 4, 5 and 6 presented the results and discussion for the productions of the rhotics, laterals and the fifth liquid respectively. Within each chapter, the first part presented findings from the auditory analysis followed by those of the acoustic analysis and the second part interpreted the findings in the first part in the context of the relevant literature in the area. While the three results and discussion chapters described individually the phonetic patterns observed for each liquid member and their surrounding sounds, the last chapter (Chapter 7), the general discussion, focussed on bringing together the main findings from the previous three chapters and interpreting them in the context of the two main research questions addressed in this thesis and the recurrent themes that emerged therein.

Summary of findings

Based on the productions of eight native male speakers of Malayalam, the general trends seem to be as follows:

With respect to the manner of articulation of the rhotics, the advanced rhotic is realised by all speakers in all cases as taps while the retracted rhotic is realised as taps or trills or approximants. Majority of the retracted rhotic tokens are realised by most speakers as taps. Irrespective of the realisation of the manner of articulation, the advanced rhotic is always realised as lamino-alveolar and the retracted rhotic as apico-alveolar. Considering the variation in the realisation of the manner of articulation of the retracted rhotic, manner of articulation does not appear be a prominent cue distinguishing cue between the two rhotics. Phonologically, however, the general non-preference for palatalized trills in the world's languages and the different phonotactic behaviour of the two rhotics in Malayalam may be suggesting that they have two different manners of articulation in spite of manner of articulation being an inconsistent distinguishing cue phonetically.

Duration of the rhotics depends on the *realisation* of their manner of articulation. Tap realisations are shorter in duration than trill realisations but it is important to remember most of the retracted rhotic tokens are also realised by most speakers as taps (apico-alveolar taps as opposed to the lamino-alveolar tap realisations of the advanced rhotic). Apico-alveolar taps are found to be shorter than lamino-alveolar taps. In other words, if the retracted rhotic is realised as a trill, it is longer than the advanced rhotic (since the advanced rhotic is always realised as a tap in the present study) but if the retracted rhotic is realised as a tap, it is shorter than the advanced rhotic. Duration therefore does not seem to be a consistent distinguishing cue between the two rhotics.

The target tap and the alveolar lateral in Malayalam both sound clearer in resonance, lamino-alveolar and appear to have a convex tongue configuration and their surrounding vowels tend to be fronted and raised in general while the target trill and the retroflex lateral both sound darker in resonance, apical/sub-apical and appear to have a concave tongue configuration and their surrounding vowels tend to be retracted and lowered. The author's auditory impressions of the liquids and their surrounding vowels corresponded to their acoustic characteristics too. The advanced rhotic (target taps) and the alveolar lateral and their surrounding vowels showed a lower F1, higher F2 as compared to the retracted rhotic (target trill) and retroflex lateral which showed a higher F1, lower F2. The target taps and alveolar laterals also had a higher F3 than the target trills and retroflex laterals. Statistical tests seem to suggest that F2 differences are consistently the most robust differences between the two rhotics and between the two laterals (see table 29 next page).

The fifth liquid sounds like a clear post-alveolar approximant. Its acoustic characteristics are a lower F1, higher F2 like the lamino-alveolar tap and lateral and as opposed to the higher F1, lower F2 of the apico-alveolar tap/trill and retroflex lateral. Interestingly the fifth liquid seems to be acoustically most similar to the lamino-alveolar tap. The fifth liquid had similar F1 and F3 values as the retroflex lateral but differed in its F2 values: higher in the fifth liquid versus lower in the retroflex lateral. This is consistent with auditory impressions of the fifth liquid sounding *clearer* and the retroflex lateral sounding *darker* (see table 29).

TAP	TRILL	ALV.LATERAL	RTF.LATERAL	FIFTH LIQUID
Voiced lamino-alveolar, fronted, palatalised, realised as taps but mostly weak with incomplete closures. Surrounding vowel quality fronted & raised.	Voiced apico-alveolar, retracted, velarized, realised as weak taps, trills, approximants. Surrounding vowel quality retracted & lowered.	Voiced lamino-alveolar, palatalised. Surrounding vowel quality fronted & raised.	Voiced sub-apical retroflex, velarized, back-to-front tongue movement. Surrounding vowel quality retracted & lowered.	Voiced post-alveolar approximant, no back-to-front tongue movement like retroflexes. Surrounding vowel quality fronted & raised.
Lower F1, higher F2 higher F3 than trills, retroflex laterals, similar F1,F2,F3 to 5th liquid	Higher F1, lower F2, lower F3 than taps, alveolar lateral;	Lower F1, higher F2, higher F3 than retroflex lateral, trills	Higher F1, lower F2, lower F3 than alveolar lateral, taps	Lower F1, Higher F2 than trills, higher F2 than retroflex laterals; Higher F1, Lower F3 than alveolar laterals, no differences with tap

Table 29. Summary of the phonetic characteristics of the five liquids in Malayalam.

