The phonetics of Wa

Experimental phonetics, phonology, orthography and sociolinguistics

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Experimental phonetics, phonology, orthography and sociolinguistics

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Dedication

This work is dedicated to the memory of Katrina Hayward, for six years my phonetics teacher, research supervisor and finally a colleague in the Department of South East Asia at SOAS. Katrina made experimental phonetics exciting, stimulating and rewarding. I am privileged to have had the benefit of her incisive scholarly criticism and warm-hearted supervision while working on this project as a doctoral candidate between 1995 and 1998. Her untimely death in February 2001 during the final preparation of this manuscript is a tragic loss.

Acknowledgements

This project was undertaken with the support and advice of many other people to whom I am deeply indebted. The wisdom and friendship of my mentor John Okell have been a great inspiration of incalculable value. John Laver's careful examination of this work as a doctoral thesis led to the excision of a considerable amount of unnecessary and flawed material, which the reader is consequently spared. Thanks go also to Arthur Abramson, Theraphan Luang-Thongkum, David Howard for their help in various linguistic matters. Any errors which remain are my responsibility.

While conducting fieldwork, many people offered logistical assistance which enabled me to meet Wa speakers and record them. My Wa teachers, Wáng Jìngliú and Xiāo Yùfēn of the Yúnnán Institute for Minorities in Kūnmíng, provided a hospitable and enthusiastic introduction to Wa language and cuisine. Marcus Young and the translators of the Wa Translation Project in Chiangmai gave generously of their time and contacts. I am grateful also to the inhabitants of Nong Kheo and Táojīnhé, the teachers of the Wa Boarder in Lashio, to I Pleek and Jim Elkins, and to my friend Sam Roung Jai of Cāngyuán.

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Final thanks go to Tim, without whose support and patience the days spent working on the manuscript might have been dull instead of enjoyable, and without whom life would not be nearly as beautiful.

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Introduction

This is a linguistic phonetic study of the Northern Mon-Khmer language Wa, spoken by about one million people in an area on the border between China's Yúnnán Province and the Shan State of Burma/Myanmar. Gérard Diffloth (1980) has worked on the historical phonology of Northern Mon-Khmer, but hitherto there has been little opportunity for the investigation of high quality phonetic data. Previously, Wa has featured in the phonetic literature chiefly on account of its contrastive use of vowel phonation types (Maddieson and Ladefoged 1985; Thongkum 1988b), one of several phonetic correlates of the phonological register contrast found in many Mon-Khmer languages.

LINGUISTIC PHONETIC DESCRIPTION

The discipline of linguistic phonetics has been defined by Peter Ladefoged as the study of those phonetic parameters which are used in the phonological description of a language (Ladefoged 1997). A linguistic phonetic description includes only those aspects of the speech sounds of a language which convey linguistic information, and not those which belong outside the domain of the language's phonology. Information about attitudes, emotions, physical characteristics or social background may also be encoded in the speech signal, but these are irrelevant to linguistic phonetics.

A phonetic description of a language further requires that phonetic facts be interpreted as a system of contrastive speech sounds which may be transcribed and compared with each other, and with the sounds of other languages. Ladefoged and Maddieson (1996:3) note that the division of phonetic strings into segments for the purposes of transcription is not straightforward.

The aim of this book is therefore to describe the phonetic facts of the sounds of Wa in terms of the simplest segment types without compromising detail, and to illustrate the types of contrasts which distinguish them from one another, so that they may be viewed in a wider, phonetic linguistic, context. It is hoped that sufficient material is presented here to inform a comparison of dialectal variants of Wa and that the instrumental data may be of value in comparing sounds in Wa with similar sounds in other languages.

This study aims to be accessible to all those who are interested in the relevance of phonetics to linguistics. It is hoped that certain sections, in particular the background information and the discussion of topics relating to the historical phonology of Wa, may be of interest to a wider readership, namely Mon-Khmerists, those working on other minority languages of South East Asia or elsewhere, or those with a general interest in Wa language, culture or society

SCOPE OF THIS MONOGRAPH

Section 1 comprises an introduction to Wa, and contains information which is not concerned with phonetics. Little general information about Wa has been published recently in English (but see Diffloth 1980; Parkin 1991); this section makes extensive use of Chinese-language materials which have been made available relatively recently (e.g. Wáng et al. (eds) 1994).

Since the experimental work in this project is based on original recordings, information about the linguistic background of the language consultants involved is included. This is particularly important given the sociolinguistic complexity of the Wa-speaking area (Bradley 1994) and the large number of dialects reported (Zhōu and Yán 1984). The recordings on which the study is based were made by the author at various locations in the Wa-speaking area. The fieldwork techniques are set out in full, with background sociolinguistic information about the speech communities from which the recordings derive.

A brief phonological account introduces the sound system of Wa, raising certain issues relating to the phonological distribution and phonological history of sounds. This treatment presupposes no familiarity with or allegiance to any particular theoretical framework of phonology. I have opted for terminology with the widest possible currency.

Much of the ground covered lies squarely within the domain of acoustic and articulatory phonetics, for which familiarity with the techniques of acoustic analysis of speech sounds is assumed. However, since the corpus of recorded materials on which this study is based comprises simultaneous audio and laryngograph recordings, there is an emphasis on sounds with a laryngeal component to their articulation. Consequently, a short general account of phonation and some of the ways in which laryngeal activity may be monitored, in particular the laryngograph, is also included. There follows a report of the experimental findings on each item in the phoneme inventory of Wa.

Besides the register contrast, which is assessed in terms of a variety of acoustic and articulatory correlates besides phonation type, Wa makes use of a number of other sounds of interest to phoneticians, such as a four-way voicing contrast in stop consonants, breathy-aspirated sonorant consonants and a rich set of vowels and diphthongs. The acoustic and articulatory characteristics of these and other sounds of Wa are described in systematic detail, with abundant illustrations and statistical evaluations.

A special focus of this project is the application of techniques in laryngography to descriptive linguistic phonetics. The experimental work is followed by a specific look at the coordination of aspiration, the register contrast and laryngeal consonants, all of which depend on some laryngeal articulation to maintain phonemic contrasts, with some discussion of the coarticulation of the register phonation types with initial consonant aspiration and with final laryngeal consonants. Some conclusions about the patterning of laryngeal activity in Wa are drawn from this.

In chapters 8 and 9, I have compiled an account of the diverse orthographic systems which have been devised for Wa, together with some annotated translated Wa texts and a brief list of Wa-language resources.

DIRECTIONS FOR FUTURE RESEARCH

Naturally, after completing a piece of work with as wide a brief as this one, it is easy to look back and identify omissions or decide that certain topics might have been treated differently. In any case, this work whets the appetite for future research.

The application of a formant-tracking device to the acoustic data would enable a more detailed survey of the rich set of diphthongs, especially if additional recorded data were acquired, working perhaps towards a more formal statement of the phonological structure of monophthongs and diphthongs and the status of glides in the phonology of Wa. This could be effectively coupled with a palatographic study of palatal and adjacent articulations to position more accurately the phonological boundary between velars and palatals. A second, closer look at vowel formants could lead to a more conclusive statement on the effect of the register contrast on vowel quality. An inverse filtering study of airflow measurements might add another perspective to our understanding of the laryngeal articulations involved. Further laryngograph work, perhaps including systematic calculation of the skewness of the glottal wave and of the DC component of the laryngograph wave (Abberton et al. 1989; Marasek 1997), which was impossible in this study, would help to formulate a model of the gestural changes in phonation type associated with aspiration and the more subtle modifications of laryngeal setting associated with the register contrast, and perhaps also of the coarticulatory processes associated with both. Such work might shape our knowledge of the role of phonation types in tono- and registro- genesis and exodus in a diachronic context and of the phonological constraints on the combination of laryngeal articulations. Another fruitful line of inquiry would be a study of the interaction of intonation with the pitch component of the register contrast.

ABBREVIATIONS

CQ	closed quotient
d.f.	degrees of freedom
F0	fundamental frequency
Lx	Laryngograph
s.d.	standard deviation

CONVENTIONS IN STATISTICAL DATA

Relevant statistical data are reproduced throughout the text. Where levels of statistical significance are tabulated, the symbol ○ is used to indicate levels of 95 per cent and higher (i.e. $p \leq 0.05$), while the symbol ● indicates 99.99 per cent and higher (i.e. $p \leq 0.001$).

1 *Wa linguistic studies*

The history of linguistic inquiry into the Wa languages stretches back more than a century, according to Gérard Diffloth's (1980) account of his sources. Many of the studies provide vocabularies or descriptive sketches of specific Wa languages, such as Lefèvre-Pontalis (1892), Drage (1907), Davies (1909), Antisdel (1912) and Harding (1927). Scott compiled notes on four Wa languages (Scott 1900), as he did for a number of languages spoken in the Shan States. Our picture of the diversity of the Wa languages is further clarified by the undertakings of the missionary Vincent M. Young, who translated the New Testament into Wa in the 1930s. The corpus of sources was enlarged later in the century by the work of Chinese researchers and Klaus Wenk (1965) and others.[1]

The first philological study of Mon-Khmer to include Wa was undertaken by Wilhelm Schmidt (1906a, 1906b), who was the first to investigate the genetic groupings within Austro-Asiatic. This seminal work was later advanced by Thomas Sebeok (1942), Robert Shafer (1952), David Thomas and Robert Headley (1970) and Paul Benedict (1975), who contributed to the classification of Mon-Khmer languages generally. Research focused on Northern Mon-Khmer by Harry Shorto (1963) and Michel Ferlus (1974) has set the scene for the most recent work, that of Gérard Diffloth (1980, 1989).

The Chinese researchers trained in the 1950s at the Chinese Academy of Social Science, Chén Xiāngmù 陈相目, Lǐ Dàoyǒng 李道勇, Wáng Jīngliú 王敬骝, Yán Qíxiāng 颜其香 and Zhōu Zhízhì, 周植志 and other scholars (see Wáng et al. 1994; Zhōu and Yán 1984) have contributed to the synchronic description of Wa and produced the fullest dictionary of Wa to date (Yán et al. 1981).

Most recently, Wa has attracted the attention of phoneticians working on phonation types in general (Maddieson and Ladefoged 1985, Ladefoged et al. 1988) or on Mon-Khmer register complexes more specifically (Thongkum 1988a and b, Svantesson 1993).

1.1 WA IN MON-KHMER CONTEXT

There is general consensus that Mon-Khmer (Austro-Asiatic) people, of which the Wa are one group, are the original inhabitants of mainland South East Asia, even if their presence is patchy in many parts of the region today. The enormously diverse Mon-Khmer languages, which according to most analyses constitute the core of Austro-Asiatic (Thomas and Headley 1970:405; Diffloth 1974:480; Bradley 1994:159; Yán and Zhōu 1995), are now found scattered from Vietnam to Eastern India and from Yúnnán in China to the Malay peninsula, with some forty million speakers (Figure 1-1).

[1] Additional references are found in Yán and Zhōu (1995).

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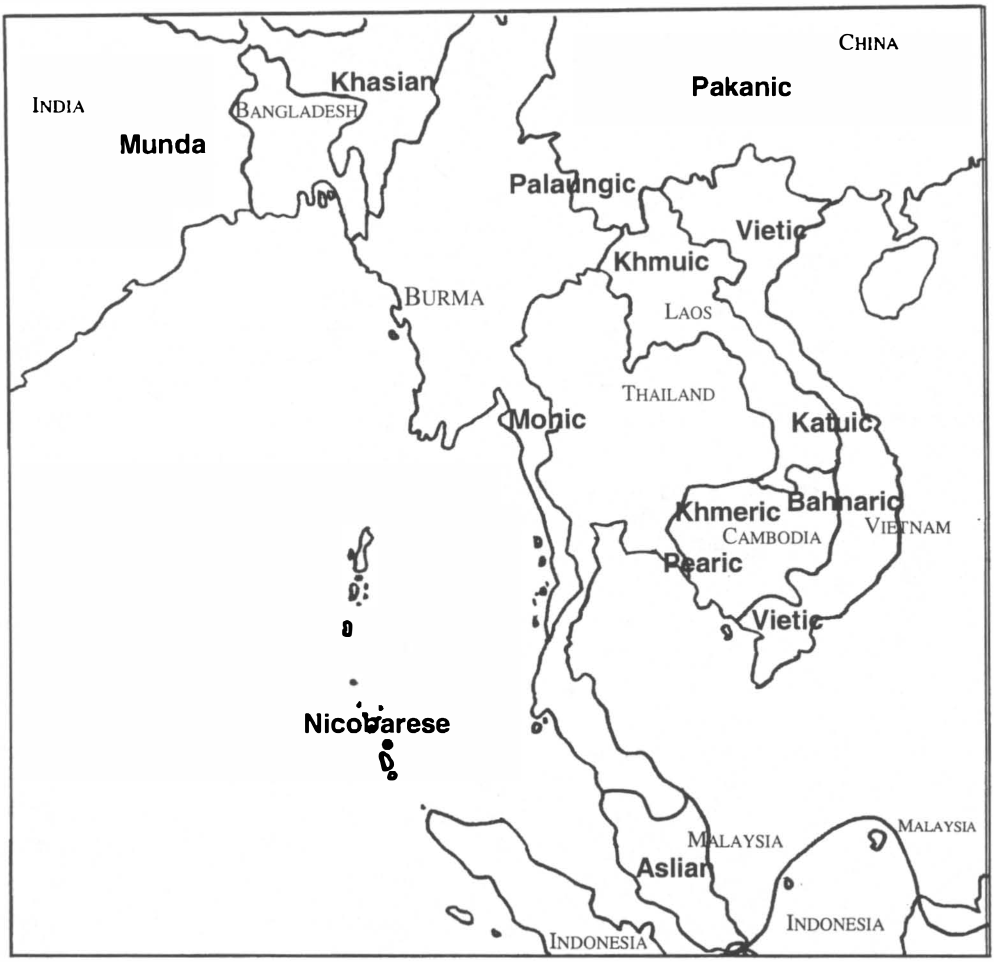

Figure 1-1: Map of South East Asia indicating the rough location of each branch of Mon-Khmer languages. See Diffloth (1974) and Bradley (1994) for more detailed maps.

1.2 LOCATION AND NUMBERS OF WA SPEAKERS

Early Chinese sources (cited in Luó 1995) offer compelling evidence that the Wa are the autochthonous inhabitants of the area they occupy. Luó writes that a group known as the *Pú* 濮 or *Bǎipú* 百濮 was in Yúnnán as early as the Qín dynasty (3rd century BC). The earliest conclusive evidence dates from the early Míng dynasty. Luó (1995) writes that a Míng dynasty source suggests that the *Pú* were the ancestors of the present-day *Púmán* 蒲满 / 蒲曼 of Shùnníng 顺宁(now Fèngqìng 凤庆) in Yúnnán (see also Ferrell 1971). *Mán* 蛮 was a generic term for the peoples of China's south-western borders; *púmán* refers here to the Austro-Asiatic peoples of China generally, including the Wa. Written sources prior to the Qín dynasty make no mention of the *Pú*. It is not clear whether this is because they were not in Yúnnán earlier than this time or because the ethnonym changed. However, it seems certain that the speakers of Northern Mon-Khmer languages were settled in the present-day Wa-speaking area earlier than other groups which now make up the majority of the population of the area, primarily speakers of Tibeto-Burman and Tai-Kadai languages.

Long-established though the presence of the Wa may have been, the sheer inaccessibility of much of the terrain they inhabit meant that the outside world's knowledge of them remained long a matter of reputation rather than of established fact. The elusive Wa captured the imagination of J. George Scott, who held various posts in the British colonial administration in Burma for thirty-five years from 1886, many of which were spent in the Shan States (Mitton 1936, Marshall 2002). Scott speculated (Scott 1932:292) that the Wa were first known of in Europe at the time of Vasco da Gama, who wrote of a 'thousand unknown natives' in his accounts of travels in the region in the late 15th century. First-hand accounts of encounters with Wa people were scarce, according to Scott, until he gathered information on the Wa during a journey from Lashio to Keng Tung in 1892–3, and wrote about them and their language (Scott 1896, 1900). The reputation of the Wa for being hot-blooded and savage is attributable to what Scott terms their 'head-hunting foible'.[2] Various non-linguistic ethnographic studies of the speakers of Northern Mon-Khmer languages have been made since these early sketches (see Parkin 1991:104–115).

Speakers of Wa are located in a geographical area referred to by Gérard Diffloth as the Waic corridor (Diffloth 1980:5), situated between the Salween and Mekong rivers, stretching approximately from 24°N to 21°N (Parkin 1991, Diffloth 1980[3]). This area straddles the south-western Chinese province of Yúnnán, the Shan States of north-eastern Burma and Northern Thailand. This area may be identified on Figure 1-2. The place names on the map are listed and given in appropriate local languages in Table 2.1.

Speaker numbers in such a geographically remote, topographically diverse and politically disparate area can at best only be estimates. In a language atlas, David Bradley (1994) estimates the total number of speakers of Wa to be 820,000.

The Summer Institute of Linguistics (SIL) Ethnologue (Grimes 1996) collates data from various sources, in addition to original SIL research. The categorisation of Wa languages is confused. SIL's major groupings, with alternative names, are Vo (Awa, Wa, K'awa, Kawa, Wa Pwi, Wakut), Parauk (Wa, Praok, Baraog, Baraoke) and Western Lawa (Wa, Wa proper, Pava, Luwa, Lua, L'wa, Lavua, Lavüa, Mountain Lawa). Their suggested total speaker numbers for these three groups are Vo 618,000, Parauk 528,400 and Western Lawa 82,000. This yields the most inclusive count of 1,228,400 speakers. Their database includes a further 27,000 speakers of Blang (Bulang, Pulang, Pula, Plang, Kawa, K'ala, Kontoi) and 7000 of Eastern Lawa (Wiang Papao Lua), bringing to 1,262,400 the estimated total population speaking any of the Wa languages included in Diffloth (1980). This figure may certainly involve a degree of overlap, given the disparity of the sources cited.

[2] Anecdotes on this 'vice' may be read in Scott (1932, Ch. 22), Harvey (1957) and Vail (1990).

[3] The area in Diffloth's article stretches further south, to include areas inhabited by speakers of all the Waic languages, a proportion of which fall outside the scope of this dissertation.

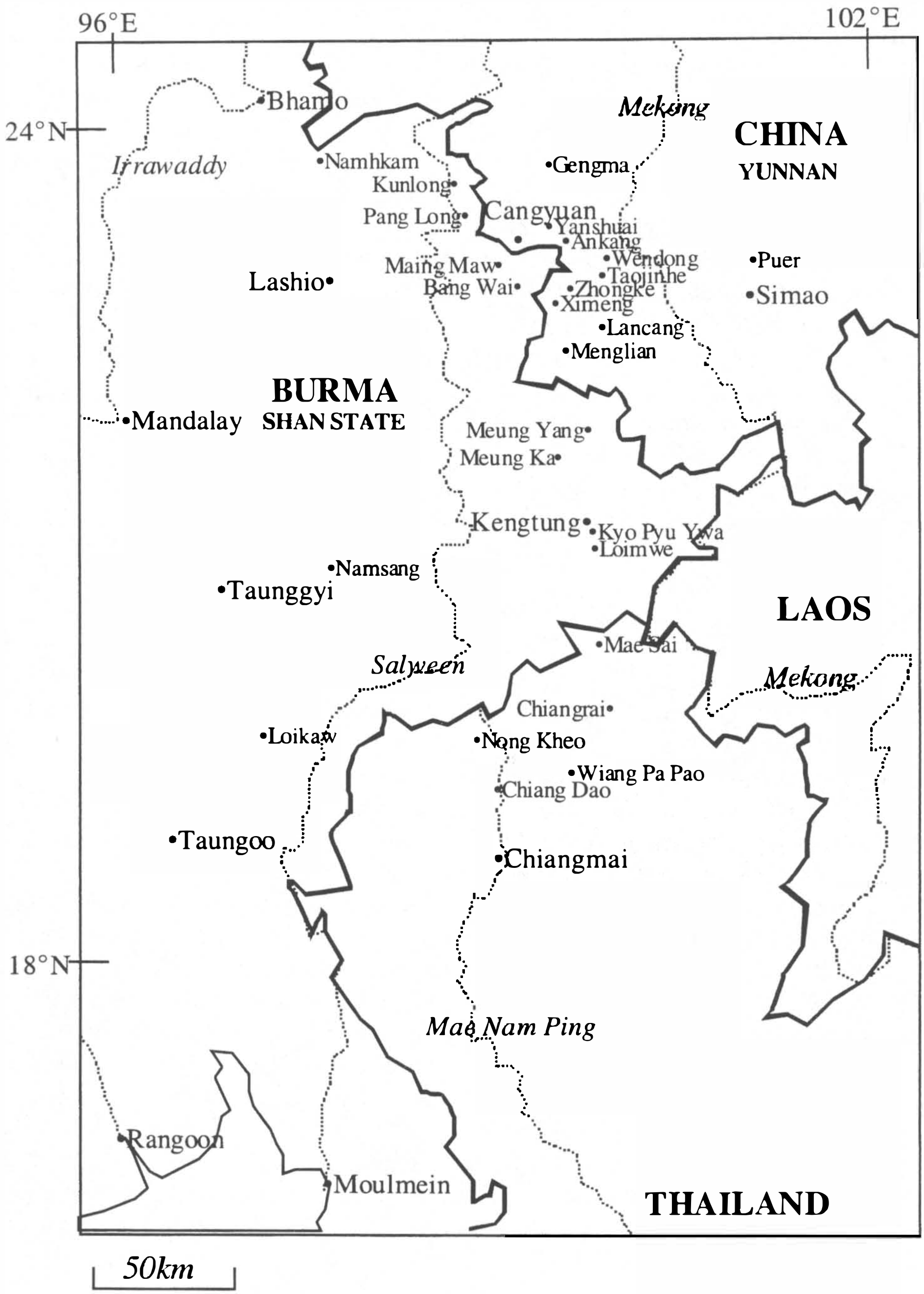

Figure 1-2: Map of the Wa-speaking areas and places of abode of the sample of Wa speakers interviewed for this study.

Table 1-1: Place names in the Wa-speaking area

Burma		*China*		*Thailand*	
Bang Wai	ပန်ဝိုင်း	Ānkāng	安康	Chiang Dao	เชิงดาว
Kengtung	ကျိုင်းတုံ; 景东	Cāngyuán	沧源; ချမ်းယင်	Chiangmai	เชียงใหม่
Kunlong	ကွမ်းလုံ; 滚弄	Fèngqìng	凤庆	Mae Sai	แม่สาย
Kyaing Maung Ywa	ကျိုင်းမောင်ရွာ	Gěngmǎ	耿马	Wiang Papao	เวีงป่าเป้า
Kyo Pyu Ywa	ကြိုးဖြူရွာ	Kūnmíng	昆明	Nong Kheo	หนองเขียว
Lashio	လားရှိုး	Láncāng	澜沧; လန်ချမ်း		
Loi Mwe	လွိုင်မွေ	Mǎsǎn	马散		
Maing Maw	မိုင်းမော	Měnglián	孟连; မုန်းလင်		
Mandalay	မန္တလေး	Pǔ'ěr	普洱		
Meung Ka	မိုင်းခတ်	Shùnníng	顺宁		
Meung Yang	မိုင်းယန်း	Sīmáo	思茅		
Namhkam	နမ့်ခမ်း	Táojīnhé	陶金河		
Namsang	နမ့်စန်	Wéndōng	文东		
Pang Long	ပန်လုံ	Xīměng	西盟		
Rangoon/Yangon	ရန်ကုန်	Àishuāi	岩帅		
Shan State	ရှမ်းပြည်	Yúnnán	云南		
Taunggyi	တောင်ကြီး	Zhōngkè	中课		
Taungoo	တောင်ငူ				
Doi Long					
Na Hax					
Yaong Krax					

WA IN BURMA

David Bradley (1994) estimates the Wa population of Burma to be 500,000 speakers. According to Anna Allott (1985), numbers of Wa speakers are included neither in the 1931 census report nor in Dr Htin Aung's 1974 entry in the Encyclopaedia Britannica, although the Wa account for more than 1 per cent of the population of Burma, which implies numbers of approximately 400,000. The SIL Ethnologue (Grimes 1996) puts the Burmese population at 558,000 speakers of Vo (Wa) and 348,400 Parauk (standard Wa) speakers, this last figure being an 'estimate' of uncertain origin.

Daw Tin Yi (1999), noting the problems associated with gathering accurate population figures in the hostile terrain of the Wa areas of Burma, records 126,788 Wa in thirteen townships in the Northern Shan State which clearly account for only a part of the Wa population of Burma. She makes no comment on the sociolinguistic situation in the communities in which she carried out her anthropological study.

WA IN CHINA

The Wa in China inhabit an area in the south west of Yúnnán province, on the Burmese border. The Chinese census of 1990 counts 352,000 people as belonging to the Wa nationality (Luó 1995). David Bradley (1994) suggests the Chinese census figures overstate the speaker population, offering 322,000 as an alternative. The SIL Ethnologue breaks the 352,000 down into 180,000 speakers of Parauk (standard Wa), 45,000 speakers of Lawa and 60,000 speakers of Vo (Wa). The shortfall can be accounted for by the crudeness of the definition of officially recognised ethnic groups in China.

Wa make up more than 83 and 71 per cent respectively of the population of the two Wa Autonomous Counties of Xīměng and Cāngyuán, over 25 per cent of the population of Měnglián Autonomous County (shared with the Dai and Lahu nationalities), and are found in sizeable numbers in Gěngmǎ, Shuāngjiāng and Láncāng counties.

WA IN THAILAND

Wa-speaking settlements in Thailand are the result of recent migrations from China and Burma during recent decades (Theraphan Luang-Thongkum, pers. comm.). The oldest settlements, up to fifty years old, are reportedly closely integrated into Thai society, though the majority have been established within the last twenty years.

Since the Thai government has not officially recognised the Wa as a separate ethnic minority, official statistics are not available. Since the blanket Thai term Lua' (ลัวะ /lúəʔ/) is used to refer to a number of different groups, including the officially recognised Lavüa, it is difficult to identify whether the published analyses of Thailand's ethnic diversity include the small number of Wa speakers as well as the more numerous speakers of other Palaungic languages. Another problem in obtaining figures arises from the reluctance of Wa refugees and immigrants in Thailand to disclose their Wa identity when dealing with officialdom.

There are Wa villages located in Mae Sai and Wiang Papao Districts of Chambray Province and in Chiang Dao District, Chiangmai Province (Theraphan Luang-Thongkum, pers. comm.).

Wa speakers resident in Thailand estimated the number of Thailand's Wa speakers to be 10,000, based on the number of Wa settlements. This total seems plausible, given

Smalley's (1994:300) figure of 7000 speakers at Wiang Papao. David Bradley's (1985:89) estimate of only 300 speakers of Palaungic languages other than Lavüa seems low.

WA OUTSIDE THE WA-SPEAKING AREA

There are no established Wa communities outside the Wa-speaking area, though there is a detectable Wa presence in Rangoon, Taunggyi and Mandalay in Burma. Small numbers of Wa reside in Kūnmíng and across Yúnnán province in China. Outside Asia, a very few isolated Wa *émigrés* are to be found in the USA and reportedly also in Germany.

1.3 Genealogical classification of Wa languages

The undisputed expert in the field of Wa historical linguistics is Gérard Diffloth, who has, in collaboration with Theraphan Luang-Thongkum, been conducting research into Mon-Khmer languages for some years. Diffloth's monograph on Waic historical phonology (Diffloth 1980) sifts through the fragmentary and often contradictory information published on Wa languages, and develops further the classification of the Wa languages proposed by Michel Ferlus (1974).

Diffloth's (1980, 1989) work investigates the relationship between the varieties of Wa which are the basis of the published and recorded materials available to him, and the probable location of the people who speak them. He coins the term Waic[4] to refer to one section of the Palaungic branch of Mon-Khmer for which he posits a common reconstructable source, Proto Waic. This reconstruction is based largely on six 'major' sources, consisting of vocabularies 'abundant enough for the purpose'. Some twenty 'minor' sources are then fitted into the framework of relationships between the major sources, resulting in a comprehensive picture of the Waic family of languages.

Broadly speaking, Diffloth identifies three distinct groups of Waic languages, namely Bulang[5], Wa and Lawa. He employs this subclassification within Waic in the etymological lexicon which assembles the etyma from all his sources, both major and minor. The areas inhabited by the speakers of the three groups of Waic languages are geographically distinct. Lawa speakers are located for the most part in Northern Thailand, while Wa speakers inhabit areas further north in the 'Waic corridor' in the Shan States and into Yúnnán. The offshoots of Bulang are spoken mostly in smaller areas to the north and north east of Keng Tung and into Yúnnán.[6]

Within the Wa group, Diffloth defines further a sub-group 'Wa proper', including three of his major sources: South Wa, Bible Wa and Kawa (Chinese *Kǎwǎ* 佧佤), as well as a number of minor sources. Diffloth later describes Kawa as Yúnnán Wa. The speech described in this study certainly falls within the Wa proper sub-group, displaying a similar degree of diversity, as might be predicted from the diverse places of origin of the consultants (see Table 2.2).

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[4] Diffloth notes that the name Wa is said to offend speakers of certain languages which fall within his definition of Waic. Bearing this in mind, I apologise sincerely for any offence my use of it may cause.

[5] Diffloth originally named this branch of Waic 'Samtau'; he later renamed it Bulang (1989:36).

[6] See Diffloth (1989) for more detail and other locations.

1.4 DIALECTS AND MUTUAL INTELLIGIBILITY

There is considerable phonological variation among Wa languages. This is documented in Diffloth's (1980) etymological lexicon and in the comparison of some Wa dialects in Zhōu and Yán (1984:100–154). The degree of mutual intelligibility of dialects was investigated by means of field work interviews with the consultants recorded for this study.

More than one consultant in the sample interviewed mentioned a dialect of Wa within the Wa-speaking area which was considered particularly difficult to understand. In imitating how this dialect sounded to them, they added final [s] to words. One person said that this characterised the dialect of Meung Yang, north of Keng Tung. Zhōu and Yán (1984:153) report that the speech of the Zhōngkè variety of the Măsăn dialect, spoken near Xīmĕng, uniquely preserves final /s/. One language consultant from Meung Yang, mentioned that he did not learn to speak standard Wa until he moved from Meung Yang to Keng Tung at the age of fourteen, and said that there was a considerable difference between the speech of these two places. It would seem then that the Wa spoken in Xīmĕng Autonomous Country and in Meung Yang are particularly incomprehensible to other Wa speakers.

Two consultants reported that they could understand other speakers and make themselves understood over a wide area particularly well because they were accustomed to moving around the area as part of their activities as Christian priests, and had become familiar with a variety of dialects of Wa. One consultant whose father had been a Christian missionary said that the speech of Christian Wa was often identifiable because of words and phrases peculiar to the Bible translation and Christian usage, phonological considerations aside.

However, the most common response was that there was little problem of any kind in understanding other Wa speakers, either because the speech of other areas was not perceived to be much different, or because Wa speakers were generally aware of and competent in a standard form of the language which could be reverted to when communication difficulties arose.

1.5 STANDARD WA DIALECT

The notion of a standard language is particularly strong among Christian Wa, for whom the language of the Wa translation of the Bible serves as a unifying factor. According to Diffloth (1980:7) the Wa dialect of the Bible translation is similar to the dialect spoken north of Keng Tung. Several Christian interviewees cited Bang Wai Wa as the standard. Bang Wai is located some 150 miles north of Keng Tung, not far from Àishuāi (see map in Figure 1-2).

Wa contacts in China in and around Cāngyuán and Láncāng, both Christian and otherwise, consider the speech of the area around Àishuāi , in Cāngyuán county, as standard. Àishuāi Wa is the basis of the writing system developed in the People's Republic of China (PRC) and so also of Wa-language publications from the PRC.

Standard Wa may thus be taken to mean the Wa spoken around Bang Wai, in the area south and south-west of Cāngyuán, arguably also including the Bible translation dialect. This corresponds to the Wa of three of Diffloth's major sources of data (South Wa, Bible Wa and Kawa), as well as to the other minor sources within Diffloth's sub-group Wa proper. For the purposes of this dissertation, standard Wa is taken to be equivalent to Diffloth's Wa proper, hereafter referred to simply as 'Wa'.

1.6 ETHNONYMS AND GLOSSONYMS

One of the problems which besets any study involving minority nationalities of South East Asia is the plethora of names used to refer to a multiplicity of ethnic groups whose languages are related to varying degrees. Diffloth (1980:6) notes succinctly that many ethnic names in South East Asia are used to refer to all sorts of minority groups without regard for their linguistic affiliation: Wa is no exception. The names used to refer to speakers of Wa languages, the Waic languages in Diffloth's (1980) classificatory framework, are many. Robert Parkin's overview of research on the speakers of the Palaungic branch of Mon-Khmer languages (Parkin 1991:104–115) contains more than twenty names used to refer to speakers of Wa languages. The term 'Wa languages' is an inclusive one: while only a portion of the speakers of Wa languages habitually refer to themselves as 'Wa', no speaker of a language *not* classifiable as Waic would normally be called Wa.

'Wa' may be used to refer to a variety of forms of speech broader than the sample included in this study. Conversely, the majority of the people whose speech is described here do not call the language they speak 'Wa'. In spite of these two anomalies, the name 'Wa' is used throughout: the following is a justification of this.

The Chinese literature notes ethnonyms in detail. The group which is officially designated Wa nationality (Chinese *Wǎzú* 佤族) in China includes the speakers of all the Waic languages found in Yúnnán except the Bulang branch. According to Zhōu and Yán (1984), only the Wa in the Zhēnkàng area north of Cāngyuán call themselves /va̤ʔ/, while those further to the south west around Xīměng and Měnglián use the names /avɤʔ/, /rɤviaʔ/, /vɔʔ/ or /avɤʔ lɔi/. The dialects of the latter group, which have lost the register contrast found in other dialects spoken in Yúnnán (Zhōu and Yán 1984:109), are referred to in Chinese as *Āwǎ* (阿佤). They are not represented in this study.

This ethnonym surfaces as *va̤ʔ* in standard Wa. Diffloth reconstructs a common Proto Waic parent *(r-)waʔ for all of these, which he glosses as 'a La, a Lawa, a Wa': a common word for a group with much in common. The intact minor pre-syllables (see Section 4.2.1) of each of the four Āwǎ ethnonyms above closely resemble the reflexes which Diffloth attributes to the Lawa subgroup in his lexicon. These contrast with the monosyllabic standard Wa cognate of the ethnonym. Again, it is the standard Wa which is represented in this study, and so the monosyllabic label Wa is more appropriate.

Speakers in the areas around and to the east of Cāngyuán refer to themselves and their language as *para̤uk*. This name appears variously as Praok, Parauk, Paraok or in PRC orthography as *Ba Rāog* (Zhōu and Yán 1984:100). The apparent contradiction of using the label Wa to refer to a language properly called *para̤uk* is resolved by considering the fact that the speech of the Cāngyuán area, this same *para̤uk*, corresponds loosely to the standard Wa which is used over a much wider area, by people whose own speech may be quite different. It would be inappropriate therefore to refer to all users of the standard language as *para̤uk*.

Wa is the ethnonym by which the great majority of speakers of Waic languages are generally known, be it in Chinese (*Wǎ* 佤), Burmese (/wa̰/ 'ဝ') or English, as is abundantly clear from the literature. The Chinese term *Kǎwǎ* 佧佤 was in general use as the official Chinese government-preferred ethnonym for the Wa nationality, but because of negative connotations in Chinese its use was discouraged and the name *Wǎ* was favoured officially after 1962 (Zhōu and Yán 1984:2).

Lastly, 'Wa' is the only name which has any currency outside the immediate area where Wa is spoken.

1.7 Sociolinguistic sample of Wa speakers

Basic information about a sample of Wa speakers, including the consultants whose pronunciation was studied, is given in Table 2.2 below. The last column of Table 2.2 indicates where the speakers have lived and (where known) the years of their movements. Most places may be located on the map in Figure 1-2. Languages spoken are abbreviated thus: A–Akha, C–Chinese, B–Burmese, L–Lahu, S–Shan, T–Thai, K–Karen, E–English, Kc–Kachin, Pl–Palaung, Dn–Danu. The abbreviations C, B, T with place names denote China, Burma and Thailand respectively. The locations are indicated on the map (Figure 1-2).

Table 1-2: Consultant profiles, showing sex, age, place of origin, languages spoken

Name	*m/f*	*age*	*langs spoken*	*Place of origin*	*Places lived*
AN	m	36	B	Maing Maw / Nam Max (near Lashio, B)	lived thirteen years in Rangoon
AP	m	25	C	Táojīnhé (C)	
APP	f	41	BLS	Maing Maw (B)	lives Lashio (B)
JN	m	45	BTCE	Yang Houg (near Cāngyuán)	1953 Meung Ma (B); 1960 Mandalay, 1981 Chiang Mai (T)
JS	m	80	CBLE	?Lashio (B)	
NKP	m	41	B	Doi Long Ywa (B)	1969 Lashio (B)
NT	m	48	LBS	Meung Yang (B)	1962 Keng Tung (B), 1970 Taunggyi; 1972 Meung Yang; 1974 Keng Tung; 1994 Chiangmai (T).
RM	m	38	CBL	Táojīnhé (C)	1972 Kunlong (B), 1980 Chiangmai (T)
SJ	m	57	C	Àishuāi (C)	some years in Běijīng
SKN	m	20	C	Táojīnhé (C)	
SRM	m	49	BK	Bang Wai (B)	1966 Rangoon, 1974 Lashio
ST	m	43	BKKc	Yaong Krax (Bang Wai, B)	lived sixteen years in Rangoon

Name	*m/f*	*age*	*langs spoken*	*Place of origin*	*Places lived*
YH	m	50	LBKSC	Panglōng; Bang Wai (B)	1960 Rangoon (B), 1973 Panlong; 1996 Chiang Mai (T).
CC	m	21	C	Cāngyuán (C)	1994 Nong Kheo (T)
CK	m	35	BSK	Maing Maw (B)	some years in Taungoo/Taunggyi (B)
KB	m	59	CL	Wéndōng (C)	1959 Běijīng, 196? Láncāng, Pŭ'ĕr
PC	m	30	TS(L)	Meung Ka (C)	1970 Nong Kheo (T)
RT	f	50	BSLK DnPl	Keng Tung (B)	lives Lashio (B)
SKG	m	58	CB	Na Hax (B)	1952 Zhènxīngcún; 1966 Burma; 1980 Zhènxīngcún
SKT	m	51	CLT	Zhènxīngcún (C)	
SP	f	?40	TLBAS	Kyaing Maung Ywa (Loi Mwe, B)	Keng Tung (B); 1979 Chiang Mai (T)
SR	m	29	C	Táojīnhé (C)	
SS	m	40	LSBT	Loi Mwe (B); parents from Yaong Rung	1970 Keng Tung (B), 1987 Nong Kheo (T)
YS	m	57	BS	Kyo Pyu Ywa, Keng Tung (B)	works in Keng Tung

Wa speakers live interspersed with speakers of many other languages. More than one person in this sample commented that speakers of other languages rarely learn Wa, sometimes even in mixed marriages. This suggestion is corroborated by the typical multilingualism of Wa speakers. A few interviewees claimed that this was because Wa is harder to learn than other languages; another explanation may be that Wa are frequently not the ethnic majority of the areas in which they live.

Most of the sample have lived in a number of different locations, with all but a few having spent a number of years away from the Wa-speaking areas. All of them are able to speak Chinese or Burmese to some degree if they have lived in China or Burma, or in several cases both. Those who have settled in Thailand also speak at least some Thai. About half of the group speak Lahu and about half of those who live or have lived in the Shan State speak Shan. Other languages known by consultants include Karen, Akha, Kachin and Palaung. A quarter of the group speak five or more languages.

2 Field methods

The experiments which the form the basis of this study were carried out on a corpus of recordings made of Wa speakers in 1996 and 1997.

2.1 SELECTION OF CONSULTANTS

The diversity of the Wa languages is such that it would be futile to attempt to select speakers of a set of Wa dialects which were fully representative of that diversity, especially in the absence of any comprehensive synchronic survey of Wa dialects. Conversely, to aim instead to concentrate on a single form of Wa by recording a group of speakers in a single location might yield a false impression of uniformity which would be roundly misrepresentative of the Wa linguistic situation. It is immediately clear from the sample of Wa speakers above that the majority of Wa speakers within the sample have spent their lives in more than one place within and outside the Wa-speaking region. Diffloth (1980) also notes widespread small-scale migrations within the region.

For this reason, the primary criterion when looking for consultants was that they should be speakers of standard Wa, whatever their geographical origins, since it seems unrealistic to assign specific Wa languages to precise geographical locations.[7]

Twenty-four Wa speakers were recorded; ultimately, the recordings of eleven of the consultants were found to be suitable for experimental analysis; the remaining recordings were discarded. They originate from locations spread over an area rather larger than, but centred on, the area associated with Standard Wa. All are native speakers of a Wa language, not necessarily Standard Wa, who reported using standard Wa in their everyday lives and with their families at home. The consultants' declared proficiency in Standard Wa is, of course, no guarantee that the corpus of recordings is dialectally homogeneous. Where cross-speaker variation was found to be significant in the experimental work, dialectal variation is cited as a possible source of the effects.

Another factor in consultant selection was accessibility. Research and travel in the Wa-speaking area is problematic for a variety of reasons. Geography, politics, economics and logistics all influenced the eventual selection of consultants.

Additionally, a degree of familiarity with some written form of Wa was required. This stipulation excluded at a stroke the great majority of the Wa population, but was necessary because the language material for recording was to be presented to consultants in written form. In cases where a consultant was unfamiliar with the standard Wa for an item in the wordlist, or unclear about exactly which word was required, the data were discarded.

Since Christian Wa are often taught to read Vincent Young's Wa translation of the Bible (*Sān-Zì Wěiyuánhuì* 1985), the literacy rate seems higher than average in Christian

[7] An exception to this generalisation is the association of Standard Wa with the village of Àishuāi ; for practical reasons, however, it was not possible to record natives of Àishuāi exclusively.

communities. There are also generally good connections between Christian Wa communities, and this scope for networking was exploited in the search for suitable consultants. Consequently, all but three of the consultants were Christian Wa who were literate in Bible orthography.

One regret is that women were under-represented in the recordings: only two women were recorded, but the recordings of one of them had subsequently to be discarded.

2.2 RECORDING PROCEDURE

Recordings took place in a number of locations, which were of varying acoustic suitability. Where possible, a quiet room was chosen without too much echo or likelihood of disturbance from life outside. The recordings were made using the following portable equipment:

- Sony TCD-D7 Digital Audio Tape-corder (DAT);
- Sony ECM-717 Electret Condenser Microphone;
- Laryngograph Ltd Field-model Fourcin-type laryngograph.[8]

Each consultant was shown the microphone and the laryngograph in advance of recording. The experimenter demonstrated the safety and comfort of the laryngograph collar when subjects seemed apprehensive[9]. Once the laryngograph electrodes and microphone were in position, the consultant was shown the frame sentence (Table 2-1), which was devised with the assistance of one of the consultants, a speaker from near Cāngyuán in Yúnnán.[10]

Table 2-1: Frame sentence used for recording

lɔk	___	*kiʔ*	*ʔah*	*nan*
like	___	they-PL	say	that.way

'They say ... like that.'