From the above table, it seems that rhotics and laterals do not form two distinct non-overlapping sound groups acoustically (at least based on the first three formant frequencies, F1, F2, and F3). In the five member liquid system, the rhotic-lateral divide does not seem to be characterised by the generally accepted notion of low versus high F3 (rhoticity often claimed to be indicated by a lowered F3 in the literature) and instead acoustically, there appears to be a lot of overlap between the two categories on the basis of resonance differences The liquid system in Malayalam seems to involve more systems of contrasts than merely rhotic versus lateral and more importantly more systems of contrasts that apply to both rhotic and lateral including clear versus dark, convex versus concave tongue body configuration, place of articulation (advanced alveolar versus retracted alveolar for the rhotics; alveolar versus retroflex for the laterals), tongue-tip constriction (laminal versus apical/sub-apical) and surrounding vowel quality (fronted and raised vowels versus retracted and lowered) (see table 29 above). It has been suggested that the differences in tongue configuration (i.e. laminal versus apical/sub-apical leading to convex versus concave tongue configuration) is a strategy used to achieve differences in resonance between contrastive sounds. The present study also suggests that resonance quality may be a strategy used in a language to **maximally differentiate** between subtly contrastive sounds. In Malayalam, consonantal resonance appears to be commonly used to differentiate between contrastive sounds: between the two rhotics, between the two laterals, between the fifth liquid and the retroflex lateral, between the dental and alveolar stops/nasals (Dart & Nihalani, 1991), singleton and geminate laterals and nasals (Local & Simpson, 1996).

Several dialects of Tamil, the parent language of Malayalam, are said to have lost the five-member liquid contrasts (Christdas, 1988, McDonough & Johnson, 1997).The fifth liquid has merged with the retroflex lateral in such dialects and others have also lost the distinction between the pre-alveolar apical and post-alveolar apical rhotics. It has been suggested that Malayalam has perhaps managed to maintain the five member liquid system and contrasts therein by virtue of employing consonantal resonance and differences in tongue configuration (i.e. laminal/convex versus apical/concave) as differentiation strategies thereby maximally differentiating contrastive sounds. More perception studies are needed before confirming the perceptual salience of resonance quality differences and its role in contrast maintenance.

With respect to the phonological characteristics of the five liquids in Malayalam as summarised in the table below, there appears to be a clearer demarcation of the rhotic versus lateral categories in Malayalam with respect to their phonological characteristics than there is with respect to their phonetic features (see table 29 on pg.268). There seems to be a lot more overlap between the rhotics and the laterals acoustically whereas there seem to be clear differences between the two categories in their phonological patterning (whether it is the rhotics not undergoing gemination versus laterals undergoing gemination or within non-compound lexical items rhotics co-occurring with laterals and rarely with each other versus laterals co-occurring with rhotics and rarely with each other).

Also from table 30 (next page), it seems that resonance might play a significant role in phonotactic patterning of the liquids, more specifically, in determining preferred combinations of liquids in non-compound lexical items in Malayalam such that within a non-compound lexical item that allows two liquids, combinations of one rhotic-one lateral of opposing resonance qualities are preferred over two rhotics or two laterals or rhotic-lateral of same resonance quality. Resonance has also been shown to be the cause of much phonetic overlap between the rhotic-lateral categories in Malayalam (see table 29, pg. 269 above). Therefore resonance quality can be said to play a significant role in both the phonological features and phonetic characteristics of the liquids in Malayalam.

PHONOLOGICAL FEATURES				
TAP	TRILL	ALV.LATERAL	RTF.LATERAL	FIFTH LIQUID
occurs in I,M, does not geminate or form clusters, tends to co-occur with lateral of opposing resonance quality in non-compound lexical items , e.g. /kaɭari/, /poruɭ/, etc. , rarely patterns in such cases with another rhotic or 5th liquid.	occurs in I,M,F, forms 2nd or 3rd element of word-initial clusters, does not geminate, tends to co-occur with lateral of opposing resonance quality in non-compound lexical items , e.g. /kalar/, /pɔ:ral/ etc., rarely patterns in such cases with another rhotic or 5th liquid.	occurs in I,M,F, forms 2nd element of word-initial & word-medial clusters, geminates, tends to co-occur with rhotic of opposing resonance quality in non-compound lexical items , e.g. /pular/, /kalar/, etc. , rarely with another lateral.	occurs in M,F; forms 2nd element of some word-initial clusters in loan words from English, geminates, tends to co-occur with rhotic of opposing resonance quality in non-compound lexical items ,, e.g., /kaɭari/, /poruɭ/ etc., rarely with another lateral.	occurs in M (intervocalically only); does not form clusters, does not geminate, tends to co-occur with lateral of opposing resonance quality in non-compound lexical items, e.g. /niʐal/, /kuʐal/, etc., does not occur word-initially so tends to pattern like other retroflex sounds in Malayalam, does not co-occur with other retroflex sounds in the same lexical item. Hence phonologically 'retroflex'

Table 30. Summary of the phonological features of the five liquids in Malayalam. I, M, F refer to word-positions: I-initial, M-medial, F-final.