Flash cards were used to prompt the consultants to insert into the frame sentence each of the words in the recording wordlist. Each numbered card showed a word in revised and original Bible Wa and PRC orthographies[11], a sentence in which the context made clear the meaning of the word, a drawing illustrating the meaning of the word (where possible), and a translation of the word into Chinese, Burmese and English.

The experimenter checked, by referring to as much of the information on the card as necessary, that the consultant understood exactly which word was intended, since the

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[8] Described in section 3.4 below.

[9] In previous recording situations, subjects' doubts concerning the safety of the collar have given rise to unnatural styles of speech or even a choking sensation.

[10] Several consultants subsequently felt that the sentence had a rather unnatural feel to it, but were happy to repeat it *ad nauseam* once they realised that the focus of the experiment was on the pronunciation rather than the meaning.

[11] Wa orthographies are described in detail in section 1.

wordlist contained a large number of minimal pairs distinguished by phonological contrasts which are unmarked in the Bible orthography. This discussion was conducted in Burmese or Chinese with each consultant, since all knew at least one of these languages. On tape, however, each consultant was encouraged to speak only Wa.

The consultant was asked to read the number on each card, and then to say the frame sentence twice with the word on the card inserted in it. For instance, Table 3.2 shows the output required on presentation of flashcard No.68.

Table 2-2: Example of consultant output: flashcard No.68

t̤iʔ ᵑgliəh ⁿdaiʔ	*lɔk*	*kʰauʔ kiʔ*	*ʔah nan*	*lɔk kʰauʔ*	*kiʔ*	*ʔah nan*
68	like	tree	they say	that.way	like tree	they say that.way
‘Sixty-eight.[12]	They say ‘tree’ like that. They say “tree” like that.’					

This procedure was straightforward for most consultants. Most gratifyingly, consultants were mostly highly motivated to demonstrate their language, and were not put off by having to perform the repetitive tasks required.

During two recording sessions, a consultant who understood clearly what was required was on hand to explain the procedure to other consultants in Wa. Some consultants felt that certain words in the standard Wa wordlist were unusual and did not consider them part of their vocabulary. When this situation arose during recording sessions, there were three possible outcomes:

1. other consultants prompted the consultant being recorded, such that he or she was then able to recognise it and read it satisfactorily;
2. the consultant supplied a cognate of the word in his/her own dialect;
3. the consultant supplied a different word altogether.

In cases 2. and 3., the material recorded was subsequently discarded.

Recordings were made in batches of ten to fifteen cards, which were discussed carefully prior to each session. The cards were shuffled freely between recordings and presented in quasi-random order. Care was taken to avoid similar words occurring consecutively, especially minimal pairs of words spelt identically in Bible orthography.

While the consultant rehearsed the recording procedure, the experimenter checked the microphone and laryngograph output levels visually by monitoring the recording levels displayed on the DAT tape recorder. No oscilloscope was available to check the quality of the laryngograph output. After careful placement of the laryngograph electrodes, the experimenter monitored it subjectively by listening on headphones for the clear buzzing sound which characterises the periodicity of the laryngograph waveform when it is amplified as if it were a sound pressure wave.

[12] Counting: it is usual for most Wa to count in Dai loanwords for numbers above twenty-nine, or else to count in Chinese or Burmese. However, the Christian Wa who contributed recordings for this study are accustomed to using Wa numbers in church situations. They responded to the formality of the recording situation by using Wa numbers here also, though occasionally a non-Wa number would slip out. So sixty-eight might be read variously as Wa *t̤iʔ ᵑgliah ⁿdaiʔ*, Dai loanwords in Wa *rʰok sip pɛt*, Chinese 六十八 *liùshíbā* or Burmese ခြောက်ဆယ့်ရှစ် *tʃʰauʔ sʰɛ̰ ʃɪʔ*.

2.3 LANGUAGE MATERIALS USED FOR RECORDING

The main wordlist consisted of the 136 words listed in the Section 9.1. This list was designed to illustrate specific aspects of the Wa sound system in detail, especially stop-consonant voicing contrasts, the register contrast, breathy–aspirated sonorant consonants, final laryngeal consonants and combinations of these. In some cases, this involved hunting through the dictionary (Yán et al. 1981) or other sources to find suitable minimal pairs and triplets. The numbers on the cards, read in Wa, proved to be another fruitful source of recorded data. Other materials recorded from selected consultants included the Parable of the Sower from the Wa New Testament (*Sān-Zì Wěiyuánhuì* 1985), reproduced in the Section 9.1. The acoustic analysis of diphthongs (Section 5.1.4) was based on recordings of a separate list of words designed *ad hoc* for use with one speaker.

The experimenter attempted to elicit a similar reading style from all consultants, though, inevitably, reading speed could not be controlled absolutely. Most of the consultants read the frame sentence with a single stress and falling intonation on the target word. Certain lexical items with a functional role in the language resisted this pattern, in particular the sentence-final emphatic particle *hɤi* and the conjunction *mai*. These words were typically given emphatic prosodic features, such as high pitch or greater duration (see Section 6.6).

3 Laboratory methods

The account of the experimental work assumes a familiarity with general phonetics and speech acoustics, as well as articulation and the organs of speech, such as may be acquired from any general textbook (*e.g.* Catford 1988, Clark and Yallop 1995, Hayward 2000, Ladefoged 1996.) However, because phonation types are a special focus of this study, a short introductory account of the larynx, phonation and phonation types is included below.

3.1 The larynx

The larynx is an elaborate organ of intricate construction and capable of delicate and complex activity. Detailed accounts of its structure and composition may be found in Laver (1980:99–109) and Orlikoff and Kahane (1995:113–121).

While this study is concerned only with its function in speech, it is worth mentioning that the larynx has another, vegetative function as a valve connecting the lungs to the pharynx and mouth. The larynx is used to seal off the thoracic cavity, so that it becomes rigid when air is compressed within it, increasing the general sturdiness of the human frame during, for instance, strenuous physical activity (Orlikoff and Kahane 1995:113). For this purpose, the larynx must be able to maintain its closure against great pressure, and the muscles involved in this type of activity are necessarily powerful (Laver 1980:104).

The larynx is built on a cartilaginous skeleton, of which three main parts are relevant for speech,[13] illustrated in Figure 3-1. The cartilages are morphologically specialised tracheal rings, although only one remains ring-shaped. The cricoid cartilage is a ring with a raised heel on the posterior side on which the thyroid cartilage sits. The thyroid is connected to the cricoid at two cricothyroid joints, which are articulated enabling the thyroid to tilt forwards and backwards. The arytenoid cartilages have been described as two triangular-based pyramids. They are attached to the heel of the cricoid inside the thyroid, and are capable of complex movement including limited rotation in the vertical and horizontal planes.

Between the thyroid and cricoid cartilages at the level of the arytenoid cartilages, the soft tissue walls of the laryngeal cavity form the glottis, bounded by the vocal folds below and ventricular folds above. The ventricular folds join to the apices of the arytenoid cartilages; the vocal folds are attached to the vocal processes of the arytenoids; the other ends of both pairs of folds connect to the inside of the thyroid cartilage. The vocal ligaments form the edges of the vocal folds between the thyroid and the arytenoids; the edges of the glottis continue back along the arytenoids, enabling the glottis to be divided

[13] The other, the epiglottis, though used in a limited number of speech sounds, is not considered here.

into an anterior ligamental part and a posterior cartilaginous part. The vocal folds are layered in structure, with a mucous surface and fibrous upper layers.

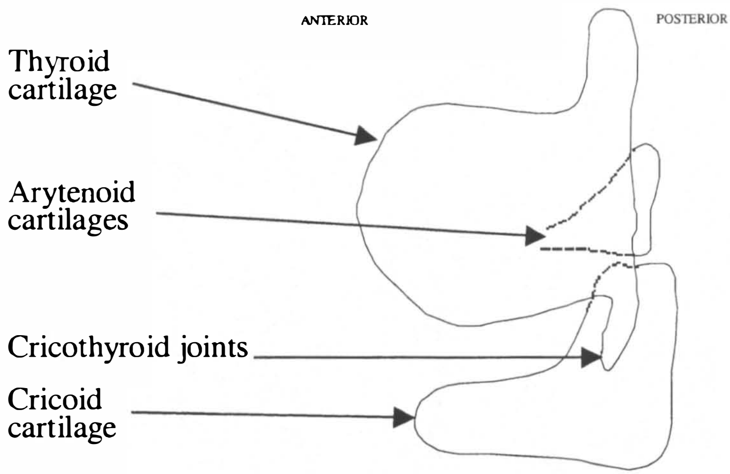

Figure 3-1: Schematic diagram of the principle laryngeal cartilages in lateral view.

The larynx has a complex musculature. All the moving parts of the larynx are attached to each other by a set of muscles known as the intrinsic laryngeal muscles. These muscles have four general functions (Orlikoff and Kahane 1995:117):

- to abduct and adduct the vocal folds;
- to change the position of the laryngeal cartilages relative to each other;
- to transiently change the dimensions and physical properties of the vocal folds;
- to modify laryngeal airway resistance.

There is no simple relationship between individual muscles and the movements within the larynx which are relevant for phonation. Rather, the activity of groups or pairs of muscles is considered. The muscles of principal interest for phonation are illustrated in Figure 3-2 and Figure 3-3.

The cricothyroid muscles tilt the cricoid cartilage relative to the thyroid cartilage above it (Figure 3-2). Since the vocal folds are attached to the thyroid, this has the effect of lengthening and shortening them. Within the vocal folds are found the thyroarytenoid muscles, which are attached to the thyroid cartilage at the front and the vocal processes of the arytenoid cartilages at the back, and play a role in closing the glottis by pulling the arytenoid cartilages together. The part of this muscle nearest the ligamental edges of the vocal folds is the vocalis muscle, contraction of which stiffens the vocal folds.

The remaining muscles in Figure 3-3 all move the arytenoid cartilages. The glottis is held shut by contraction of the interarytenoid and lateral cricoarytenoid cartilages; the posterior cricoarytenoid muscle is the only muscle which abducts the vocal folds (Hirose 1975). These functions are summarised below in Table 3-1.

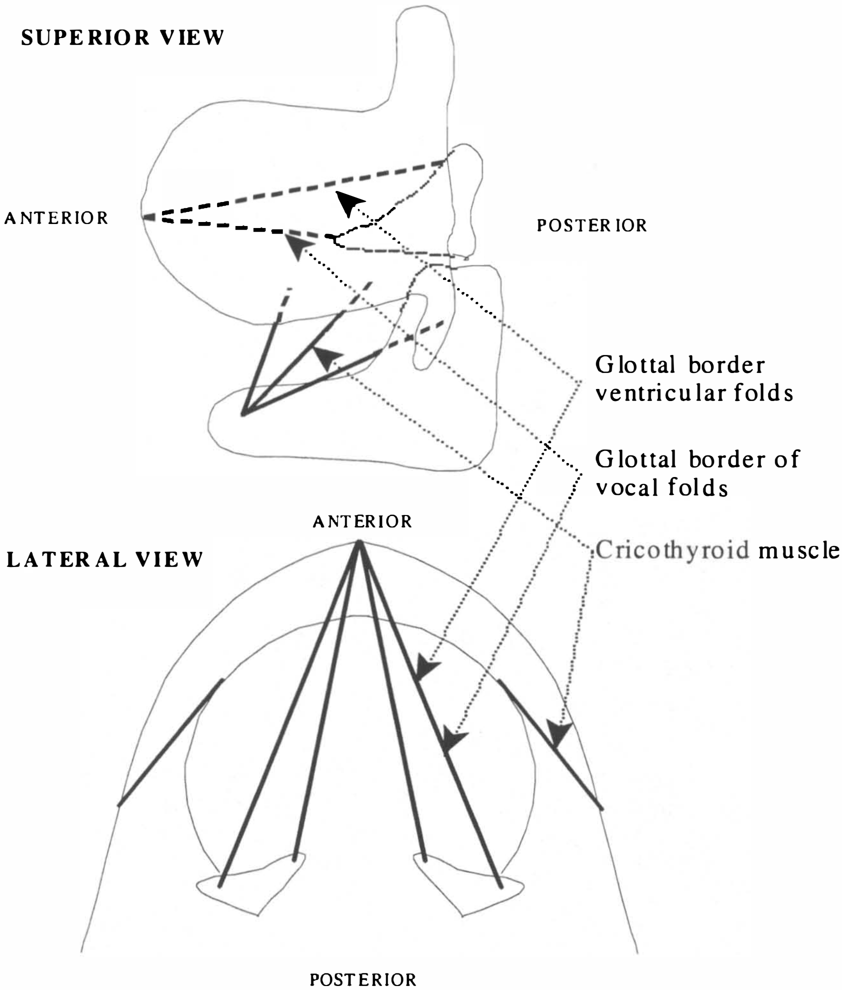

Figure 3-2: Schematic diagram of the function and location of the laryngeal muscles connecting the cricoid cartilage to the thyroid cartilage and related organs, in lateral and superior view. (After Laver 1980:100).

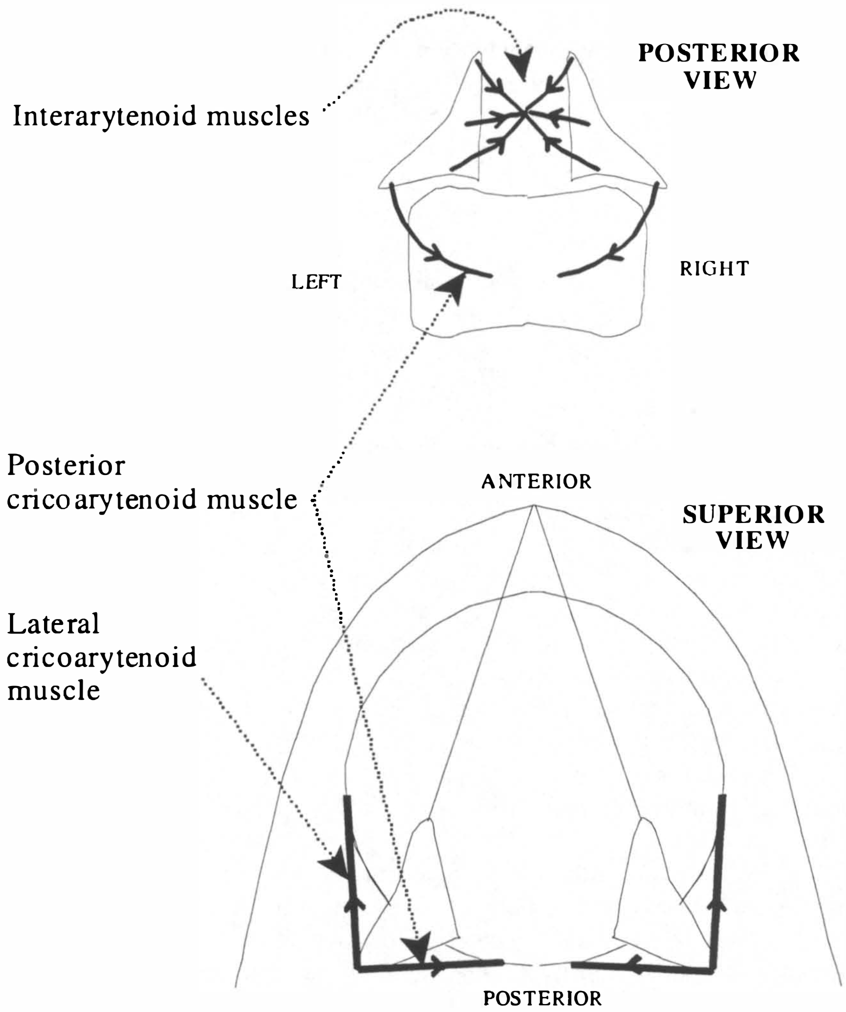

Figure 3-3: Schematic diagram of the function and location of the laryngeal muscles connecting the arytenoid cartilages to each other and to the cricoid cartilage, in posterior and superior view. (After Laver 1980: 100).

3.2 Phonation

A prerequisite of vocal fold vibration is the maintenance of a sufficient difference in air pressure between the sub- and supralaryngeal cavities. This transglottal pressure drop is the effective driving pressure from which all of the acoustic energy in the vocal signal is derived (Orlikoff and Kahane 1995:129). The transglottal pressure drop powers the movement of pulmonic air upwards through the glottis into the pharyngeal cavity. As the airstream passes through the narrowing of the glottis, its velocity increases as a function of the degree of constriction, since the overall flow rate is constant (given a constant driving pressure). An increase in velocity requires that more energy be converted to kinetic energy, which has the effect of reducing the static potential energy at the constriction, since the total energy in the system must remain constant. The reduction in potential energy translates into a negative pressure at the constriction, a phenomenon known as the Bernoulli effect (Catford 1977:32).

According to the myoelastic-aerodynamic theory of phonation, a cycle of vocal fold vibration is initiated when Bernoulli-generated suction causes the vocal folds to snap shut, only to be forced open again each time by the subsequent build-up of subglottal air pressure. Maintaining the cycle of vocal fold vibration depends on sufficiently high airflow, sufficient narrowing of the glottis to activate the Bernoulli effect, and sufficient compliance of the vocal folds to enable the Bernoulli-generated force to suck them together and the subglottal pressure to prise them open again.

In the myoelastic-aerodynamic theory of phonation, sustained vocal fold vibration depends on the preservation of an equilibrium of subglottal air pressure, and of vocal fold consistency and proximity. It is the balance of all three factors which enables phonation; the values of each one can vary provided the others adjust in compensation. Laver (1980:108) outlines three parameters of muscular tension within the larynx which control the last two factors. These are illustrated in Figure 3-4. Identifying the muscles which are responsible for these categories of laryngeal activity is for the most part straightforward. Adductive tension is brought about by contraction of the interarytenoid muscles. The opposite of adductive tension, namely abduction of the vocal folds, is brought about by contraction of the posterior cricothyroid muscle, the only abductor of the vocal folds (Hirose 1975). Longitudinal tension is understood to mean contraction of the vocalis muscle and/or of the cricothyroid muscles. Medial compression implies activity which closes the ligamental glottis but not necessarily the cartilaginous glottis also, principally by contraction of the lateral cricothyroid and thyroarytenoid muscles. These categories of laryngeal activity, their physiological implications and the muscles responsible are summarised in Table 3-1.

3.3 Phonation types

Using this framework, Laver (1980) defines four basic phonation types, namely modal voice, falsetto (not discussed here), whisper and creak.

In modal phonation, medial compression and adductive tension are moderate. Moderate longitudinal tension also may be added in the lower fundamental frequency range. Modal phonation is produced by vibration of the vocal folds along their entire length.

Creak is possible only in the lowest part of the range of fundamental frequencies of which a speaker is capable, occurring consistently below 70Hz, and normally between 50 and 25Hz (Marasek 1997:26). The laryngeal settings for creak are not fully understood

(Laver 1980:122–126), but it is thought to involve high adductive tension and medial compression combined with weak longitudinal tension.

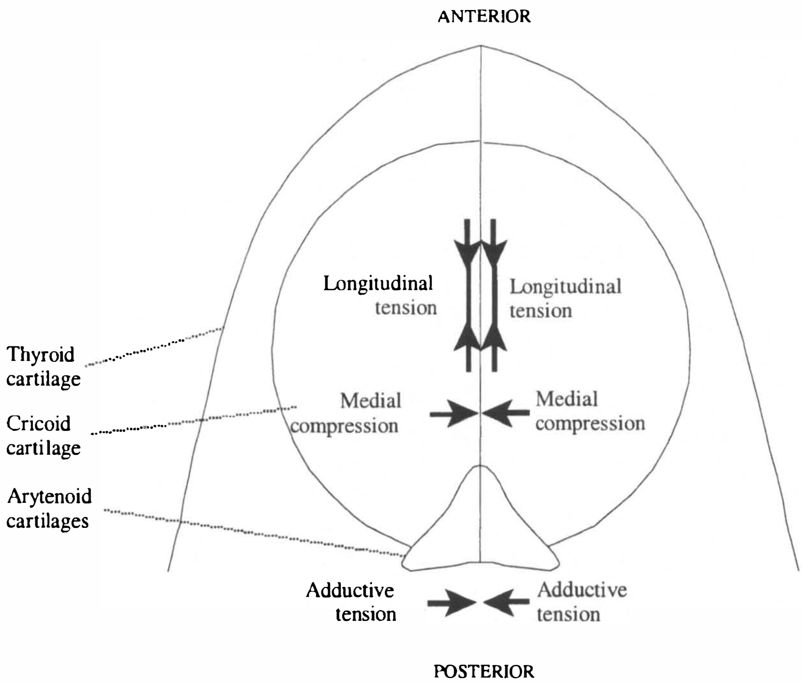

Figure 3-4: Laryngeal parameters in the articulatory description of phonation types. (After Laver 1980:109).

Table 3-1: Functions of intrinsic laryngeal muscles

parameter	*muscles*	*movement*
medial compression	lateral cricoarytenoid	brings together vocal processes of arytenoid cartilages
	thyroarytenoid	(reinforces same action by tensing vocal folds)
adductive tension	interarytenoid	pulls arytenoid cartilages together, closing cartilaginous glottis
longitudinal tension	vocalis	tenses vocal folds actively
	cricothyroid	stretches vocal folds longitudinally

Whisper (looked at in more detail in Section 6.5) involves low adductive tension and high medial and longitudinal tension: the cartilaginous glottis is open but the ligamental glottis is held tightly shut.

Tense and lax voice are additional settings which may be superimposed on any of the above. Tense voice involves a higher degree of tension in the entire vocal tract, all other things being equal; lax voice implies the opposite (Ní Chasaide and Gobl 1997:451).

These modifications may also be referred to as slack and stiff voice, respectively. Breathiness is another modification which can be applied to modal voice (Catford 1977:99; Laver 1980:139). Breathy voice involves minimal adductive tension and weak medial compression. Longitudinal tension is generally low, and may be varied for the purposes of varying fundamental frequency. There is leakage of air through the glottis even at the point of maximum vocal fold contact in the vibration cycle.

Since these basic phonation types are not, for the most part, mutually antagonistic in a physiological sense, a number of additional compound phonation types may be defined by combining them. For instance, creak is the basis of creaky voice. It has been suggested that the articulation of creaky voice may vary from speaker to speaker, but one possibility is the combination of modal phonation at the ligamental vocal folds with creak in the cartilaginous vocal folds (Laver 1980:139).

3.3.1 MEASURING PHONATION TYPES

Extracting information about activity in the larynx is made problematic by its inaccessible location. Studies of the larynx are, therefore, generally constrained by the methods of investigation available. Here, as in other areas of phonetic investigation, there is a trade-off between the ease of measurement or observation and the quality of the data thereby made available. In a comprehensive survey of phonation type measurement techniques, Marasek (1997) classifies the methods available as visual or indirect, with a third alternative: auditory evaluation by careful listening. The methods used in this study are introduced below; a broader survey of techniques may be found in Ní Chasaide and Gobl (1997) and Marasek (1997).

Investigation of laryngeal activity using acoustic techniques involves inferring information about the larynx from acoustic data in the form of sound spectra, or indirectly, by inverse filtering of the speech pressure wave. Information about the voice source is encoded in measurable changes in airflow through time, reflecting the opening and shutting cycles of the vibrating vocal folds.

In the source-filter model of speech production (Fant 1960), the acoustic output may be thought of as the combined output of the glottal source and the vocal tract filter function which is subsequently applied to it. It follows that information about the glottal source is present in the eventual output and may be investigated provided the subsequent shaping of the vocal tract filter may be somehow removed. Inverse filtering has the advantage of showing the glottal source in great detail, but the need to adjust the acoustic filter for each speech sample severely constrains the volume of data which can realistically be processed, and so definition in the time domain is sacrificed.

Sound spectra are an attractive choice of source material because they are easily acquired, but the task of deriving solid information about the laryngeal source underlying the spectrum is hampered by the filtering effect of the supralaryngeal vocal tract.

The low frequency region of the spectrum has been the focus of many studies of phonation type in languages because it may be measured from the unfiltered acoustic speech output (Bickley 1982; Kirk et al. 1984; Maddieson and Ladefoged 1985, Ladefoged et al. 1988). The measures used in this study involve comparing the amplitude on narrowband spectra of the fundamental and the second harmonic and of the dominant harmonic peak in the first formant with the fundamental, referred to as H2–H1 and F1–F0 respectively. Where the first harmonic, referred to as H1 or F0, is relatively more energetic compared to (though not necessarily of greater amplitude than) the first harmonic or the first formant peak, the phonation type can be said to be relatively breathier; when the reverse is true, the phonation type is relatively creakier.

The problems encountered in applying the H2–Hl and Fl–F0 measures to spectra representing a range of vowel qualities are discussed in Section 6.3.4.

Changes in phonation type which affect the damping characteristics of the glottal source are reflected as differences in spectral tilt, though obtaining objective measures of this is not easy (Jackson et al. 1985, 1986; Watkins 1997). Steeper spectral tilt is linked to breathy and lax phonation types with high levels of airflow; more gradual tilt with creaky and tense phonation types (Ní Chasaide and Gobl 1997). Jackson et al. (1985, 1986) made use of source spectra obtained by inverse filtering. Watkins (1997) and the present study make use of amplitude differences commonly observable in the higher region of the spectrum which are clearly visible, though not referred to explicitly, on the long term average spectra of phonation types produced in Ní Chasaide and Gobl (1997:448). A measure of this type is applied to the Wa data in Section 6.3.6.

Noise is an important component of the acoustic output of several phonation types, though one which is difficult to assess quantitatively (Ní Chasaide and Gobl 1997:441). Acoustically, there is little to distinguish breathiness noise from whisper noise (Laver 1980:133), since both involve an audible friction noise source resulting from the high airflow rate. In the type of voiceless whisper considered in Section 6.5, the fundamental is quite absent, though replaced by a frequency-specific noise source. In breathy voice the fundamental is not only present but dominant.

3.4 LARYNGOGRAPHY

The Fourcin laryngograph, an electroglottograph (EGG), described fully by Abberton et al. (1989) and Marasek (1997), is a simple and portable device which allows non-intrusive investigation of movement within the larynx.[14] Two electrodes are placed externally on the neck on either side of the thyroid cartilage as near as possible to the position of the vocal folds within. The resistance to the current passed between the electrodes changes as the vocal folds and other parts within the larynx vibrate or move. The changing resistance to the current which passes between the electrodes may be plotted graphically—the resulting image is known as the laryngograph waveform or *Lx*, illustrated in Figure 3-5.

The resistance to the current decreases as the surface area contact between the vocal folds increases, in a relationship which has been shown to be inversely proportional. The gruesome experiment carried out by Scherer et al. (1988, and references) found that the amplitude of the laryngograph waveform is very closely correlated to the area of vocal fold contact.

The laryngograph waveforms used in this study plot the current passing through the vocal folds, such that vocal fold closure is represented by a peak and no vocal fold contact by a trough. It is possible to plot instead the resistance to the current, such that the closed glottis, in which the resistance to the current is least, appears as the minimum, and the open glottis as a maximum.

Parameters may be extracted from the laryngograph waveform to approximate the same parameters of the glottal source wave; the parameter used in this study is closed quotient.

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[14] Further background reading on the function and structure of the larynx and vocal fold vibration may be found in: Laver (1980), Orlikoff and Kahane (1996) and Ní Chasaide and Gobl (1997).

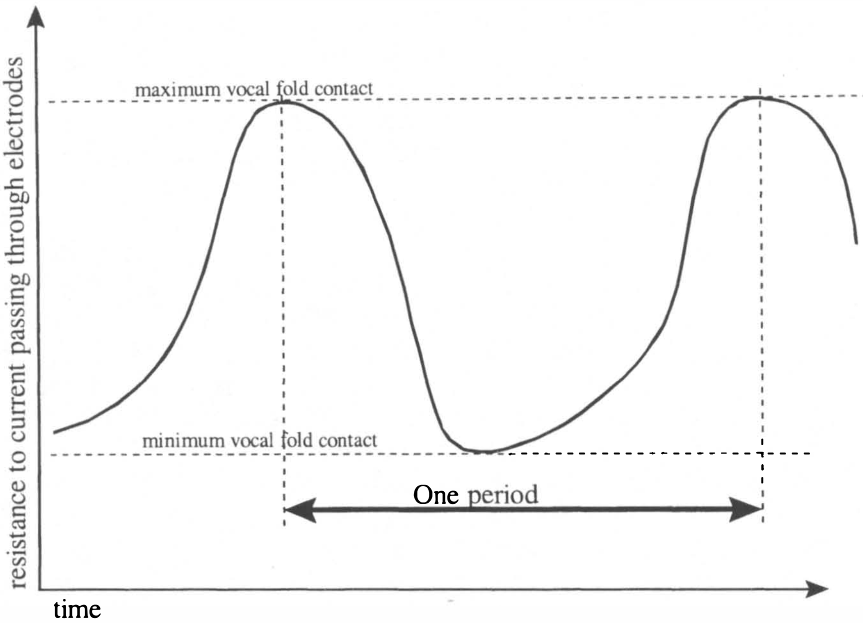
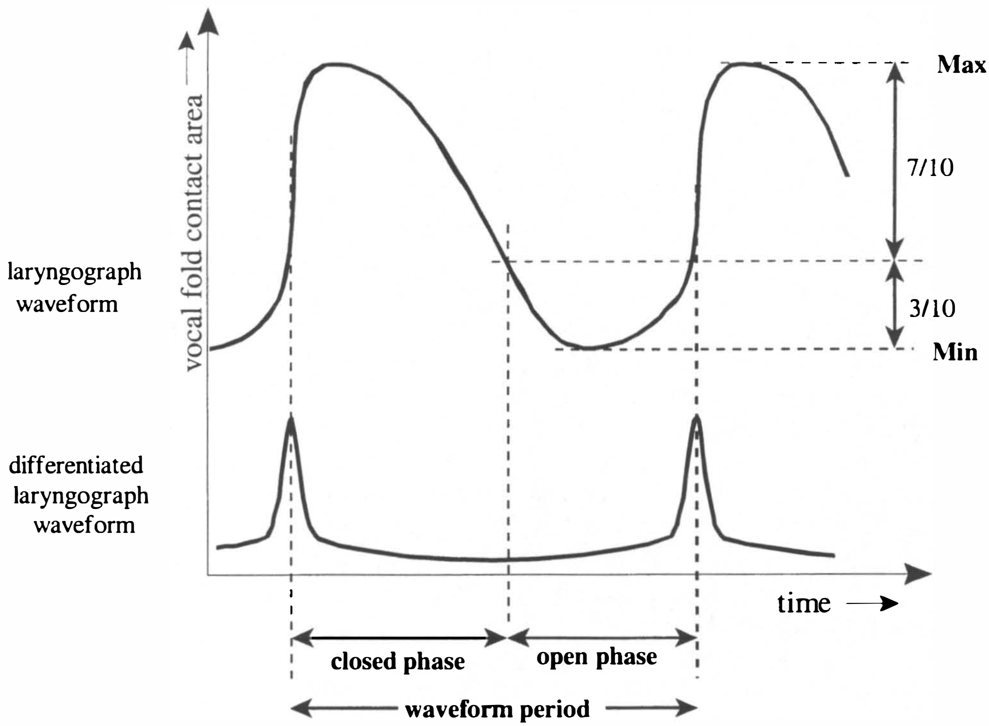


Figure 3-5: Stylised laryngograph waveform showing period of vocal fold vibration (T). The frequency f of the vibration is calculated as $f = (1/T)$.

3.4.1 CLOSED QUOTIENT (CQ)

Closed quotient has been used in the fields of speech pathology (Abberton et al. 1989) and other vocal research (Howard et al. 1990; Howard 1995), but less often in a linguistic context (see, however, Lindsey et al.1992, Marasek 1997). Closed quotient is defined as the portion of the waveform period T for which the glottis is closed, expressed as a percentage. This portion of each period is known accordingly as the *closed phase*, the remaining part of each cycle being the *open phase*. The method of closed quotient calculation outlined below is the method which the Laryngograph Analyser software package uses to derive closed quotient automatically from laryngograph data, period by period (see Figure 3-6). Other methods for calculating closed quotient are described in Howard (1995) and Marasek (1997). Several studies (e.g. Marasek 1997; Ní Chasaide and Gobl 1997) consider instead the Open Quotient, which is essentially the same measure expressed instead as the proportion of the waveform period taken up by the open phase.

It is generally true of vocal fold vibration that the closure is rapid, while the opening phase takes up more of the cycle (Orlikoff and Kahane 1995:142). The closure is observable on the laryngograph trace as the upward slope of each period of the waveform, representing the increase in vocal fold contact area from the first contact between the lower lips of the vocal folds to the point where maximal contact area is reached, the peak of the waveform. A sharply defined peak in the differentiated laryngograph waveform, representing the point at which the vocal fold area contact is increasing most rapidly, may be used to define the instant of closure. 'The closing edge of the Lx waveform is detected by a software algorithm based on detecting the main positive peaks in the differential' by the Laryngography Analyser software (D. Miller, Laryngograph Ltd, pers. comm.). This peak is also used by the computer to calculate the periodicity of the waveform, also used in this study.



$$\textbf{closed quotient} = \frac{\textbf{closed phase}}{\textbf{waveform period}}$$

Figure 3-6: Calculating closed quotient from the laryngograph waveform.

Given that the decrease in vocal fold contact takes place more gradually, and exhibits considerable variation, there is typically no consistently distinct minimum in the differentiated waveform. Furthermore, the open phase is the part of the vocal fold vibration cycle about which the laryngograph provides the least information. The end of the closed phase is defined as the point where the negative-going waveform crosses a threshold set at a fixed proportion of the overall peak-to-trough displacement, in this case the ratio is 7:3. This ratio, like the parameters involved in any of the methods for measuring CQ, is essentially arbitrary, but has been found convenient and reliable in previous studies using the Fourcin laryngograph (Davies et al. 1986). The aim of setting a threshold is to 'ensure freedom from waveform artefacts often associated with the EGG minimal contact phase' (Howard 1995:165).

Closed quotient increases in response to activity which causes the vocal folds to stay closed for more of the vibration cycle, in other words higher levels of all three parameters of Figure 3-4: adductive tension, medial compression and longitudinal tension. An inverse relationship between closed quotient and vocal fold abduction may be inferred from a study by Rothenberg and Mahsie (1988). Conversely, lower closed quotient is an indication of lower levels of these parameters. Ní Chasaide and Gobl (1997) attribute a high closed quotient to creaky and tense phonation and low closed quotient to breathy voice, and imply that a slight decrease in closed quotient is consistent with lax phonation. Ní Chasaide and Gobl (1997:440) find that closed quotient controls the lower components of the source spectrum, such that a lower closed quotient corresponds to an increased level of the very lowest harmonics of the source spectrum.

3.4.2 SOME PRACTICAL PROBLEMS WITH CLOSED QUOTIENT

Laryngographically derived closed quotient is found (see Section 6.3.5 below) to be an efficient means of quantifying the phonation type component of the register contrast. Breathy register phonation type has consistently lower closed quotient than clear register; the breathy phonation of aspiration has lower closed quotient still. These measurements map onto the phonation type continuum in a straightforward way, such that it might be tempting to use closed quotient as a direct index of phonation type. Unfortunately, this is problematic for two reasons.

Firstly, phonation type varies for many reasons besides its phonologically significant role in speech. Habitual phonation type may vary from speaker to speaker, as is evident in Figure 6-3, Figure 6-4 and Figure 6-11. Therefore, it would be as futile to attempt to define specific closed quotient levels for either of the registers as it would to attempt to define specific frequency levels for individual tones in a pitch-based tone language which would be valid for all speakers.

The second problem is that the consistent pairing of high closed quotient with creakier phonation type and lower closed quotient with breathier phonation type, in the sense of the phonation type continuum mentioned above, breaks down when applied to the creaky extremes of the phonation type continuum. This is certainly not because creaky phonation ceases to have an increased closed quotient beyond a certain level of creakiness, but rather because the algorithm used to calculate it by the computer (explained in 3.4.1) produces unpredictable results for creaky phonation. An example of this is the falling closed quotient contour of the last four periods of /ʔ/ (see Figure 6-41) Yet for two speakers, NKP and NT, /ʔ/ is associated consistently with a rising closed quotient contour.

3.5 ACOUSTIC ANALYSIS

The sound recordings were analysed using two computer software packages in the Phonetics Laboratory at the School of Oriental and African Studies:

- PCLx Laryngograph Analyser (version 3), by Laryngograph Ltd. (PCLx)
- Speech Workstation (version 3) by Loughborough Sound Images. (LSI)

The above software packages and the hardware used to run them constrained the volume of data which could be processed. Both the PCLx and LSI software packages allow imaging of acoustic data as speech pressure waveforms, sound spectra and sound spectrograms; the editing and file management capabilities of the two programs vary somewhat in graphic and data resolution, and speed of screen drawing and printing. The laryngograph recordings can be displayed alongside simultaneous acoustic data in both packages; PCLx allows fundamental frequency and closed quotient to be derived from the laryngograph trace and displayed simultaneously.

The original digital audio recordings were sampled into both programs as required. The sampling rates chosen depended largely on the task in hand. Files sampled at 12kHz were used for measuring formant frequencies, when irrelevant information about spectral profile above 6kHz was traded for enhanced resolution.

Information was derived from all three acoustic image types. PCLx and LSI both allow the effective bandwidth of sound spectra and spectrograms to be adjusted quickly and easily. This facility was taken advantage of to provide the optimum display for clarity of measurement.

4 Wa phonology

This section establishes the phonological contrasts which inform the subsequent phonetic analysis. This phonological analysis is supported by evidence from historical phonology, including a discussion of some alternative proposals.

4.1 PHONOLOGICAL OVERVIEW

4.1.1 PHONEME INVENTORY

The phonemic transcription and descriptive labels used throughout imply the values described in Table 4-1–Table 4-4. The phonemic transcription used here employs symbols with their IPA values (1993 revision), with the notable exception of /c j/ and /y/ and subject to certain other notational conventions outlined below. Where a phoneme has a range of allophones, that range of sounds includes the sound represented by the IPA value of the phoneme symbol used here. Phonemic transcription is placed in slant brackets / / throughout, except whole morphs, which are given in italics. Where sub-phonemic detail of any kind is included, transcription is given in square brackets [ ] and uses the IPA (1993 revision).

The phonemic analysis of Wa in this study draws on two existing accounts. The first was formulated by Chinese scholars: Zhōu and Yán (1984), and Wáng and Chén (1981). This analysis underpins the system of contrasts represented in the PRC orthography (see Section 7.2.3), with which it can function as an exact transliteration: each symbol of Zhōu and Yán's phoneme inventory has an exact correspondence in the PRC spelling system for Wa, in a one-to-one mapping relationship.

The second is Diffloth's interpretation of the PRC writing system, labelled 'Kawa' (Kăwă) in Diffloth (1980). This notation is guided by historical phonology rather than phonetic accuracy, and, in certain respects, makes evident the common historical origins of certain sounds in complementary distribution in a way which ignores much phonetic detail. Diffloth's analysis is discussed further in Section 4.2.4.

Table 4-1: Transcription of consonants

			bilabial		*dentalveolar*		*palatal*		*velar*		*glottal*
Stop	*plosive*	*voiceless*	p	p^h	t	t^h	c	c^h	k	k^h	ʔ
		Voiced	^{m}b	$^{m}b^{h}$	^{n}d	$^{n}d^{h}$	^{ɲ}j	^{ɲ}jh	^{ŋ}g	$^{ŋ}g^{h}$	
	Nasal		m	m^h	n	n^h	ɲ	$ɲ^h$	ŋ	$ŋ^h$	

Table 4-1: *Continued*

		labio-dental		*alveolar*		*palatal*		*glottal*
Fricative	*voiceless*			s				h
	Voiced	v	v^h					
approximant	*median*			r	r^h	y	y^h	
	Lateral			l	l^h			

Table 4-2: Transcription of vowels

	front	*back*	
	unrounded		*rounded*
Close	i	ɯ	u
mid-close	e	ɤ	o
mid-open	ɛ		ɔ
Open		a	

Table 4-3: Transcription of polyphthongs

diphthongs			*triphthongs*
iu	ɯi	ui	iau
ia	ɤi	ua	uai
ei		ou	
		oi ɔi	
ai	aɯ	au	

Table 4-4: Transcription of register

clear	*breathy*
V	V̤

4.1.2 NOTATIONAL CONVENTIONS

PALATAL STOPS

/c ɟ/

These symbols were chosen for their general prevalence in South East Asian linguistic literature. The alternative transcriptions are the IPA symbols for post-alveolar and alveolo-palatal affricates /tʃ dʒ/ and /tɕ dʑ/ respectively. /c/ may be realised as one of a range of allophones, not all of which are affricates. The IPA affricate symbols are avoided because it would be inaccurate to transcribe an unreleased final palatal stop [c˺] as /tʃ/ or /tɕ/.

PALATAL APPROXIMANTS

/y yʰ/

The Wa palatal approximants are transcribed here as /y/, as the IPA palatal approximant symbol [j] having been used for the voiced palatal stops already,

LABIO-DENTAL FRICATIVE

/v vʰ/

/v/ occurs as an initial consonant only. An alternative analysis of Wa consonants in which /v/ is in complementary distribution with a labial-velar glide /w/ is considered in Section 4.2.4.

4.1.3 ASPIRATION

Where pairs of consonants in Table 5.1 share the same place of articulation, they appear in unaspirated (left) and aspirated (right) pairs. A single symbol (superscript /ʰ/) is used to indicate aspiration of all consonants. The phonetic detail of aspirated plosives, nasals, liquids and glides is examined in Section 0. Aspiration and segmental /h/ seem to be articulated with a similar laryngeal gesture, though the acoustic correlates of aspiration may vary. /ʰ/ may be represented acoustically by either pulsed breathy-voiced aspiration [ɦ] or voiceless cavity friction aspiration [h], or indicate that a continuant is wholly or partially voiceless and/or breathy-voiced and/or followed by [ɦ] or [h]. Phonetic variation in the realisation of aspiration is more a matter of free variation and/or speaker preference rather than allophonic variation with a conditioned distribution.

4.1.4 VOICING OF PLOSIVES

Voicing of plosives is represented by a voiced plosive symbol preceded by a superscript homorganic nasal symbol: /ᵐb ⁿd ᶮɟ ᵑg/, reflecting the fact that voicing implies both prenasalisation and uninterrupted voicing throughout the stop in a majority of cases. The prenasalisation is homorganic with the plosive in all cases. The phonetic detail of plosive voicing varies a great deal, as described in Section 5.2.2.