Phonologically, the fifth liquid has been shown to pattern with retroflexes in its non-occurrence in word-initial position, patterning with non-retroflex liquids within the same or adjacent syllables in polysyllabic non-compound words in order to avoid presence of two identical sounds in close proximity. The fifth liquid has also been shown to behave more like the rhotics in Malayalam than the laterals, the strongest evidence for this being its non-gemination. Only the rhotics and the fifth liquid do not geminate in Malayalam (see table 30 above). It seems to be that the fifth liquid is phonologically a retroflex rhotic approximant and therefore ‘dark’ while phonetically it tends to be realised as a clear post-alveolar approximant. The principle of **Extrinsic Phonetic Interpretation** (EPI) has been proposed to account for this pattern which Carter (1999) also used to explain similar patterns observed for liquids in British English dialects (cf. chapter 1, pg.20). According to EPI, phonology cannot be equated to purely phonetic features but involves abstract relational categories. It is based on the notion that phonetic detail patterns with phonological categories in a 'partly-absolute-partly-relative' fashion.

The phonological analysis proposed to explain the findings observed for the liquids in Malayalam in the present study is Firthian Prosodic Analysis (FPA) which is a declarative phonology in that it is a static and descriptive rather than derivational and process-driven (Ogden & Local, 1994). This approach views phonetics and phonology as being essentially separate but relational, the relationship mediated by exponency statements that state how a particular phonological structure maps onto the phonetics (Honeybone, 2005: 82-83). Phonetic detail and phonological structure share a partly-absolute-partly-relative relationship and from the results of the present study it seems that consonantal resonance forms a significant part of this relationship for the liquids in Malayalam.

Limitations

The data for the present study was elicited in natural surroundings and a certain number of tokens produced by almost every speaker had to be discarded due to noisy backgrounds. This may have also increased the difficulty in being able to reliably detect and measure F4 values. Lab recordings would have ensured better quality sound recordings but on the other hand it would have reduced the naturalness of the participants' speech. The recordings in the present study were carried out in the participants' homes which involved a certain degree of informality and therefore ensured that their productions sounded relatively natural.

Implications of present study

The present study has several implications for research in the fields of phonetics and phonology. It raises important questions regarding the widely accepted notion in the literature that presupposes that phonological features are effectively phonetic features, and that phonological structure and phonetic detail have a one-to-one mapping and that phonetic detail must be completely accounted for in the phonological structure. The results of this study will contribute albeit modestly to the recent literature favouring a non-segmental non-linear approach to phonology and supports a unique understanding of the phonetics-phonology relationship based on applying the FPA to real phonetic data. This study proposed the FPA to account for the patterns observed for the liquids in Malayalam whereby phonetics and phonology are viewed as entirely separate but relational (by means of phonetic exponency statements).

Secondly, results of this study suggest that effects of resonance, often termed *secondary articulation*, can affect a wider stretch of speech than merely individual segments and form an important aspect of the contrast maintenance strategies among liquids in Malayalam. Often phonetic terminology can be misleading and a case in point is resonance or secondary cavity resonance or secondary articulation as the phenomenon is variously called. Approaching resonance only as an effect of *secondary* articulation might take away from identifying its potential to play a larger role in contrast maintenance and other aspects of the phonetics and phonology of a language. As Carter (2003: 238) rightly said, “what is secondary in a degree of stricture sense may in fact be an important part of the phonetics of any given stretch of speech”. This result draws attention to the significance of a parametric approach to phonetic analyses and the need for auditory and impressionistic analysis alongside acoustic analysis in order to not overlook what may seem less significant owing to connotations of traditional phonetic descriptions.

Thirdly, this is the first experimental phonetic study of the liquids in Malayalam to the best of the author’s knowledge. A few individual experimental studies have been done on the rhotics (Srikumar and Reddy, 1988) and on the laterals (Menon, 1973) separately but despite a thorough search, no previous study of all the five liquids was found by the present author and that too with more than one speaker. Lastly, it is the first auditory and acoustic study of the fifth liquid in Malayalam and results of this study seem to suggest that it is a third rhotic in the consonant system of the language. Malayalam is a largely under-studied language with respect to research in phonetics and phonology with only a handful of international publications. This study is a modest attempt at establishing some ground work in phonetics research on the language and therefore contributes to the relatively sparse literature on Malayalam and Dravidian phonetics and phonology in general.