4.1.5 DIPHTHONGS

Phonological and historical arguments for an analysis which recognises five phonologically unitary diphthongs in Wa are given below in Section 4.2.4. The number of

Wa diphthongs listed in Chinese analyses is unusually large in the context of Maddieson's (1984:133) cross-linguistic survey, but their accounts include phonetic detail freely, such that any vocoid with changing vowel quality is eligible for their diphthong inventories, but the phonemic status of the diphthongs is not addressed. The number of possible diphthongs is calculated as fourteen (plus two triphthongs) by Zhōu and Yán (1984) and as seventeen (plus two triphthongs) by Wáng and Chén (1981). The additional items are diphthongs found only in Chinese loanwords. Two items judged to be diphthongs by Zhōu and Yán were excluded from this investigation. The rising diphthong [iɛ], which occurs in open syllables only after palatal initials, is judged to consist of a monophthong /ɛ/ preceded by a transitional palatal glide (see Section 5.2.1). The centring diphthong [ɛə] is a possible variant of /ia/ or /ɛ/ before velar finals only.

4.1.6 REGISTER

The register contrast is a suprasegmental feature which is not confined to vocalic segments. The domain of the register contrast is the syllable, so it is not confined to vocalic segments and may be detected in adjacent sonorants, as demonstrated by the coarticulatory data in Section 6.7. Breathy register is transcribed using the IPA breathy phonation diacritic [̤] underneath the first vowel symbol of the syllable in which it occurs. The phonation types observed in clear register and in syllables with aspirated or glottal consonant initials, in which no phonological register contrast obtains, are arguably phonetically distinct (see Section 6.7), but both are unmarked in this phonemic transcription.

4.1.7 SYLLABLE STRUCTURE

The Chinese analysts (Zhōu and Yán 1984; Wáng and Chén 1981) describe the segmental tier of the Wa syllable as a two-element object with an initial and a final, following the *fǎnqiè* template which is used to describe the phonological structure of Chinese syllables in the Tāng dynasty Chinese rhyme dictionaries (Norman 1988:24). According to the Chinese accounts, a Wa syllable must comprise an initial, a final and a register specification. The initial consists of one or two consonants; the final of at least one and up to three vowels plus an optional final consonant. This structure may be expressed as in Table 4-5.

Table 4-5: Chinese analysis of Wa syllable structure (ignoring register). Optional elements are in parentheses (Wáng and Chén 1981:40)

Initial	*final*
C_1 (C_2)	(V_1) V_2 (V_3) (C_3)

In this framework, C_1 is unrestricted but C_2 is exclusively /r/ or /l/. The final consonant C_3 may be a stop (see Section 5.2.4), nasal or either of /ʔ/ or /h/ (Section 5.3). The three vowel slots enable the formula to generate an overabundance of diphthongs and triphthongs. Zhōu and Yán (1984:11) point out that in practice, syllables with three vocalic elements are rare. The only possible triphthongs are /uai/ and /iau/. A more tightly constrained model of syllable structure is considered in Section 4.2.4.

The register contrast is termed 'tense' (*jǐn* 紧) and 'lax' (*sōng* 松) in the Chinese tradition. Syllables with initial aspirates or laryngeal consonants in which the register contrast does not apply are referred to as 'secondarily tense' (*cìjǐn* 次紧).

4.2 HISTORICAL PHONOLOGY

The phonological reconstructions used as historical evidence in this section are from a single source: Diffloth (1980). Additional standard Wa cognates for items in Diffloth's etymological lexicon are supplied from other sources (chiefly Yán et al. 1981) where necessary. Diffloth's work on historical phonology is more concerned with the process of phonological change through time than with synchronic phonetic description. Much of his reconstruction is based on crude descriptions of languages from which he has had to interpret the likely phonetic details. The following section makes substantial use of his reconstructions of Proto Waic, which are marked PW* throughout the section below.

4.2.1 MON-KHMER SESQUISYLLABICITY AND HISTORICAL MORPHOLOGY

Henderson's (1952) description of the phonological structure of Khmer shows how monosyllables may be augmented by morphological affixation. She defines the three Khmer structural types illustrated in Table 4-6. The initial element of the 'simple monosyllable' is described as 'extensile', yielding an 'extended monosyllable', or may have a 'minor syllable' added to it, yielding a 'minor disyllable'. The minor syllable, a fourth structural type, is a syllable with restricted variation.

Table 4-6: Khmer morphology and syllable types (from Henderson 1952:150–151)

simple monosyllable	ចាំ	/cam/	'await, keep watch'
	កើត	/kaɤt/	'be born, grow'
	ដេក	/de:k/	'sleep'
extended monosyllable	ប្រចាំ	/prə̱cam/	'watch one another'
	ខ្នើត	/kẖnaɤt/	'waxing of moon'
	ផ្ដេក	/p̱hde:k/	'put to bed'
minor disyllable	បង្ចាំ	/bɔ̱ŋcam/	'to pledge'
	បង្កើត	/bɔ̱ŋkaɤt/	'give birth'
	បន្ដេក	/bɔ̱ŋde:k/	'go to bed'

The beginning of the Mon-Khmer extended monosyllable is morphologically complex, the remains of a morphologically rich disyllabic stage of Proto Mon-Khmer (Diffloth 1980). A similar pattern can be observed in a broad range of Mon-Khmer languages, including Northern Mon-Khmer (see Shorto 1963 on Palaung and Riang-Lang; Svantesson 1983a on Kammu), where a syllable may have a prefix with a restricted structure added to it. This bulging syllable, neither monosyllabic nor disyllabic, has been called a sesquisyllable by Matisoff (1973), a term which captures the structure's intermediate status. Sesquisyllabicity encompasses Henderson's extended monosyllables and minor disyllables in Khmer. The part which is added on to the monosyllable is referred to here as a presyllable.

Within Northern Mon-Khmer, presyllables survive in varying stages of decay. In Wa the morphological system of prefixation has all but disappeared, leaving only a few prefixes which cover a broad, ill-defined range of functions. Wáng and Chén describe Wa sesquisyllabicity in terms of a 'typical syllable' and an 'appended syllable' (Wáng and Chén 1981:40). With only a few exceptions, a single presyllable survives in Wa, transcribed here as /s./.

> In Praok [Wa], si- probably results from the generalization in almost all prefixial contexts of a prefix which originally corresponded to those with an initial s- in the other two languages [Palaung and Riang-Lang]. (Shorto 1963:55)

Shorto proposes that Wa /s./ may be a vestige of a prefix *siC-, where the second consonant C may be a stop. The second consonant of this prefix, or the single consonant of the other Wa prefixes /^{m}b/- and /^{ŋ}g/- which he describes, is preserved only when the initial consonant of the host syllable is /r/ or /l/, permitting the formation of a morphologically complex consonant cluster. The prefixes /^{m}b/- and /^{ŋ}g/- cannot form any other clusters: if they are prefixed to a morpheme with any other initial consonant, the stops are deleted, leaving behind only their voicing. Illustrative examples of these vestiges of Wa affixational morphology are given in Table 4-7.

Table 4-7: Morphological processes in Wa (data from Wáng and Chén 1984)

a. /^{ŋ}g/ prefixation and cluster formation

lah	> ^{ŋ}*glah*	'six'	> 'sixty'
laŋ	> ^{ŋ}*glaŋ*	'long'	> 'length; this long'
rauɯʔ	> ^{ŋ}*grauɯʔ*	'deep'	> 'depth'; 'this deep'

b. Voicing of initial stop

pṳ	> ^{m}*bṳ*	'thick'	> 'thickness; this thick'
ti̤ŋ	> ^{n}*di̤ŋ*	'big'	> 'size'; 'this big'

c. /s./ prefixation and voicing of stop

kiap	> *s.*^{ŋ}*giap*	'pinch' (v.)	> 'clip' (n.)

Whatever their provenance, these morphological processes involving alternation of voiceless and voiced plosives are not productive in the modern language. The morphological processes in Table 4-7 which entail the voicing of an initial stop can only be described as the replacement of one (voiceless) phoneme by another (voiced) one, rather than as the addition of a prefix. The integrity of voiced plosives as single phonemes, despite their complex phonetic structure, is not in question. Additionally, /s./ may occur in some words as an optional and morphologically redundant prefix, as in Table 4-8. The surface phonetic realisation of /s./ is described and discussed further in Section 5.4.1.

Table 4-8: Morphologically redundant /s./ prefixation

^{n}daiʔ ~ s.^{n}daiʔ	'eight'
^{ŋ}gaɯʔ ~ s.^{ŋ}gaɯʔ	'happy'

The analysis of /s./ as a presyllable rather than a cluster-forming consonant is suggested by a number of facts, though we might expect the presyllable-syllable sequence (or sesquisyllabic structure) simply because it is widely observed in Mon-Khmer languages. Within Wa this structure is not restricted to the /s./ presyllable. In addition to a very small number of lexical items with presyllables other than /s./, the sesquisyllabic structure is observed when the first element of a bisyllabic (often reduplicative) sequence is reduced, undergoing a phonological simplification in the process. Reduction of this kind tends towards a consonant + indeterminate vowel, or maximally to the /s./ presyllable, pronounced with or without an epenthetic vowel, as in Table 4-9. An epenthetic vowel may be present between presyllable and main syllable in the resulting sesquisyllable, the nature of which is examined in Section 5.4.1.

Table 4-9: Reduction of bisyllables to sesquisyllables.
Data from Wáng and Chén (1981)

su so	> [su.so] ~ [sə.so] ~ [s^{j}.so] ~ [s.so]	'muddled up'
ci kua	> [tɕi.kwa] ~ [ɕi.kwa] ~ [s^{j}.kwa]~ [s.kwa]	'smallpox'
^{ɲ}ja̤ ra̤h	> [^{n}dʑa̤.ra̤h] ~ [^{n}dʑi̤.ra̤h] ~ [tɕi̤.ra̤h] ~ [s^{j}.ra̤h] ~ [s.ra̤h]	'frog'

The difference in phonological structure between sesquisyllables and monosyllables with initial consonant clusters is also evident from the fact that the two can occur together in single lexical items, with a morphologically complex provenance, as in Table 5.10.

Table 4-10: /s./ presyllables in conjunction with initial consonant clusters

s.^{m}blap	'strike, kick'
s.prih	'chapped'
s.^{ŋ}g^{h}rah	'rinse'
s.^{ŋ}glɯ̤ik	'urge, hasten'

The sesquisyllabic structure supports the status of the glottal stop as an independent initial consonant phoneme. Firstly, in Proto Waic (Diffloth 1980) and elsewhere in Mon-Khmer, glottal stops occur freely as first or second item in initial clusters. Glottal stops as the first item in Proto Waic clusters have disappeared in Wa in all cases, though their presence before sonorants played a role in the subsequent development of register. As the second item in Proto Waic clusters, however, glottal stops survive in Wa. But if no Proto Waic initial consonant survives, an initial glottal stop is supplied in Wa. If the first item in Proto Waic cluster survives as an /s./ presyllable, then the glottal stop's phonemic status is clear, since /s.ʔ/- is distinct from a simple /s/- initial. Relevant examples are given in Table 4-11.

Table 4-11: /s./ presyllables contrasted with initial /s/-

/s./ presyllables			initial /s/-		
PW*sʔaŋ	> Wa *s.ʔaŋ* [sʲ.ʔaŋ]	'bone'	PW*??	> *saŋ* [saŋ]	'want, will'
PW*sʔur	> Wa *s.ʔu* [sʲ.ʔu]	'warm'	PW*??	> *su* [su]	'intentionally'
PW*??	> Wa *s.ʔut* [sʲ.ʔut]	'swollen, ill'	PW*sut	> *sut* [sut]	'pick up'
PW*??	> Wa *s.ʔoʔ* [sʲ.ʔoʔ]	'rubber'	PW*soʔ	> *soʔ* [soʔ]	'dog'

4.2.2 DIACHRONIC DEVELOPMENT OF REGISTER AND VOICING CONTRASTS

The development of the register contrast, 'registrogenesis', shares much in common with the wider phenomenon of tonogenesis, the phonologisation of allophonic variations in fundamental frequency. In the most commonly attested model of tonogenesis, the allophonic variation in vowel fundamental frequency is brought about by phonetic perturbations of vowel onset fundamental frequency conditioned by voicing in initial consonants (Hombert et al. 1979). This process is attested in a great many languages in South East Asia (Matisoff 1973, Maran 1973, Henderson 1982).

The same mechanism is generally held to be responsible for the development of Mon-Khmer register, including the register dimension of the Vietnamese tonal system (Haudricourt 1954), though it is by no means the only mechanism attested in the region. Svantesson (1989) has shown that within Northern Mon-Khmer there are three mechanisms which have given rise to tones and registers. This begs the question: if the tone generating mechanism is the same, why does it produce register in Mon-Khmer and tone elsewhere? Matisoff (1973) offers the attractive explanation that the sesquisyllabic structure of Mon-Khmer languages makes them inherently 'register-prone'. He posits that the sesquisyllabic structure is intermediate between a hypothetically 'tone-prone' monosyllabic structure, in which the robustness of phonemic contrasts is threatened by the breakdown of initial and final consonants and so shifts the burden of contrast to formerly allophonic and phonologically redundant suprasegmental variation, and a 'tone-free' polysyllabic structure, in which the unrestricted combination of consonants and vowels leaves sufficient scope for maintaining phonological contrasts through combinations of segments without the need for suprasegmental tones.

In Diffloth's (1980) account, the loss of the Proto Waic voiced/voiceless contrast in stops gave rise to clear and breathy registers. An analogous process took place with sonorants, in which plain sonorant initials, inherently voiced, developed breathy register. Clear register sonorants in Wa are the reflexes of earlier /ʔ/+sonorant clusters. Examples of both processes are shown in Table 4-12.

Table 4-12: Diachronic development of register

a. Development of register from loss of Proto Waic stop voicing contrast

PW*voiceless stop > voiceless initial, clear register

*kɔn	> *kɔn*	'child'
*cak	> *cak*	'deer'
*tiʔ	> *taɯʔ*	'vegetable'
*pon	> *pon*	'four'

PW*voiced stop > voiceless stop, breathy register

*gat	> *kɛ̤t*	'much'
*joŋ	> *ca̤uŋ*	'foot'
*day	> *ta̤i*	'flower'
*bon	> *po̤n*	'able to'

b. Development of register in syllables with initial sonorants.

PW*ʔ + sonorant > sonorant, clear register

*ʔmoŋ	> *mauŋ*	'look up'
*ʔmɔʔ	> *moʔ*	'hide'
*ʔŋar	> *ŋa*	'twenty'
*ʔyoŋ	> *yauŋ*	'village'
*ʔlɔŋ	> *lɔŋ*	'coffin'

PW*sonorant > sonorant, breathy register

*maʔ	> *mɛ̤ʔ*	'mother'
*ɲaʔ	> *ɲɛ̤ʔ*	'house'
*ŋɔk	> *ŋɔ̤k*	'neck'
*yoʔ	> *ya̤uʔ*	'see'
*lɒŋ	> *lṳŋ*	'black'
*wah	> *vɛ̤h*	'wide'

As stated above, the register contrast does not apply in syllables with aspirated initials, be they stops or sonorants. Svantesson's (1983a) account of Kammu phonology shows that the distribution of Kammu tone is similar to that of Wa register, in that high and low tone do not contrast after aspirated initials. This distribution may be accounted for by the fact that aspiration, both in stops and sonorants, existed in Proto-Waic in the form of clusters with *h which were unaffected as registrogenesis progressed. The relevant examples of stops are few but convincing, but more abundant data are provided for aspirated sonorants. The roles of *ʔ in conditioning clear register and *h in blocking registrogenesis explain why the register contrast is similarly neutralised after initial laryngeal consonants /ʔ/ and /h/. Examples are given in Table 4-13.

Table 4-13: Diachronic development of aspiration in stops and sonorants

PW*voiceless initial + h > voiceless aspirated initial

*k^{h}oʔ	> *k^{h}auʔ*	'tree'
*k^{h}iʔ	> *k^{h}iʔ*	'month'
*k^{h}oc	> *k^{h}oc*	'wash self'
*p^{h}ɒn	> *p^{h}uan*	'five'
*p^{h}ɤm	> *p^{h}um*	'fart'

PW*(nasal + voiceless initial + h) > voiced aspirated initial
Unaccountably absent from Diffloth (1980)

PW*h + voiced initial > aspirated sonorant initial

*hlaʔ	> *l^{h}aʔ*	'leaf'
*hloŋ	> *l^{h}auŋ*	'high'
*hwaʔ	> *v^{h}aʔ*	'leaf monkey'
*hmɒm	> *m^{h}ɔm*	'good'

Voicing of initial voiceless stops in Wa may arguably occur as an independent morpheme of uncertain origin, and with a variety of functions, in some cases as a remnant of the voiced consonant prefixes discussed earlier (Shorto 1963). The morphological origin of prefixed words, such as *^{ŋ}goi* 'lizard' or *^{n}dai* 'skirt' in Table 4-14, is transparent but not productive in the language. Voiced stops also occur in lexical items which cannot possibly be considered morphologically complex in a synchronic analysis, for example 'lizard' and 'skirt' in Table 4-14. However, there is abundant evidence in Diffloth's (1980) reconstruction of Proto Waic that some voiced stops in Wa are the reflexes of Proto Waic etyma which are apparently morphologically unanalysable but also phonologically complex with a sequence of initial homorganic nasal segments.

Table 4-14: Development of stop voicing

PW*(nasal + voiceless initial) > voiced initial + clear register

*(ʔ)ŋkoy	*^{ŋ}goi*	'lizard'
*ntay	*^{n}dai*	'skirt'

PW*(nasal + voiced initial) > voiced initial + breathy register

*ŋgɒl(ʔr)	*^{ŋ}gṳ*	'cut down'

Diffloth (1980) fails to reconstruct any Wa voiced aspirate initials, though there is no reason to suspect that they should not be have been present in Proto Waic in the form of *(nasal + stop + h) clusters. Nasal segments preceding stops were seemingly unaffected as registrogenesis and associated phonological changes took place; presumably a nasal would be similarly unaffected by the presence of *h following a stop in a *(nasal + stop + h) cluster.

How best to represent voicing in the phonological inventory of the modem language is not straightforward. Diffloth (1980:35) asserts that: 'Nowhere do we find in the present-day languages an actual voiced vs voiceless distinction preserved in the initial stops.' Diffloth prefers to transcribe the voiced stops as nasal + voiceless stop: 'mp nt ɲc ŋk', while the Chinese scholars transcribe the same sounds using the phonetic symbols for voiced stops /b d dʑ g/, mentioning prenasalisation as phonetic detail (Zhōu and Yán 1984:8–9). The phonetic evidence, presented in Section 5.2.2, supports both approaches. One the one hand, voiced unaspirated alveolar stops which are realised phonetically as [d] are quite unsegmentable. On the other hand, if they surface as [nt] they appear to be cleanly divisible into two acoustically and articulatorily discrete components: [n] + [t]. However, this is not the whole story, since there are two further possibilities: [nd] and [dt]. The current analysis chooses to represent the prenasalisation, and hence the phonetic segmentability, of the most common surface phonetic representation of voiced stops and their phonologically complex origins in transcribing them as /^{m}b ^{n}d ^{ɲ}j ^{ŋ}g/ rather than /b d j g/.

4.2.3 DIACHRONIC DEVELOPMENT OF DIPHTHONGS

The phonetic structure of the diphthongs of Wa is surveyed in Section 5.1.4. Here, the phonological status of diphthongs is considered. Evidence from Mon-Khmer historical phonology supports the inclusion of five phonologically unitary diphthongs in the phoneme inventory of Wa, shown in Table 4-15, which are the reflexes of Proto Waic monophthongs. There are no diphthongs in the Proto Waic vowel system reconstructed by Diffloth (1980:37), although vowels with changing quality were present in the form of vowel-glide sequences.

Table 4-15: Diphthongs in Wa derived from Proto Waic monophthongs

	unrounded		rounded
rising	ia		ua
falling	ai	aɯ	au

The development of a number of diphthongs in the Khmer vowel system was conditioned by the register contrast. Diffloth (1980:37) suggests that vowel diphthongisation conditioned by register may be a generally observable phenomenon which does not take place with tones.

He goes on to highlight parallels between the diachronic diphthongisation of vowels in Khmer and in Wa, and stresses that these are innovations which occurred independently in Khmer and Wa. Register is a conditioning factor in two diphthongising processes:

a. open vowels in breathy register (Khmer 2nd register) become rising[15] diphthongs with on-glides of closer vowel quality;

[15] See section 5.1.4 for discussion of 'rising' and 'falling' diphthongs.

b. non-open vowels in clear register (Khmer 1st register) become falling diphthongs with off-glides of closer vowel quality.

In Khmer, these changes have taken place since the introduction of the writing system, so that in the modern written language the same vowel symbol is read differently according to the registral properties of the preceding consonant (Henderson 1952; Huffman 1970). Examples are given in Table 4-16.

Table 4-16: Diphthongisation conditioned by register in Khmer (data from Henderson (1952))

	1st register					2nd register			
a.	*a: / *a >	[a:]	ហាម	/ha:m/	'prohibit'	[ic]	មាន	/miən/	'have'
	*a + stop >	[a]	កាប់	/kap/	'cut'	[e]	ពាក់	/pek/	'wear'
b.	*o >	[ao]	តោង	/taoŋ/	'clutch'	[o:]	រោម	/ro:m/	'surround'
	*ə: >	[aə]	ហើយ	/haəj/	'already'	[ə:]	ឃើញ	/kʰə:ɲ/	'see'

Unlike Wa, the earlier stage of Khmer envisaged by Diffloth had long and short vowels which developed into separate diphthongs. In Wa, the same diphthongs are in complementary distribution in open and closed syllables which have subsequently developed in the language since the loss of certain final liquid consonants and are conditioned additionally by the place of articulation of final consonants. Examples of diphthongisation in Wa are given in Table 4-17.

Table 4-17: Diphthongisation conditioned by register and final consonant in Wa

	clear register	*breathy register*
PW*a (usually) before velars >		
	/a/	/i̤a/ ([i̤ɛ]~[ɛə̤])
	laŋ 'long'	*t̤i̤ak* 'jungle'
		k̤i̤at (also *k̤ɛ̤t*) 'very'
PW*a elsewhere >		
	/a/	/ɛ̤/
	ma 'field'	*s.mɛ̤* 'seed'
PW*o before velars, laryngeals and lost PW*-l >		
	/au/	/a̤u/
	hauk 'go up'	*ca̤uŋ* 'leg'
	pauʔ 'each other'	*ᵐga̤uh* 'peck'
	kau 'ten'	

Table 4-17: *Continued*

PW*o elsewhere >		
	/o/	/o̤/
	ʔot 'be located'	*^{m}bo̤* (<PW*bor)
PW*ə before velars, laryngeals and lost PW*-l >		
	/aɯ/	/a̤ɯ/
	haɯk 'hair'	*kra̤ɯŋ* 'clothes'
	kaɯʔ 'body'	*ɲa̤ɯʔ* 'drink'
	paɯ 'grey' (<PW*pəl)	*ma̤ɯ* (<PW*məl)
PW*ə elsewhere >		
	/ɯ/	/ɯ̤/
	ʔɯn 'put'	*cɯ̤m* 'peas'

Other diphthongisation processes, in which the register contrast is not involved, do not pattern so neatly, but are nonetheless derived from earlier monophthongs. PW*e yields a falling diphthong /ai/ before velars and PW*-ʔ in both registers; PW*ɛ yields a rising diphthong /ia/ in most contexts, providing the only instances of this diphthong in clear register. For reasons which are unclear, PW*ɒ yields a variety of back vowel reflexes in both registers, though predominantly /ṳ/ in breathy register. Diffloth's (1980:67) partial explanation is that it must have diphthongised to *uə at a late stage of Proto Waic.

Table 4-18: Various diphthongisation processes affecting Proto Wa vowels

PW*ɛ (no specific context) >			
	/ia/	*ʔiak*	'small'
		^{m}gian	'finger'
	/a/	*l̤iah*	'six'
		t̤iam	'low'
PW*e (before velars and -PW*ʔ) >			
	/ai/	*taiʔ*	'hand'
		kaiŋ > kaɲ †	'head'
	/i/	*ŋa̤ɪʔ*	'day'
		ka̤iŋ > kaɲ †	'work'

Table 4-18: *Continued*

PW*ɒ (no specific context)			
> diphthongs	/ua/	*kuat*	'cold'
	/ṳa/	*kṳat*	'old'
> monophthongs	/o/	*s.ʔoh*	'dry'
	/ṳ/	*ŋṳ*	'fire'
		yṳh	'do'

* See Section 4.2.4 for an explanation of this reanalysis.

4.2.4 PHONOLOGICAL STRUCTURE OF DIPHTHONGS IN DIACHRONIC PERSPECTIVE

We have evidence that five, namely those listed above in Table 4-15, of the fifteen diphthongs and triphthongs are derived from single Proto Waic monophthongs. What, then, of the remaining ten diphthongs? The total absence of diphthongs and vowel clusters in Diffloth's reconstructed Proto Waic suggests that they have not arisen from sequences of monophthongs. Rather, the historical evidence points to an analysis of the remaining diphthongs using only the nine monophthongs in the phoneme inventory in combination with consonants.

Such an analysis is possible by ignoring surface phonetic detail and relaxing the distributional constraints on certain initial consonants. All the phonemic contrasts of the language can be expressed in terms of the consonant elements in Table 4-19, the nine monophthongal vowels and the five 'true' diphthongs, that is, those which evolved from monophthongs by means of a diachronic process of diphthongisation.

Elements in this system are placed between straight lines | | to avoid confusion with the working transcription of Table 5.1. This system of contrasts in this arrangement is the same as that in Diffloth's (1980) phonemic analysis of Wa.

Table 4-19: A representation of the phonemic contrasts in Diffloth (1980)

Consonants

	labial	*alveolar*	*palatal*	*velar*	*glottal*
plosive	p	t	c	k	ʔ
nasal	m	n	ɲ	ŋ	
fricative	w	s			h
approximant			l r	y	

Consonant modifications

Aspiration	^{h}
voicing	^{n}

Aspiration and voicing may be represented as two bound elements $|^h|$ and $|^n|$, with certain distributional constraints. $|^n|$ may only precede plosives, and is homorganic with the partner consonant it is bound to. |^{h}| may not follow |s| or either of the glottal consonants |h| or |ʔ|.

A single element |w| can be posited to replace /v/ and /w/. This seems uncontroversial, given that the two /v/ and /w/ are in complementary distribution and that free variation between allophones of this kind [v]~[w] is not unusual in Asian languages, for example Khmer and Běijīng Chinese. As an initial consonant in the guise of /v/, |w| patterns like /y/ and the two liquids /l r/ in being susceptible to aspiration. In other contexts, |w| as /w/ mirrors the distribution of |y| as a glide (see Table 4-21).

This analysis also assumes three predictable phonotactic processes. The first is the on-glide associated with palatal consonants, discussed in more detail in Section 5.2.1. The second is the fronting of velar finals, whereby final /k/ and /ŋ/ are fronted to /c/ and /ɲ/ respectively, following the diphthong /ai/, and the third concerns the representation of final -/ìh/ as final |s|.

Final -/aɲ/ and -/ac/, phonetically -[a^{i}ɲ] and -[a^{i}c], can develop diachronically in two ways, either through fronting of a velar final after /ai/ or through the appearance of a glide between /a/ and a final palatal. This has resulted in pairs of homophones, such as of *m^{h}aɲ* 'male' and *m^{h}aɲ* 'ask'. The former is the reflex of a Proto Waic velar final, the latter of a palatal final. Diffloth (1980) preserves a distinction between the /ai/ + velar and /a/ + palatal sequences, though for certain items both are offered as alternatives. Examples are given in Table 4-20.

Table 4-20: Merger of palatals and velars after close front vowels

Proto Waic	*Diffloth (1980) transcription*	*examples + gloss (phonemic transcription)*	*narrow transcription*
PW*-eŋ	-/aiŋ/ or -/aɲ/	*kaɲ* 'head' *ka̤ɲ* 'work' *m^{h}aɲ* 'male'	-[a^{i}ɲ]
PW*-aɲ	-/aɲ/	*m^{h}aɲ* 'ask' *taɲ* 'weave' *pa̤ɲ* 'white' *na̤ɲ* 'army'	
PW*-ek	-/aik/ or -/ac/	*ʔac* 'older brother' *v^{h}ac* 'dark'	-[a^{i}c]
PW*-ac	-/ac/	*va̤c* 'sword' *ka̤c* 'shy' *m^{h}ac* 'sand'	

In the absence of any experimental evidence to confirm a consistent phonetic difference between a fronted velar after /ai/ and a palatal, Diffloth's analysis is historically faithful, but phonetically redundant. The approach adopted throughout this work is to analyse such sequences using a palatal final wherever possible, whatever the historical origins of the diphthong. The Chinese scholars (Zhōu and Yán 1984; Wáng and Chén 1981) take a third stance in treating all palatal finals and all fronted velars as final /-ik/ sequences (see Table 7-12). The three analyses may be compared in Table 4-21. By the same token, breathy register /i̤a/ diphthongs which arise from PW*a before velar finals (see Table 4-18), may be reanalysed if they are preceded by palatal consonants. The palatal on-glide is attributed to the consonant and the sequence is reanalysed as palatal + /ɛ̤/.[16] The palatal glide has wider implications for the phonological analysis of diphthongs. Any instance of (vowel + [i] + velar) may be expressed as (vowel + palatal), since this predicts the [i] glide, after which any velar will front to a palatal. Examples of how the diphthongs [ɔi oi ui ɯi ɤi] may be reanalysed in this way are given in Table 4-21.

Table 4-21: Analyses of back vowel + [i] diphthongs

Proto Waic	*Contrasts in Diffloth (1980) transcription*	*phonemic transcription*	*Chinese analysis*	*narrow transcription*	*gloss*
final palatal stops and nasals					
*hɔc	|hɔc|	*hɔc*	hɔik	[hɔⁱc˺]	'finish'
*khoc	|kʰoc|	*kʰoc*	khoik	[khoⁱc˺]	'wash self'
*pruc	|pruc|	*pruc*	pruik	[pruⁱc˺]	'wing'
*pəc	|pɯc|	*pəc*	pəik	[pɯⁱc˺]	'take off clothes'
*mɔɲ	|mɔ̤ɲ|	*mɔ̤ɲ*	mɔ̤iŋ	[mɔ̤ⁱɲ]	'mouth'
*rmuɲ	|mo̤ɲ|	*mo̤ɲ*	mo̤iŋ	[mo̤ⁱɲ]	'wife'
*sʔuɲ	|s.ʔuɲ|	*s.ʔuɲ*	s.ʔuiŋ	[s.ʔuⁱɲ]	'snake'
*kəɲ	|kɯɲ|	*kɯɲ*	kɯiŋ	[kɯⁱɲ]	'father'
reflexes of PW*-s					
*lʔos	|los|	*loih*	loih	[loiɕ]~ -[ç]~ -[h]	'grease'
*ʔmus	|mus|	*muih*	muih	[muiɕ]~ -[ç]~ -[h]	'love'
*bus	|pɯ̤s|	*pɯ̤ih*	pɯ̤ih	[pɯ̤iɕ]~ -[ç]~ -[h]	'carry on back'
reflexes of PW*-y					
*koy	|koy|	*koi*	koi	[koi] ~ [kwɛ]	'have'
*buy	|puy|	*pui*	pṳi	[pui] ~ [pwi]	'person'
*ʔəy	|ʔɯy|	*ʔɯi*	ʔɯi	[ʔɯi]	'raise animals'

The set of diphthongs [ɔi oi ui ɯi ɤi] also occurs with final /h/, in which context they may be reanalysed using final |s|, a device which the historical phonology can justify. Diffloth (1980:17) comments that: 'Very few Waic languages have a final -s contrasting with a final -h today. In [Wa] *-s has evolved phonetically to -[ɕ] which creates notation problems ... In [Wa] -ih is found after back vowels, representing the reflex of Proto Waic *-s.' After vowels other than back vowels, however, *-s has merged fully with *-h, and in no context is an alveolar sibilant fricative heard. In the PRC orthography, /h/ is used for

[16] This reanalysis is mirrored in a change from early drafts of the PRC orthography (see section 1), which originally analysed these sequences as (palatal consonant + diphthong), e.g. **nyīiex** for *ɲɛ̤ʔ* 'house', **yīiem** for *yɛ̤m* 'grandmother'. These were subsequently respelt **nyīex, yīex** respectively.

the reflexes of both *-s and *-h, and /ih/ for reflexes of *-s preceded by a back vowel. The diphthongs [ɔi oi ui ɯi ɤi] also occur in open syllables, the historical reflexes of back vowels followed by *y. These may be analysed as a final glide |y|, as in Table 4-21.

Positing final glides is a solution which enables the syllable structure to be simplified, reducing the degree of redundancy in the less constrained formulation of syllable structure given earlier in Table 4-5. In the simplified structure, given below in Table 4-22, any the consonants in Table 4-19, including glides, may occupy any C slot and any of the nine monophthongs /i e ɛ a ɔ o u ɤ ɯ/ or one of the phonologically unitary diphthongs /ia ua ai aɯ au/ the V slot. There is clearly a discrepancy in the generative power of this formula and the formula in Table 4-5, a difference commensurate with each formula's degree of phonetic accuracy.

Table 4-22: Wa syllable structure in Diffloth (1980), ignoring register

initial	*vowel*	*final*
C_1 (C_2)	V	C

5 *Segmental phonetics*

5.1 Vowels

5.1.1 DESCRIPTIVE SCHEMATA FOR VOWEL QUALITY

AUDITORY-PROPRIOCEPTIVE CLASSIFICATION

In linguistic phonetics it has long been traditional and remains convenient to describe vowels in terms of two proprioceptively defined axes in the dimensions high-low and front-back, a system attributed to the work of Melville Bell (1867) and Henry Sweet (1877) which underpinned the development by Daniel Jones (1922) of the vowel quadrilateral, a theoretical device delimiting the extremes of vowel quality variation found in languages. Although not represented spatially on the vowel quadrilateral, lip rounding also plays a part in determining vowel quality in the vowel systems of all languages, and may be represented as a third dimension of the vowel quadrilateral. However, since vowel systems most commonly only contrast front unrounded vowels with back rounded ones (Maddieson 1984:124), the two dimensional vowel quadrilateral is often sufficient. Daniel Jones's set of primary cardinal vowels reflects the 'default' lip configurations by including front unrounded and back rounded vowels, evenly spaced around the perimeter of the vowel quadrilateral. Some languages (including most of the Mon-Khmer languages with Wa among them) base additional phonological contrasts on this third dimension of lip-rounding. Daniel Jones defined a supplementary set of secondary cardinal vowels in which the lip-settings of the primary cardinals are reversed, to give a set of vowels which maximally exploits the three dimensions of vowel quality variation: high-low, front-back and rounded-unrounded. Figure 5-1 is a representation of the peripheral cardinal vowels in the three-dimensional vowel space.

Catford (1981) discusses how the points on the quadrilateral may relate to actual tongue position. He suggests that reference to the 'highest point of the tongue' was a misleading concept introduced by those who had assumed that the perceived tongue-positions which guide the 'Bell–Sweet' system were an attempt by phoneticians ignorant of the acoustics of vowels to express their auditory impressions of vowels. Recent work has highlighted a discrepancy between X-rays of actual tongue position and traditional proprioceptive vowel classification (e.g. Ladefoged and Maddieson 1996:284–5). However, Catford defends the articulatory basis of the 'Bell–Sweet' system from the criticism which has been levelled at it on these counts, suggesting that articulatory measurements support the use of the conceptual vowel space more than they contradict it.

Catford reminds us that practical training is required to learn how to position vowels in the vowel quadrilateral and that auditory impressions of vowels may often contradict articulatory and acoustic fact. He stresses (Catford 1988: Ch. 8 *passim*) that correct production of the cardinal vowels depends on the way they *sound* and *feel* relative to each other. Mona Lindau (1978) has shown by performing statistical tests that the correlation between auditory, acoustic and articulatory assessments of sets of vowels is in fact extremely high, once measurements are normalised.

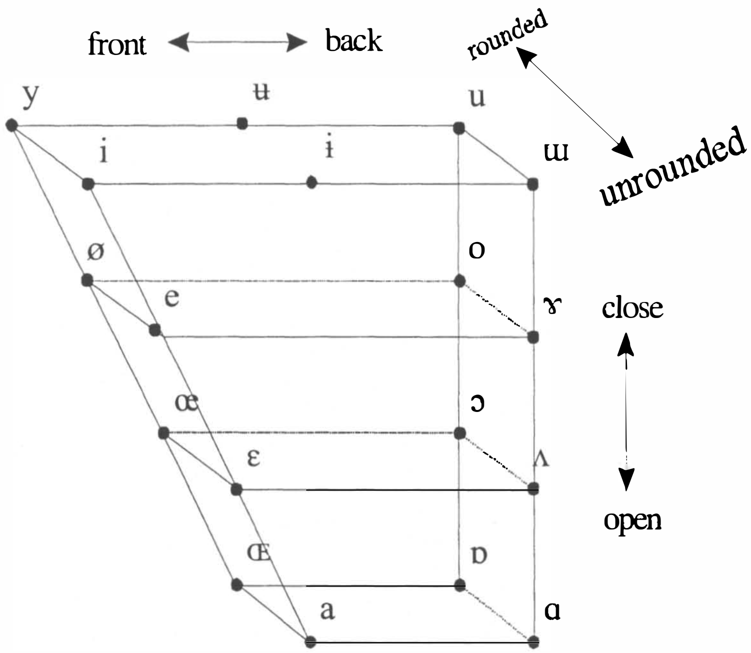


Figure 5-1: The peripheral cardinal vowels displayed in a three-dimensional space representing the three major dimensions of vowel quality. Adapted from Ladefoged and Maddieson (1996:283).

Lindau (1978) describes a set of vowel features which are sufficient to account for all phonological contrasts and processes involving vowels. She compares the vowel systems from a number of languages to produce compelling evidence that the parameters of high-low and front-back as represented by the conventional vowel quadrilateral are the fundamental features of vowels, with additional supplementary features of lip position and phonation type, both of which are significant for Wa.

ACOUSTIC DESCRIPTION

The acoustic description of vowels is done primarily by the measurement of formant frequencies, the peaks of resonance in the vocal tract as configured to articulate a particular vowel. The source-filter model of the vocal tract (Fant 1960) and the sound spectrograph (Joos 1948) enables the formant structure of vowels to be crudely translated into the auditory-proprioceptive dimensions of the vowel quadrilateral. The best fit is achieved in a two-formant model of vowel classification, where the first and second formants correspond inversely to the vertical and horizontal dimensions of the vowel quadrilateral respectively, as illustrated in Figure 5-2.

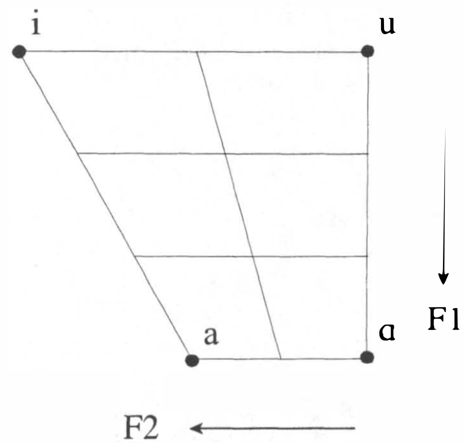


Figure 5-2: Correlation of acoustic properties of vowels with the auditory-proprioceptive vowel quadrilateral.

Catford (1981) surveys the attempts which have been made to reconcile the vowel quadrilateral with two-formant measures of vowels, either by distorting the quadrilateral to fit the formant chart, or vice versa. The success which this achieves seems correlated largely only with the level of sophistication of the diagram. In any case, even in a simplistic two-formant vowel model, formant resonances are not determined independently by some identifiable articulatory parameter, and nor does the lip position translate straightforwardly into changes in formant frequency.

Rather, by modelling of the vocal tract as a set of tubes of varying lengths separated by constrictions (Fant 1960), the acoustic theory of vowel production holds that it is the number of resonating cavities and their relative sizes, and the location and size of the constrictions separating them, which determine formant frequencies.

Descriptions of vowels rarely need to record more than the frequency of the formant peaks in the spectrum. The amplitudes of formants are largely correlated with their frequencies, and so do not need to be specified. Gunnar Fant (1956) wrote that 'a specification of formant frequencies ... conditions the essential physical structure of the vowel'.

It appears, however, that the amplitude of formants does have something to contribute to the accurate description of vowels. When a vowel system incorporates contrasts based on different phonation types, variations in the spectral profile of the glottal source are of independent significance (Ní Chasaide and Gobl 1997). This aspect of vowels is of crucial importance for Wa.

AUDITORY CONSIDERATIONS

The non-linearity of the human auditory system's perception of pitch means that there is a mismatch between the auditory and acoustic representation of vowels. Intimately connected with the perception of formants is the fact that the effective bandwidth of the acoustic filtering effect of the auditory system is narrow at low frequencies and widens as frequency increases. Experiments which explored the characteristics of the auditory filter (cited in Moore 1997) have established that the equivalent rectangular bandwidth, used to approximate the frequency response curve of the auditory filter, may be calculated as a function of frequency according to the equation

$$BW_{ER} = 24.7(4.37f+1)$$

where BW_{ER} is the equivalent rectangular bandwidth and f the frequency in kHz. The ear can resolve the fundamental even in vowels with low F1, since at 200Hz the effective bandwidth of the auditory filter is still less than 50Hz. By 3kHz, the bandwidth has increased only to 350Hz, enabling resolution of at least the first three formant peaks, provided that they are reasonably evenly spaced. For this reason, formant frequencies are measured using the Bark (Z) scale which models the auditory system's frequency response characteristics (see Moore 1990 for more on this topic). The Bark scale has been shown to be proportional to the distance along the basilar membrane in the cochlea, the inner ear's auditory 'filterbank' (Zwicker 1975). The formula

$$Z = \frac{26.81f}{1960+f} - 0.53$$

used to convert acoustic frequency into the Bark scale, is the one proposed by Traunmüller (1990) where f is the frequency in Hertz and Z is the resulting Bark scale value. The relationship between Bark and Hertz is illustrated in Figure 5-3.

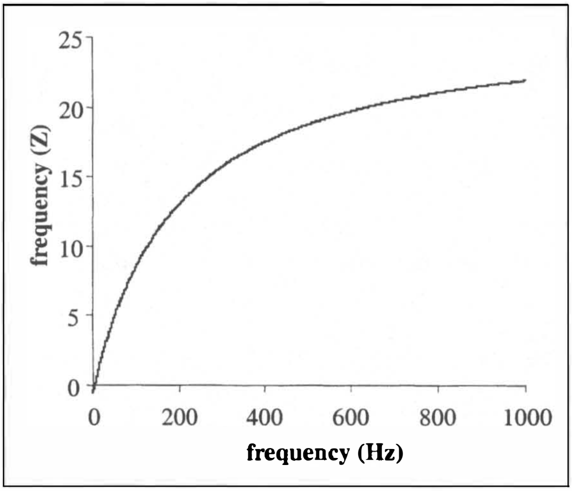


Figure 5-3: Acoustic frequency (kHz) compared with the Bark scale (Z) model of auditory frequency.