Directions for Future Research

The present study has revealed several avenues of research that future scholars can take up. Now that an initial attempt has been made at establishing some of the more basic phonetic characteristics of the liquids in Malayalam, future researchers can engage in a more in-depth acoustic analysis of the liquids including measuring the higher formants including F4 since recent research has revealed the possible significance of F4 in distinguishing among liquids in other languages (Narayanan et al, 1999, Waltmunson, 2005). Although the present author also collected female data similar to the male data presented in this study, they were not analysed due to time constraints and future work can also look at how similarly or differently the female data pattern with respect to the trends observed for the male data in this study. Other potential sociolinguistic areas of research include studying variation in realisations of the liquids, particularly the fifth liquid and the tap, trill, among speakers of different age groups. Acquisition of these five liquids by monolinguals and bilinguals can also form a relevant and interesting area of future research.

Coarticulation and the extent of its effects is another related area that was only briefly touched upon in the present study and will most definitely be a promising area of research since /l/ and /r/ are known to have complex long-domain effects, with some current researchers suggesting that in languages like English coarticulatory effects of /r/ are perceptually more salient than those of /l/ (West, 2000). In languages that have larger liquid inventories like Malayalam, what will be the nature of coarticulatory effects of the different liquids? How will the effects of one compare and contrast with respect to the other four?

One inevitable area of research that can confirm and further strengthen the results of the present study regarding whether the fifth liquid is a central approximant and thereby a rhotic is in-depth articulatory work based on EPG, ultrasound and/or MRI techniques. Such articulatory work will also shed light on articulatory similarities and differences between the other rhotics and laterals in the language and the relationship between the acoustic and articulatory domains.

As mentioned in the introduction, the present study is an initial attempt at establishing the basic auditory and acoustic characteristics of the liquid system in Malayalam, some members of which have never been the topic of experimental research previously. The present author hopes that the results of this study will encourage further research on rhotics, laterals and the nature of their phonetic and phonological interaction in larger liquid inventories and also on the other aspects of the phonetics and phonology of Malayalam and other members of the Dravidian language family.

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APPENDIX A

Word-list

A)/ɾ/ initially

1) ‘randeh’ /ɾaɳɖə/ *two*

2) ‘raathri’/ɾa:tri/ *night*

3) ‘reekha’ /ɾe:kʰa/ *line*

4) ‘riiti’’ /ɾi:ti/ *norm*

5) ‘rokkam’/ɾɔkkam/ ready cash

6) ‘roomam’/ɾɔ:mam/ *hair*

7) ‘ruchi’ /ɾuʧi/ *taste*

8) ‘ruupam’ /ɾu:pam/ *statue/figure*

9) ‘rektam’ /ɾektam/ *blood*

B) /ɾ/ medially

1) ‘chiira’ /ʧi:ɾa/ *Spinach*

2) ‘puuram’/pu:ɾam/ *multitude*

3) ‘tiiram’ /ti:ɾam/ *shore*

4) ‘eruma’/eɾuma/ *ox*

5) ‘pura’ /puɾa/ *house*

6) ‘ira’ /iɾa/ *prey*

7)’kuru’/kuɾu/ *pimple*

8) ‘piira’ /piɾa/ *paste*

9) ‘kara’ /kaɾa/ *shore*

10) ‘oraal’/ɔɾa:ɭ/ *one person*

11) ‘ara’ /aɾa/ *waist/half*

12) ‘vira’/viɾa/ *tapeworm*

13) ‘paara’/pa:ɾa/ *cross bar/harassing object or situation*

14) ‘chiri’ /ʧiɾi/ *smile*

15) ‘kari’/kaɾi/ *soot*

16) ‘kuura’/ku:ɾa/ *small hut*

17) ‘ ari’ /aɾi/ *rice*

18) ‘maram’ /maɾam/ *tree*

19) ‘nira’/niɾa/ *multitude/series*

20) ‘kora’/kɔɾa/ *barking*

C) / r/ initially

1) ‘Rava’/rava/ *corn flour*

2) ‘Raanchuka’ /ra:ntʃuka/ *seize suddenly*

3) ‘Raddakkal’ /radda:kkal/ *cancellation*

4) ‘Raani’ /ra:ɳi/ *queen*

5) ‘Rokkam’/ɾɔkkam/ *ready cash*

6) ‘Riksha’ /ɾikʃa/ *rickshaw, two-wheeled hooded carriage drawn by a single man*

7) ‘ Ruppika’/ɾuppika/ *Rupee (Currency of India, Pakistan, Sri Lanka)*

D) / r/medially

1) ‘choRi’ /ʧɔri/ *scab*

2) ‘aRa’ /ara/ *chop/chamber*

3) ‘muRa’ /mura/ *order/rule/custom*

4) ‘paaRa’ /pa:ra/*rock*

5) ‘chiRi’ /ʧiri/ *lip*

6) ‘iiRa’ /i:ra/ *anger*

7) ‘kuuRa’ /ku:ra/ *cloth/soiled cloth*

8) ‘kaRa’/kara/ *stain*

9) ‘kuRi’ /kuri/ *note/invitation*

10) ‘kaRi’ /kari/ *curry*

11) ‘maRa’ /mara/ *root / screen/ secret*

12) ‘puRa(m)’/pʊram/ *the outer/back/reverse side*

13) ‘piiRa’/pi:ra/ *worthless/ torn/ vile*

14) ‘oRa’/ora/ *holster/ sheath/ envelope*

15) ‘viRa’ /vira/ *shivering /trembling /quake/ tremor*

16) ‘kuRu’ /kʊrʊ/ *short/ small/ dried-up*

17) ‘niRa’ /nira/ *state of being full*

18) ‘kooRa’ /ko:ra/ *rough unbleached cloth/ dried tender arecanut*

E) /l/ initially

1) ‘lipi’/lipi/ *script*

2) ‘liila’ /li:la/ *joviality*

3) ‘leelam’ /le:lam/ auction

4) ‘laabham’/la:b^{h}am/ *profit*

5) ‘loolam’/lo:lam/ *simple/unsteady*

6) ‘lunki’ /luŋki/ *dhoti*

7) ‘luuta’ /lu:ta/ spider

F) /l/ medially

1) ‘loolam’/lo:lam/ *simple/unsteady*

2) ‘vila’ /vila/ *price*

3) ‘niila’ /ni:la/ *blue*

4) ‘vala’ /vala/ *net*

5) ‘kola’ /kɔla/ *murder*

6) ‘kula’ /kula/ *bunch of fruits or flowers*

7) ‘veela’ /veela/ *work*

8) ‘ila’ /ila/ *leaf*

9) ‘mala’ /mala/ *mountain*

10) ‘oola’ /o:la/ *leaf of palm trees*

11) ‘maala’ /ma:la/ *chain or necklace*

12) ‘mula’ /mula/ *breast*

13) ‘muula’ /mu:la/ *corner*

14) ‘kala’ /kala/ *art*

15) 'kali' /kali/ *anger*

16) 'puli' /puli/ *tiger*

G) /ɭ/ medially

1) 'veeLi' /veeɭi/ *marriage*

2) 'kaLi' /kaɭi *game or play*

3) 'kiLi' /kɪɭi/ *bird*

4) 'poLi' /pɔɭi/ *slice or layer/lie or tell-tale*

5) 'tula' /tuɭa/ *hole*

6) 'ooLam'/o:ɭam/ *wave or ripple*

7) 'chuLi'/ʧuɭi/ *wrinkle or fold*

8) 'puLi' /puɭi/ *bitter/ tamarind*

9) 'muLa' /muɭa/ *sprout/seedling/bamboo*

10) 'kuLi' /κuɭi/ *bath*

11) 'vaLa' /vaɭa/ *bangle*

12) 'vaaLa' /va:ɭa/ *scabbard fish*

H) /ʐ/ medially

1) ‘uuzham’/u:ʐam/ *time or term /shift*

2) ‘muzha’ /muʐa/ *swelling*

3) ‘mazha’ /maʐa/ *rain*

4) ‘kuzhi’/kuʐi/ *hole*

5) ‘kiizhe’/ki:ʐe/ *under*

6) ‘puzha’/puʐa/ *river*

7) ‘pazham’/paʐam/ *banana*

8) ‘kozha’ /ko:ʐa/ *bribe*

9) ‘aazham’ /a:ʐam/ *depth*

10) ‘mozhi’ /mɔʐi/ *testimony*

11) ‘pizha’ /pɪʐa/ *penalty or fine*

12) ‘taazhu’ /ta:ʐə/*lock*

13) ‘kazhi’ /kaʐi/ *eat*

14) ‘vaazha’ /va:ʐa/ *plaintain*

15) ‘tuzha’/tuʐa/ *rowing*

16) ‘tozhi’ /tɔʐɪ/ *kick*

Liquid Fragments data set

I) r (word-medial trill Fragment)