The experimental evidence is that formants must be at least 3.5Z apart to be perceived independently (Chistovich 1985, Johnson 1989). Perceptual experiments have shown that formants which are separated by an auditory frequency of less than 3.5Z, such as F1 and

F2 in high back rounded and low vowels, or F2 and F3 in front vowels, are fused into a single percept by the human auditory system. For the same reason, the higher formants (F3 and above) are unlikely to be resolved independently, since the acoustic width of the 3.5Z band increases with frequency. Using calculations derived from Figure 5-3 above, the relationship between the 3.5Z necessary for perceptual discrimination of formants and the centre frequency of the gap between formants is shown in Figure 5-4.

In this model, the discriminable distance between formants is approximately half the centre frequency: the dotted lines marked on Figure 5-4 show this for a centre frequency of just over 2kHz. This means that for a hypothetical vowel with formants 1kHz apart, F2 at 1.5kHz would not be resolved with F3 at 2.5kHz. In general, we might expect F2 to be resolved from F3 only when it is lowered, as in back vowels. The precise frequencies of the higher formants (F3 and above) would appear to have little relevance for the identification of vowel phonemes. However, the amplitude of higher formants influences spectral profile in a way which is auditorily perceptible.

This study investigates two contexts in which higher formants do contribute to phonemic contrasts distinguishing Wa vowels: lip rounding of back vowels and phonation type.

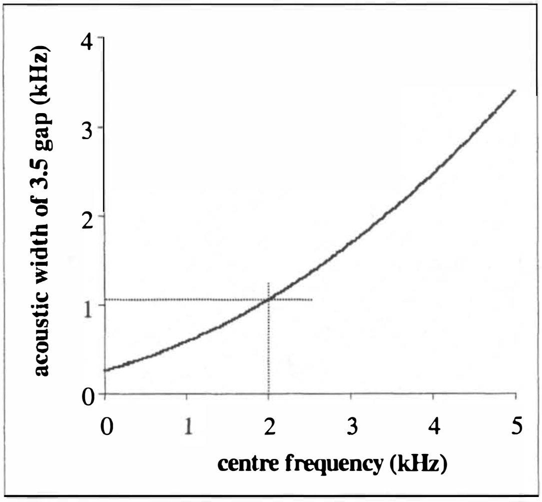


Figure 5-4: Effective width in Hertz of a 3.5Z band as a function of its centre frequency in Hertz.

CROSS-LINGUISTIC CONSIDERATIONS

The vowel systems of Mon-Khmer languages are known for their richness, as exemplified by Khmer in Eugénie Henderson's classic description (Henderson 1952:159).

Descriptions of the Wa vowel system concur in recognising nine distinct vowel qualities (Diffloth 1980; Wáng and Chén 1981; Zhōu and Yán 1984; Svantesson et al. 1981). The cross-linguistic comparative work of Maddieson (1984:127–8) suggests that this is not unusual: more than 10 per cent of his sample have nine or more distinctive vowel qualities, though the modal average is five (Maddieson 1984:127).

Writing from the perspective of historical phonology, Gérard Diffloth (1991:15) describes the Wa vowel system as 'rich and complicated'. He ascribes its above-average complexity to two factors. The first of these is extensive lexical borrowing from Tai languages; the second is the influence on vowel quality of registers and final consonants. These effects are of particular interest since they represent the sort of predictable phonetic interactions which are known to be responsible for the mutation of vowel systems in Mon-Khmer languages, in conjunction with either tonogenesis (Svantesson 1989, 1991a) or registrogenesis (Diffloth 1980).

5.1.2 EXPERIMENTAL ANALYSIS OF VOWEL QUALITY

The nine contrastive vowel qualities listed in the phoneme inventory are reproduced in Table 5-1. The vowel qualities are discussed independently of register in this section; the influence of the register contrast on vowel quality is treated separately in the Section 6.3.7. The data are based on the recordings of eleven consultants reading each item in Table 5-2 twice, yielding forty-four recordings of each of the nine vowel qualities (twenty-two of each register).

Table 5-1: The contrastive vowel qualities of Wa

	front	*Back*	
	unrounded		*rounded*
close	i	ɯ	u
mid-close	e	ɤ	o
mid-open	ɛ		ɔ
open		a	

Table 5-2: Words used in the experimental study of vowel quality

clear register		*breathy register*	
pi	'flute'	*pi̤*	'forget'
ke	'gourd'	*te̤*	'arrow'
tɛ	'sweet'	*tɛ̤*	'peach'
ka	'afterwards'	*ka̤*	'gnaw'
pɔ	'side of body'	*pɔ̤*	'don't'
po	'mortar'	*mo̤*	'crawl'
pu	'fly'	*pṳ*	'thick'
rɤ	'pull'	*rɤ̤*	'boat'
sɯ	'pour'	*sɯ̤*	'straight'

The amplitudes and frequencies of the first five formants of each vowel were made by hand from 512-point amplitude spectra, the first sample point of which was approximately one third of the way into the vowel. Since this was typically at least 100ms after the vowel onset, the likelihood of formant transitions distorting the measurements was small. Spectra with 50, 80 and 120Hz bandwidths were all compared.

Some predictable problems were encountered when attempting to identify formant frequencies consistently, especially in close back rounded vowels where F1 and F2 often overlap and higher formants are greatly attenuated. Following Ladefoged and Bladon (1982:190), inconsistencies and anomalies were dealt with by ensuring that all measurements fell within the expected range. When no harmonic peak stood out clearly, the frequency of the formant was determinable by eye after changing the spectrum bandwidth or by shifting the spectrum window slightly. Peaks in unexpected positions were ignored. The frequency of split peaks was read as the centre of the split, while the amplitude was recorded as that of the peaks. Single peaks which appeared where two were expected were treated as two peaks superimposed, as was typically the case with back rounded vowels, for which a plausible F2 reading was frequently discernible as a bulge on the right hand side of the F1 peak, as illustrated in Figure 5-5 and Figure 5-6. It was found impossible to identify F5 and sometimes also F4 in certain vowels for certain speakers.

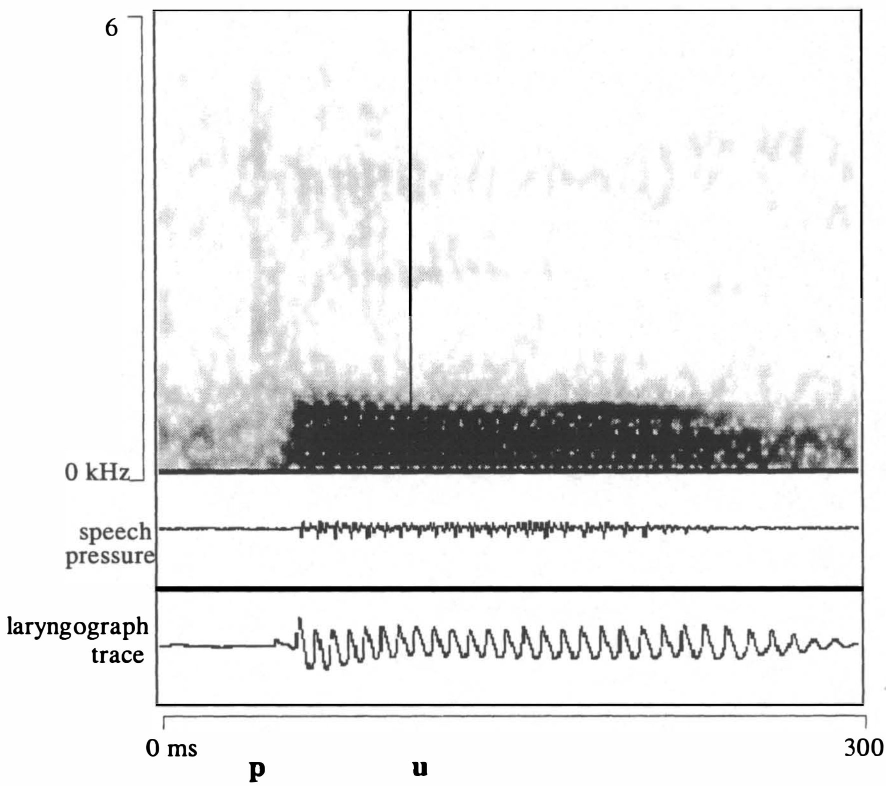


Figure 5-5: Spectrogram (100Hz bandwidth), waveform and laryngograph trace of *pu* 'fly' spoken by AP. A spectral slice at the point of the vertical line is given in the following Figure.

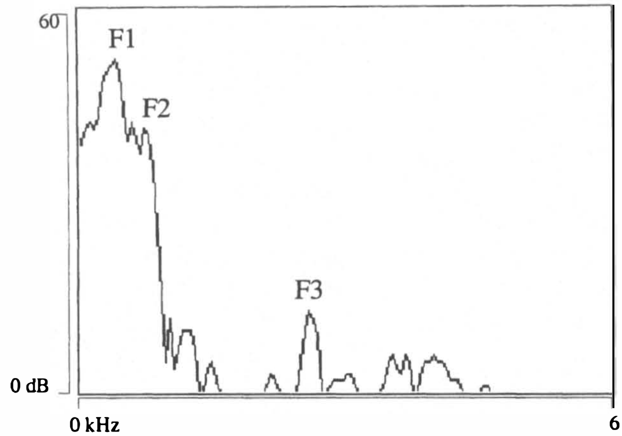


Figure 5-6: Spectrum (100Hz bandwidth) of /u/ in *pu* 'fly' spoken by AP. F1,2,3 are measured as 365, 710 and 2600Hz.

GRAPHICAL REPRESENTATION OF VOWEL FORMANT DATA

The following diagrams compare some of the ways of illustrating the acoustic properties of vowels in the dimensions of the classification system illustrated in Figure 5-1. A numerical summary of the measurements of the first five formants, using both acoustic (Hz) and auditory (Z) scales of frequency, is given in Table 5-3.

Figure 5-7 and Figure 5-8 give a visual impression of the degree of variation in vowel quality within the whole sample. This variation is concealed in Figure 5-9 and Figure 5-10, in which mean values of F1 are plotted against F2, using the acoustic and auditory frequency scales, respectively.

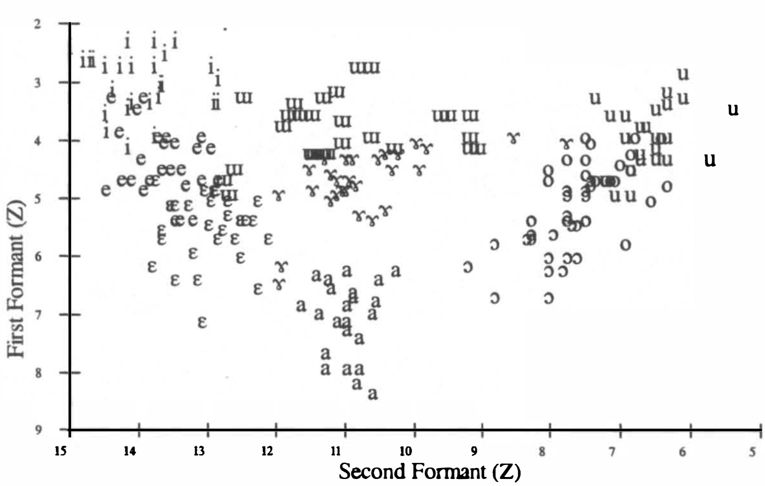


Figure 5-7: Plot of F1 and F2 in Bark (Z) of nine vowels. Forty-four tokens of each vowel (eleven speakers x four reps each). The register contrast is not marked in this figure.

Table 5-3: Mean frequency (Hz and Z) and amplitude (rel dB) of five formants of Wa vowels, clear and breathy registers pooled. Each figure represents the mean of forty-four measurements

vowel	*F1*			*f2*			*f3*			*f4*			*f5*		
	freq (Hz)	*freq (Z)*	*amp (dB)*	*freq (Hz)*	*freq (Z)*	*amp (dB)*	*freq (Hz)*	*freq (Z)*	*amp (dB)*	*freq (Hz)*	*freq (Z)*	*amp (dB)*	*freq (Hz)*	*freq (Z)*	*amp (dB)*
i	308	3.11	57	2237	13.76	35	3003	15.69	35	3569	16.78	36	4244	17.81	30
e	429	4.28	61	2135	13.45	42	2704	15.01	39	3535	16.72	36	4306	17.89	30
ɛ	571	5.52	64	1893	12.64	47	2607	14.77	42	3610	16.85	39	4556	18.22	34
a	793	7.19	63	1445	10.85	55	2453	14.37	40	3606	16.84	37	4518	18.17	27
ɔ	577	5.57	63	885	7.81	57	2559	14.65	28	3436	16.54	34	3830	17.20	26
o	470	4.66	61	787	7.15	54	2516	14.54	21	3395	16.47	22	3840	17.22	22
u	378	3.81	58	687	6.43	51	2296	13.93	15	3148	15.99	17	3696	16.99	19
ɤ	362	3.65	61	1401	10.64	36	2181	13.59	34	3358	16.40	29	4012	17.48	28
ɯ	463	4.59	62	1344	10.38	45	2270	13.86	35	3401	16.48	31	3854	17.24	29

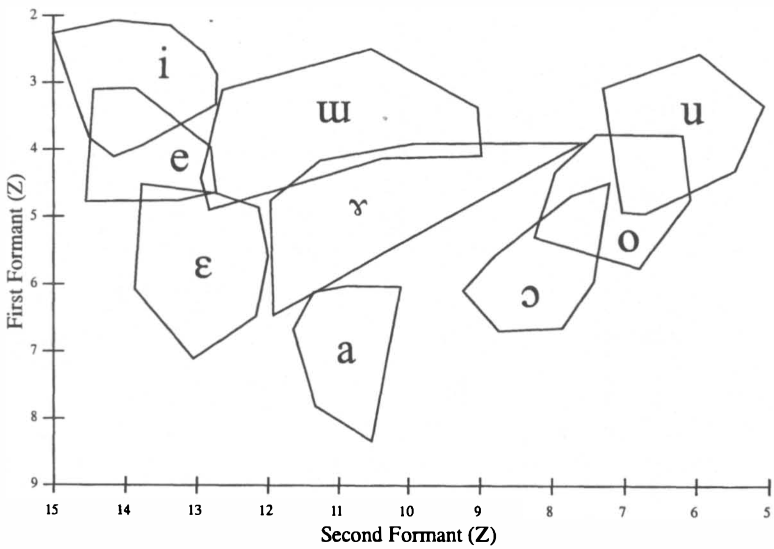


Figure 5-8: Variation in Fl and F2 in Bark (Z) of nine vowels. Outlines of forty-four tokens of each vowel (eleven speakers x four reps each).

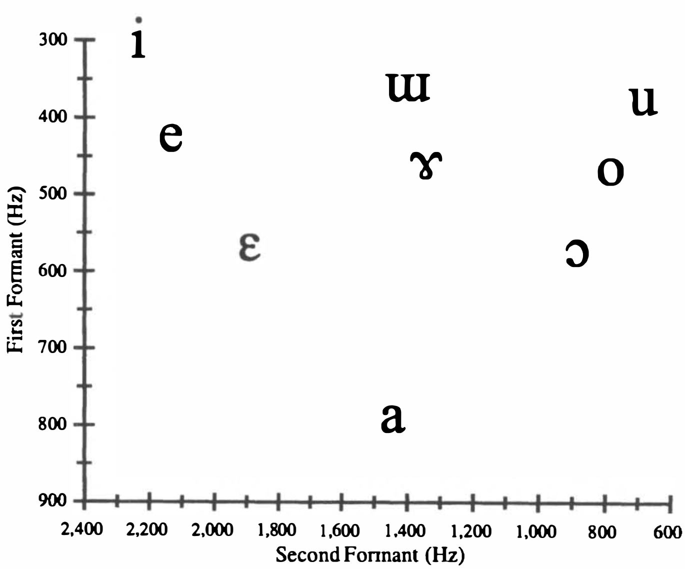


Figure 5-9: Mean Fl and F2 in Hertz of nine vowels. Markers represent means of monophthongal vowels in both phonation types for eleven speakers.

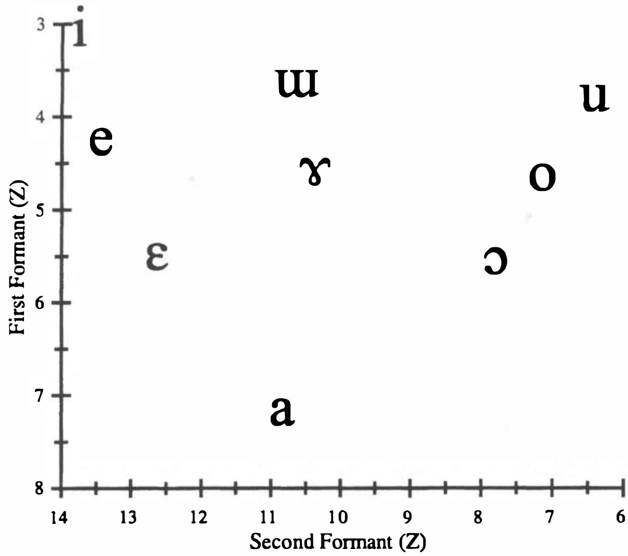


Figure 5-10: Mean Fl and F2 in Bark (Z) of nine vowels. Markers represent pooled data of both phonation types for eleven speakers.

F2'

The auditory model described above suggests that formants within 3.5Z of each other are merged into a single integrated percept. One way of representing this is to model the possible perceived values of such combinations and to substitute them graphically for the measured formants. One model suggested by Fant (1973) proposes a method of calculating F2', the probable perceived value of F2, from the first three formants by the equation

$$F2' = F2 + \frac{(F3 - F2)(F2 - F1)}{2(F3 - F1)}.$$

The altered perception of F2 comes into play only if F2 is within 3.5Z of either Fl or F3, which is true for all the mean Wa vowels here (see Figure 5-11). The resulting Fl–F2' plot is shown in Figure 5-12.

The various representations of the acoustic characteristics of the Wa monophthongs in the plots above support the previous assessments of nine contrasting vowel qualities. Using the Bark scale provides the best approximation of the vowel quadrilateral, placing the vowels in the most symmetrical and evenly-spaced array (Figure 5-10). Plotting F2' has little to contribute, although theory suggests that the perception of F2 would generally be determined by a combination of real F2 and another formant.

Wa contrasts three vowel heights in both front unrounded vowels /i e ɛ/ and back rounded vowels /u o ɔ/, as suggested by the outlines of the Fl:F2 plots in Figure 5-8. Of the remaining three vowel qualities, /a/ suggests a fourth vowel height acoustically, though it cannot be classified as obviously front or back. When /a/ occurs in diphthongs (see Section 5.1.4), the openness of /a/ is consistently maintained, but there is considerable variation in the front-back dimension, suggesting that it is the height dimension of /a/ which is distinctive.

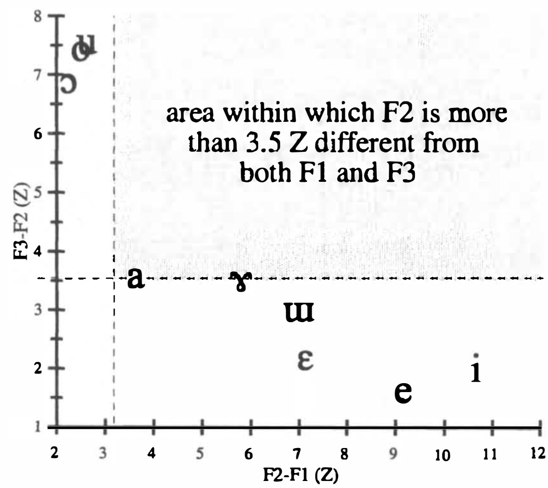


Figure 5-11: Perceptual integration of formants: F2–F1 and F3–F2. F2 is more than 3.5Z different from F1 or F3 for vowels in the shaded area.

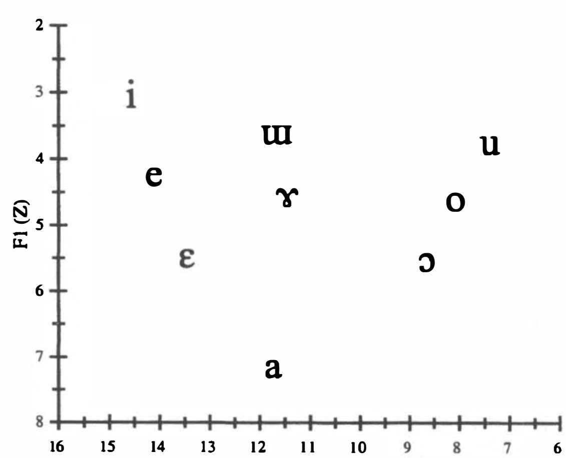


Figure 5-12: Perceptual integration of formants: F1 plotted against F2'.

CLOSE BACK OR CLOSE CENTRAL?

One weakness of the representation of vowel contrasts in the acoustic F1–F2 domain is the inadequate treatment of back unrounded vowels. It is not clear how to classify /ɤ/ and /ɯ/ in the front-back dimension.