1) 'daRshanam' /darʃanam/ divine sight

2) 'gaRbham' /garbʰam/ pregnancy

3) 'taRkam' /t̪arkam/ argument

4) 'caRmam' /carmam/ skin

5) 'vaRgam' /vargam/ caste

6) 'maRmam'/marmam/

7) 'shaRkara' /ʃarkaɾa/ jaggery / molasses

8) 'paRvatam' /parvatam/ mountain

9) 'kaRtaaveh'/kart̪a:və/ Lord

10)'kaRmam' /karmam/ action / act

II) R (word-final trill Fragment)

1) 'kayaR' /kajar/ *rope*

2) 'payaR' /pajar/*beans*

3) ‘nyaya**R**’/ɲjaja**r**/ *sunday*

4) ‘waya**R**’ /vaja**r**/ *waist*

III) **l** (word-medial alveolar lateral fragment)

1) ‘kaa**l**paadeh’ /ka:**l**pa:də/ footprint

2) ‘ta**l**samayam’ /ta**l**samajam/ at that time, then, live

3) ‘taa**l**paryam’ / ta:**l**parjam/ interest

4) ‘paa**l**kaaran’ /pa:**l**ka:ɾan/ milkman

5) ‘sa**l**peereh’ /sa**l**pe:ɾə/ reputation

6) ‘sa**l**kaaram’ /sa**l**ka:ɾam/ hospitality

7) ‘aa**l**taRa’ /a:**l**tara/ a platform built around the foot of a banyan tree

H) /l/ finally

lV) (word-final alveolar lateral fragment)

1) ‘paa**l**’ /pa:**l**/ *milk*

2) ‘kaa**l**’ /ka:**l**/ *leg*

3) ‘cuu**l**’ /cu:**l**/ *broom*

4) ‘veyi**l**’ /veji**l**/ *sunny*

5) ‘nuul’ /nu:l/ *thread*

6) ‘kool’ /ko:l/ *stick*

V) ɭ (word-medial retroflex lateral fragment)

1) ‘vaaLpayateh’ /va:ɭpajatə/ sword fighting

2) ‘aLtaara’ /aɭt̪a:ɾa/ altar

3) ‘aaLkuuTTam’ /a:ɭku:ʈam/ crowd

4) ‘aaLbalam’ /a:ɭbalam/ manpower

5) ‘uLkaNNeh’ /uɭkaɳɳə/ inner eye, intuition

6) ‘uLbhaagam’ /uɭbʰagam/ inside/ interior

VI) ɭ (wordfinal retroflex lateral fragment)

1) ‘aaL’ /a:ɭ/ *person*

2) ‘kooL’/ko:ɭ/

3) ‘mooL’/mo:ɭ/ *daughter*

4) ‘oraaL’/ɔɾa:ɭ/ *one person*

APPENDIX B

```
form Calculate Formants, Pitch, Intensity and duration for all segments
	comment Where are the sound files?
	sentence directory1 J:\sound files 1-4M\New
	comment Where are the TextGrids?
	sentence directory2 J:\sound files 1-4M\New
	comment Where to save the results file?
	sentence directory3 J:\sound files 1-4M\New
	comment Length of window over which formants are calculated:
	positive formantLength 0.025
	comment Time step for formants/Pitch calculation:
	positive timeStepFormant 0.005
	positive timeStepPitch 0.005
	comment Minimum ceiling for Pitch extraction (the maximum ceiling is determined by the 75%Quantile*1.5):
	positive minPitch 75
	comment Maximum number of formants for calculation:
	positive maxFormantNum 5
	comment Maximum formant frequency for males and females (MALE on the left; FEMALE on the right)
	positive maleMaxformant 5000
	positive femaletMaxFormant 5500
endform

clearinfo
countLine = 1
Create Strings as file list... list 'directory1$'\*.wav
numberOfFiles = Get number of strings
nbLines = numberOfFiles*1000

Create Table... resultsReenuSpeaker1 'nbLines' 34

Set column label (index)... 1 file_name
Set column label (index)... 2 speaker
Set column label (index)... 3 gender
Set column label (index)... 4 word
Set column label (index)... 5 c/v
Set column label (index)... 6 phoneme
Set column label (index)... 7 duration
Set column label (index)... 8 timeOnset
Set column label (index)... 9 timeMidpoint
Set column label (index)... 10 timeOffset
Set column label (index)... 11 f1_onset
Set column label (index)... 12 f2_onset
Set column label (index)... 13 f3_onset
Set column label (index)... 14 f4_onset
Set column label (index)... 15 f1_mid
Set column label (index)... 16 f2_mid
Set column label (index)... 17 f3_mid
Set column label (index)... 18 f4_mid
Set column label (index)... 19 f1_offset
Set column label (index)... 20 f2_offset
Set column label (index)... 21 f3_offset
Set column label (index)... 22 f4_offset
```

```
Set column label (index)... 23 f0_min
Set column label (index)... 24 f0_mean
Set column label (index)... 25 f0_max
Set column label (index)... 26 f0_onset
Set column label (index)... 27 f0_midpoint
Set column label (index)... 28 f0_offset
Set column label (index)... 29 intensity_min
Set column label (index)... 30 intensity_mean
Set column label (index)... 31 intensity_max
Set column label (index)... 32 intensity_onset
Set column label (index)... 33 intensity_midpoint
Set column label (index)... 34 intensity_offset

nama$ = selected$ ("Table")

for i from 1 to numberOfFiles
select Strings list
fileName$ = Get string... i

speaker$ = mid$ ("'fileName$'", 1, 2)
sex$ = mid$ ("'fileName$'", 4, 1)
Read from file... 'directory1$'\'fileName$'
name$ = selected$ ("Sound")
Read from file... 'directory2$'\'name$'.TextGrid
select Sound 'name$'
if sex$ = "F"
To Formant (burg)... timeStepFormant maxFormantNum femaletMaxFormant formantLength 50
elsif sex$ = "M"
To Formant (burg)... timeStepFormant maxFormantNum maleMaxformant formantLength 50
endif
select Sound 'name$'
To Pitch... timeStepPitch minPitch 700
q1 = Get quantile... 0 0 0.25 Hertz
q3 = Get quantile... 0 0 0.75 Hertz
max_pitch = q3*1.5
Remove
select Sound 'name$'
To Pitch... timeStepPitch minPitch max_pitch
To PointProcess
meanPeriod = Get mean period... 0 0 0.0001 0.02 1.3
select Sound 'name$'
To Intensity... minPitch timeStepPitch yes

select Sound 'name$'
select TextGrid 'name$'
finishing_time = Get end time
nbInter = Get number of intervals... 4

for j from 1 to nbInter
select TextGrid 'name$'
label$ = Get label of interval... 4 j
if label$ <> "#"
end = Get end point... 4 j
start = Get starting point... 4 j
duration = (end - start)
```

```
duration_ms = round(duration*1000)
mid = start+(duration/2)
mid_before = mid-(meanPeriod/2)
mid_after = mid+(meanPeriod/2)
start_before = start
start_after = start+meanPeriod
end_before = end-meanPeriod
end_after = end

select Pitch 'name$'
f0_min = Get minimum... 'start' 'end' Hertz Parabolic
if f0_min = undefined
f0_min = -1234
endif
f0_mean = Get mean... 'start' 'end' Hertz
if f0_mean = undefined
f0_mean = -1234
endif
f0_max = Get maximum... 'start' 'end' Hertz Parabolic
if f0_max = undefined
f0_max = -1234
endif
select Intensity 'name$'
intensity_min = Get minimum... 'start' 'end' Parabolic
if intensity_min = undefined
intensity_min = -1234
endif
intensity_mean = Get mean... 'start' 'end' energy
if intensity_mean = undefined
intensity_mean = -1234
endif
intensity_max = Get maximum... 'start' 'end' Parabolic
if intensity_max = undefined
intensity_max = -1234
endif


select Intensity 'name$'
intensity_start = Get maximum... 'start_before' 'start_after' Parabolic
start_maximum = Get time of maximum... 'start_before' 'start_after' Parabolic
select Pitch 'name$'
f0_start = Get value at time... 'start_maximum' Hertz Linear
if f0_start = undefined
f0_start = -1234
endif
select Intensity 'name$'
intensity_start = Get value at time... 'start_maximum' Cubic
select Formant 'name$'
f1_start = Get value at time... 1 'start_maximum' Hertz Linear
if f1_start = undefined
f1_start = -1234
endif
f2_start = Get value at time... 2 'start_maximum' Hertz Linear
if f2_start = undefined
f2_start = -1234
```

```
endif
f3_start = Get value at time... 3 'start_maximum' Hertz Linear
if f3_start = undefined
f3_start = -1234
endif
f4_start = Get value at time... 4 'start_maximum' Hertz Linear
if f4_start = undefined
f4_start = -1234
endif

select Intensity 'name$'
intensity_mid = Get maximum... 'mid_before' 'mid_after' Parabolic
mid_maximum = Get time of maximum... 'mid_before' 'mid_after' Parabolic
select Pitch 'name$'
f0_mid = Get value at time... 'mid_maximum' Hertz Linear
if f0_mid = undefined
f0_mid = -1234
endif
select Intensity 'name$'
intensity_mid = Get value at time... 'mid_maximum' Cubic
select Formant 'name$'
f1_mid = Get value at time... 1 'mid_maximum' Hertz Linear
if f1_mid = undefined
f1_mid = -1234
endif
f2_mid = Get value at time... 2 'mid_maximum' Hertz Linear
if f2_mid = undefined
f2_mid = -1234
endif
f3_mid = Get value at time... 3 'mid_maximum' Hertz Linear
if f3_mid = undefined
f3_mid = -1234
endif
f4_mid = Get value at time... 4 'mid_maximum' Hertz Linear
if f4_mid = undefined
f4_mid = -1234
endif

select Intensity 'name$'
intensity_end = Get maximum... 'end_before' 'end_after' Parabolic
end_maximum = Get time of maximum... 'end_before' 'end_after' Parabolic
select Pitch 'name$'
f0_end = Get value at time... 'end_maximum' Hertz Linear
if f0_end = undefined
f0_end = -1234
endif
select Intensity 'name$'
intensity_end = Get value at time... 'end_maximum' Cubic
select Formant 'name$'
f1_end = Get value at time... 1 'end_maximum' Hertz Linear
if f1_end = undefined
f1_end = -1234
endif
f2_end = Get value at time... 2 'end_maximum' Hertz Linear
if f2_end = undefined
```

```
f2_end = -1234
endif
f3_end = Get value at time... 3 'end_maximum' Hertz Linear
if f3_end = undefined
f3_end = -1234
endif
f4_end = Get value at time... 4 'end_maximum' Hertz Linear
if f4_end = undefined
f4_end = -1234
endif


 rf1start = 'f1_start:3'
 rf2start = 'f2_start:3'
 rf3start = 'f3_start:3'
 rf4start = 'f4_start:3'
 rf1mid = 'f1_mid:3'
 rf2mid = 'f2_mid:3'
 rf3mid = 'f3_mid:3'
 rf4mid = 'f4_mid:3'
 rf1end = 'f1_end:3'
 rf2end = 'f2_end:3'
 rf3end = 'f3_end:3'
 rf4end = 'f4_end:3'


select TextGrid 'name$'
start_label = start + 0.0001
titi = Get interval at time... 1 'start_label'
tata = Get interval at time... 3 'start_label'
label1$ = Get label of interval... 1 'titi'
label2$ = Get label of interval... 3 'tata'


select Table 'nama$'
Set string value... 'countLine' file_name 'fileName$'
Set string value... 'countLine' speaker 'speaker$'
Set string value... 'countLine' gender 'sex$'
Set string value... 'countLine' word 'label1$'
Set string value... 'countLine' c/v 'label$'
Set string value... 'countLine' phoneme 'label2$'
Set numeric value... 'countLine' duration 'duration_ms'
Set numeric value... 'countLine' timeOnset 'start_maximum'
Set numeric value... 'countLine' timeMidpoint 'mid_maximum'
Set numeric value... 'countLine' timeOffset 'end_maximum'
Set numeric value... 'countLine' f1_onset 'rf1start'
Set numeric value... 'countLine' f2_onset 'rf2start'
Set numeric value... 'countLine' f3_onset 'rf3start'
Set numeric value... 'countLine' f4_onset 'rf4start'
Set numeric value... 'countLine' f1_mid 'rf1mid'
Set numeric value... 'countLine' f2_mid 'rf2mid'
Set numeric value... 'countLine' f3_mid 'rf3mid'
Set numeric value... 'countLine' f4_mid 'rf4mid'
Set numeric value... 'countLine' f1_offset 'rf1end'
Set numeric value... 'countLine' f2_offset 'rf2end'
```

```
Set numeric value... 'countLine' f3_offset 'rf3end'
Set numeric value... 'countLine' f4_offset 'rf4end'
Set numeric value... 'countLine' f0_min 'f0_min:3'
Set numeric value... 'countLine' f0_mean 'f0_mean:3'
Set numeric value... 'countLine' f0_max 'f0_max:3'
Set numeric value... 'countLine' f0_onset 'f0_start:3'
Set numeric value... 'countLine' f0_midpoint 'f0_mid:3'
Set numeric value... 'countLine' f0_offset 'f0_end:3'
Set numeric value... 'countLine' intensity_min 'intensity_min:3'
Set numeric value... 'countLine' intensity_mean 'intensity_mean:3'
Set numeric value... 'countLine' intensity_max 'intensity_max:3'
Set numeric value... 'countLine' intensity_onset 'intensity_start:3'
Set numeric value... 'countLine' intensity_midpoint 'intensity_mid:3'
Set numeric value... 'countLine' intensity_offset 'intensity_end:3'

select Table 'nama$'
countLine = countLine + 1
#select Spectrogram 'name$'
#Remove
endif
endfor
select all
minus Strings list
minus Table 'nama$'
Remove
Endfor
select Table 'nama$'
Write to table file... 'directory3$'\'nama$'.xls
```