Relying on their own experience in practical articulatory phonetics to maximally constrain the movement of the vocal organs, Ladefoged and Bladon (1982) have looked into the effects on the formant frequencies of cardinal vowels of altering lip configuration without changing tongue position. Their findings are that as an independent articulatory parameter, lip position affects F2 and F3 in close front and close back vowels in quite different ways. In close front vowels, the articulatory action of rounding the lips lowers F3 greatly and F2 only slightly, while in close back vowels the same action lowers F2 greatly and alters F3 only slightly. There was found to be an abrupt articulatory boundary between vowels displaying these patterns of F2 and F3 change with lip-rounding. Moreover, the boundary is located in the front-back continuum at a point which was apparently different for the two authors: Ladefoged's close central vowels behaved like front vowels, Bladon's more like back vowels. They found further that rounding the lips lowered both F2 and F3 to a lesser degree in more open central vowels.

It is clear from Figure 5-10 that /ɤ/ and /ɯ/ have substantially lower F2 than /o/ and /u/ respectively. Figure 5-13 shows that for the most part /ɤ/ and /ɯ/ are little different from /o/ and /u/ respectively in terms of F3. In the light of Ladefoged and Bladon's observations, this finding suggests that /ɤ/ and /ɯ/ have the same tongue positions as /u/ and /o/ but with lip rounding removed, and that they should be classified as close back vowels rather than close central vowels.

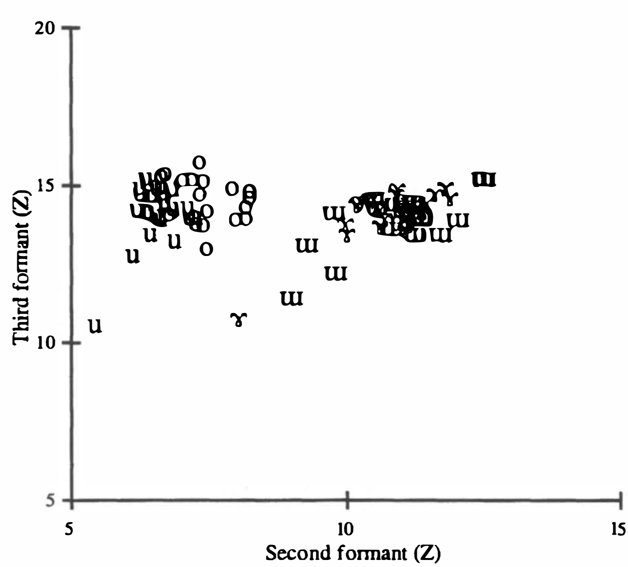


Figure 5-13: Plot of F2 and F3 (Z) of high back vowels /o u ɤ ɯ/. Eleven speakers.

However, close back and close central vowels may be distinguished by considering the perceptual integration of formants less than 3.5Z apart. F2 remains perceptually distinct from both Fl and F3 in close back unrounded vowels, while F2 and F3 are close enough to be integrated in close central unrounded vowels. From the positions of /ɤ/ and /ɯ/ in Figure 5-11, it appears that Fl and F2 remain perceptually distinct but that F2 and F3 are integrated for /ɤ/ and /ɯ/, suggesting that they are central rather than back vowels.

The difficulty in classifying unrounded vowels in this area of the vowel space may explain, incidentally, why no languages contrast high back unrounded vowels with high central unrounded vowels,[17] and why the descriptions of vowel systems with non-front unrounded vowels are frequently vague with respect to vowels of this kind, describing them and/or transcribing them either as back vowels with the symbols [ɤ ɯ] or as central vowels with [ə ɨ], or using the two interchangeably (see Huffman 1970, Henderson 1952, Jacob 1968 for Khmer; Haas 1964, Hudak 1987 for Thai; Diffloth 1980, Zhōu and Yán 1984, Svantesson 1993 for Wa).

With regard to these Wa data, however, it is possible, and even likely, that there is considerable variation both between speakers and within the speech of individual speakers both of the boundary between the front and back variational paradigms and of the articulatory characteristics of the vowels /ɤ ɯ/ relative to /o u/ in the front-back dimension.

ACOUSTICS OF LIP ROUNDING

The sum of the first three formant frequencies is proposed as an acoustic measure of lip-rounding by Kent et al. (1996:204). Applied to the Wa data, this measure could be expected to show the difference between rounded and unrounded high back/central vowels with similar Fl by reflecting the lowering effect of lip-rounding on F2 or F3 indiscriminately. This is useful for descriptive purposes, particularly as it places the peripheral vowels in a plausible hierarchy of lip rounding from /i/ to /u/. The sum of the first three formants of the Wa vowels is shown in Figure 5-14.

This measure contributes nothing new to the ambiguity of F2 and F3 with regard to the articulatory front-back dimension. However, it does reinforce the fact that the vowels /ɯ ɤ/ are auditorily and acoustically distinct from /u o/ respectively, and confirms that lip rounding is an articulatory factor contributing to the acoustic difference between these two pairs of vowels.

5.1.3 VOWEL DURATION

Vowel duration is contrastive in Mon-Khmer generally and in other Northern Mon-Khmer languages, such as Kammu (Svantesson 1983a), though not within Waic (Diffloth 1980). Since vowel quantity is not phonologically contrastive in Wa, it does not require special emphasis in this study. However the duration of Wa vowels is prone to variation for other reasons. Vowel duration is assessed here in terms of :

- intrinsic vowel duration;
- comparative length of monophthongs and diphthongs;
- closed syllable vowel shortening.

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[17] A possible exception is the Papuan language Nimboran: see Ladefoged and Maddieson 1996:291.

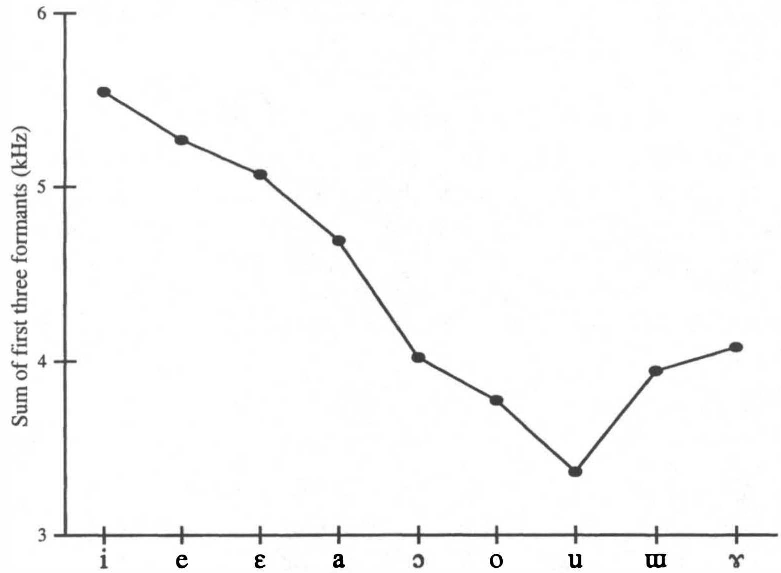

Figure 5-14: Sum of first three formants as a measure of lip-rounding in Wa vowels. Each marker represents the mean of approx. forty-four data points.

VOWEL DURATION AS A PHONETIC UNIVERSAL

According to Maddieson (1997), one approach to phonetic universals is to categorise aspects of speech behaviour as either automatic: 'the necessarily universal [...] result of inherent properties of the mechanisms by which speech is produced and processed' (Maddieson 1997:619), or as learned detail predicted by language-specific and phonological rules. Phonetic variations may become candidates for inclusion in the category of 'automatic' universals simply because they are widely observed and reported, but it is more difficult to establish physiologically-based, invariant explanations for them. Laver (1994) draws a similar distinction between intrinsic and conditioned factors in speech.

Intrinsic vowel duration is the phenomenon whereby close vowels are shorter than open vowels, all things being otherwise equal. The measurements of vowel duration in American English made by Peterson and Lehiste (1960:702) are consistent with this. The widely accepted physiological basis of intrinsic vowel duration is explained by Catford (1977), who reasons that the articulators must move further to and from the position required to articulate an open vowel, and that the greater distance necessarily takes longer to travel.

The effect of vowel shortening in syllables closed by a final consonant is so commonly observed as to be potentially universal, though it is certainly not a necessary effect of the way CV or CVC sequences are articulated. Maddieson (1985:216) proposes that closed syllable vowel shortening functions as a cue to the syllabic constituency of a string of segments.

Another proposed universal is the influence of consonant voicing on the duration of a preceding vowel, reported for a number of languages including English (Peterson and Lehiste 1960:702). In that study, Peterson and Lehiste found that vowels were about fifty per cent longer before voiced stops than voiceless ones.

STATISTICAL EVALUATION OF VOWEL DURATION

Measurements of duration were incorporated into the design of a number of independently conducted experiments in this work: monophthongs and diphthongs, stops and laryngeal consonants. Pooling all the duration measurements enables a good number of open syllable duration measurements (540) to be amassed. The rather smaller number of closed syllables was bolstered by measuring an additional two repetitions of each of six syllables from the wordlist (given in Table 5-4) for each speaker, yielding an additional 120 data points.

Table 5-4: Additional closed syllables included in vowel duration measures

clear register		*breathy register*	
krawŋ	'drum'	*kra̤wŋ*	'clothes'
tiam	'write'	*ti̤am*	'low'
kaɲ	'head'	*ka̤ɲ*	'work'

In the great majority of cases, vowel duration measurements were made with reference to an acoustically salient event, such as the release of a preceding plosive or nasal consonant. The syllables in which the initial consonant was a glottal fricative /h/ or an approximant /r/ were excluded from the duration measurements. The endpoint of open syllables was measured as the cessation of vocal fold vibration, the last peak on the laryngograph trace. The endpoint of the vowel in closed syllables had to be made with respect to final stops, nasals or glottal consonants. For stops and nasals, the end of the vowel was read from the spectrogram as the formation of the oral closure. All the duration measurements were made from syllables which were known to have been either the first or second of the repetitions recorded from each consultant, and so recitation order was included in the experimental design. Register was also included, using a three-way classification of clear, breathy or post aspirated (as in Section 6.7). ANOVA tests were carried out to assess the factors determining vowel duration. The design and results of the tests are given in Table 5-5 below.

The overwhelming effect of between-speaker differences ($F(10,539) = 147.89$, $p < 0.0005$) is illustrated in Figure 5-15, in which the consultants have been ranked for mean vowel duration. The figures are given in Table 5-6. Interestingly, the four speakers with the longest vowels are all preachers. The significance of this is discussed in Section 6.6.

The vowel quality effect is illustrated in Figure 5-16, also ranked with the longest first. The figures are given in Table 5-7. These measures are consistent with the phenomenon of intrinsic vowel quality, with the exception of the back unrounded vowel /ɵ/. Note also that the magnitude of the effect of intrinsic vowel duration is much smaller than that of between-speaker variation: the difference between the maximum (/a/) and minimum (/ɯ/) means with respect to vowel quality in Table 5-7 represents less than 20 per cent of the mean of the whole sample, while the spread of speaker means, from the longest vowels (NT) to the shortest (SRM), is more than 80 per cent of the grand mean of the whole sample.

Table 5-5: Design and results of ANOVA test for vowel duration.

Dependent variable: vowel duration
Independent variables:

	d.f.	*F*	*p*	*sig*
open syllables				
vowel quality (9 or diphthong)	9,539	6.239	< 0.0005	●
speaker (10)	10,539	147.885	< 0.0005	●
register (clear, breathy, post-aspirated)	1,539	33.997	< 0.0005	●
recitation order (first or second)	2,539	2.356	0.0960	
closed syllables				
speaker (10)	9,168	21.693	< 0.0005	●
recitation order (first or second)	1,168	0.91	0.3410	
register (clear, breathy, post-aspirated)	2,168	1.025	0.3130	
type of final consonant (stop or nasal)	1,168	23.581	< 0.0005	●
place of articulation of final consonant (bilabial, palatal or velar)	2,168	5.157	0.0070	○

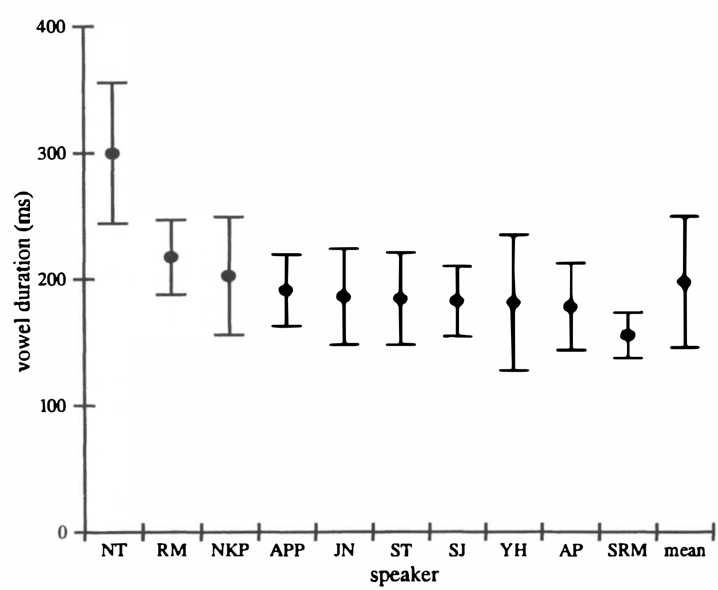

Figure 5-15: Duration of open syllable vowels by speaker. Markers represent the mean (+/– 1 s.d.) of between thirty-six and fifty-four tokens.

Table 5-6: Duration (ms) of open vowels by speaker

speaker	*mean*	*s.d.*	*N*
NT	530.31	67.97	54
YH	439.79	64.40	48
SJ	427.57	33.18	54
RM	385.98	63.75	54
NKP	339.58	56.34	48
ST	325.23	43.85	48
APP	303.33	89.91	48
JN	292.04	66.52	48
AN	288.89	40.13	36
APP	275.07	28.77	54
SRM	238.13	27.65	48
all	353.43	101.45	540

Table 5-7: Duration of open syllable vowels by vowel quality

vowel quality	*mean*	*s.d.*	*n*
a	381.57	109.72	84
diphthongs	378.39	106.55	44
ɛ	370.79	99.30	104
ɔ	363.16	88.48	44
o	350.77	103.67	44
e	345.50	96.87	44
u	334.68	103.12	44
i	329.07	100.54	44
ɤ	319.32	84.00	44
ɯ	311.80	89.56	44
mean	353.43	101.45	540

Diphthongs were represented as a tenth vowel category for the purposes of this analysis, since there were too few examples of each diphthong in the corpus of recordings to attempt a systematic survey of their relative durations. These findings, while only preliminary, suggest that diphthongs resemble open vowels with respect to intrinsic duration. This makes intuitive sense since all the diphthongs in the sample (with the exception of /ui/) include an open vowel element.

The remaining significant effect on duration detected by the ANOVA test was that of listing. First repetition syllables (mean 366.1ms, s.d. 105.05, n = 270) were about 25ms longer than second repetition syllables (340.7ms, s.d. 99.42, n = 270). This difference represents about 7 per cent of the sample mean. Given that the first item in a list of two identical items might naturally be read with more emphasis, the second item being merely an echo of the first, then this effect mirrors the lengthening of vowels in stressed syllables in English reported by Laver (1994:448).

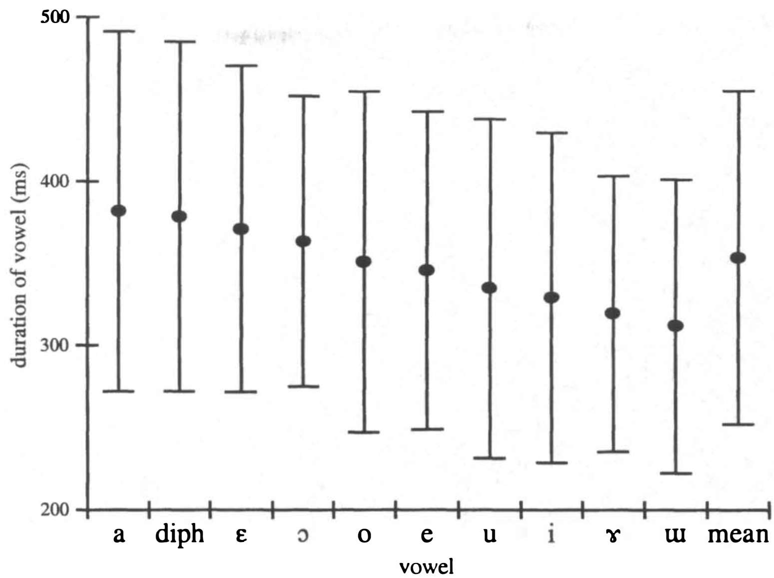

Figure 5-16: Duration of open syllable vowels by vowel quality. Each marker represents the mean (+/– 1 s.d.) of forty-four or more tokens.

The degree of between-speaker variation in closed syllable vowel duration is much less. The findings for closed syllables set out in Table 5-8 are illustrated in Figure 5-17. A post-hoc Scheffé test found that the mean duration of closed syllable vowels in the recordings of consultant NT was significantly different from that of all the other speakers. None of the other means are significantly different from one another, except for RM from SRM, who have the longest and the shortest vowels in the set, respectively, if the exceptional duration of NT's vowels is excluded. The difference between RM and SRM's mean durations is 30 per cent of the sample mean.

Recitation order does not have a significant effect on the duration of closed syllable vowels. The remaining effects which were found to have statistical significance were the manner (stop or nasal) and place of articulation of the final consonant.

Vowels preceding nasals (mean 205.5ms, s.d. 50.05, n = 129) were about 33ms longer than vowels before stops (mean 172.0ms, s.d. 50.30, n = 40). This significant result ($F(1,168) = 13.65$, $p = 0.0003$) is presumably attributable to the quasi-universal influence of consonant voicing on the duration of preceding vowels mentioned earlier: final stops are voiceless (but see Section 5.2.4), while final nasals are voiced. The magnitude of the difference does not approach that reported by Peterson and Lehiste (1960), though a direct comparison of that study with these findings is impossible since in Wa there can be no minimal pair with contrasting voiced and voiceless final stops.

The sample was defective with respect to final consonant place of articulation, since only bilabial, palatal and velar nasal finals are considered. The results are given in Table 5-9. Duration increases as the place of articulation moves further back in the mouth. This result, while apparently significant, is difficult to interpret. Duration perturbations conditioned by consonant place contrasts have been explained in terms of articulatory movement, similar to Catford's explanation of intrinsic vowel duration above. If the conditioning factor of the effect is indeed physiological, then vowel quality is as relevant as consonant place.

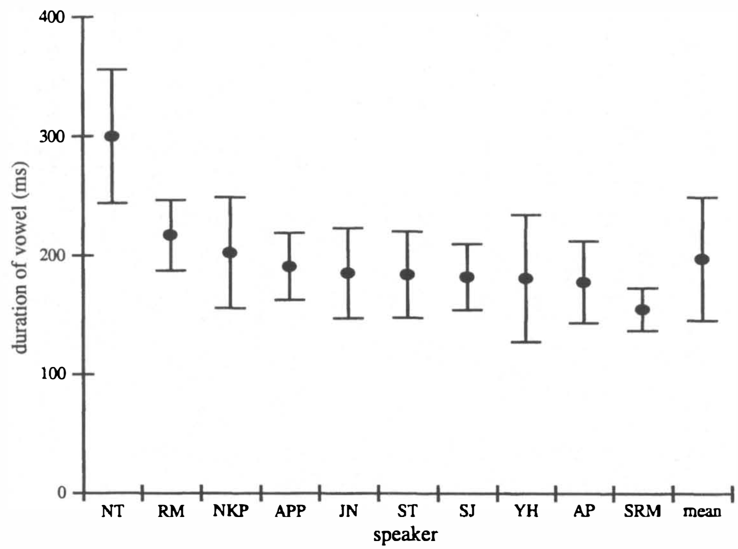

Figure 5-17: Duration of closed syllable vowels by speaker. Markers represent the mean (+/– 1 s.d.) of forty-four or more tokens.

Table 5-8: Duration of closed syllable vowels by speaker

speaker	*mean (ms)*	*s.d.*	*n*
NT	300.00	55.98	16
RM	217.15	29.72	20
NKP	202.50	46.48	14
APP	190.84	28.19	19
JN	185.31	37.95	16
ST	184.00	36.40	16
SJ	182.25	27.60	20
YH	181.13	53.38	16
AP	177.81	34.37	16
SRM	155.06	17.82	16
mean	197.53	51.96	169

Table 5-9: Final nasal place contrasts and vowel duration (ms)

place	*mean*	*s.d.*	*n*
bilabial /m/	191.81	43.73	43
palatal /ɲ/	209.37	59.98	38
velar /ŋ/	214.58	44.88	48
all	205.46	50.05	129

Not all the contrastive vowel qualities were represented in the sample of closed syllables, so vowel quality was not included in the design. Since vowel quality was not controlled in these measurements, the interpretation must be left open. However, it is possible to compare the duration of monophthongs and diphthongs. Table 5-10 gives the figures for open and closed syllables. In open syllables, diphthongs are on average 7.7 per cent longer than monophthongs; in closed syllables they are 10.2 per cent longer. The difference is significant for the sample as a whole (F(1,740) = 6.542, p = 0.018). Open syllable vowels are, according to the figures in Table 5-10, approximately 75 per cent longer than closed syllable vowels, the closed to open ratio is therefore 4:7.

Table 5-10: Vowel duration (ms) in closed and open syllable monophthongs and diphthongs

	mean	*s.d.*	*n*
open syllables			
diphthongs	378.39	106.55	44
monophthongs	351.22	100.80	496
all open syllables	353.43	101.45	540
closed syllables			
diphthongs	209.58	58.89	123
monophthongs	190.18	58.00	78
all closed syllables	202.05	59.16	201
all syllables	312.37	113.92	741

The factors influencing vowel duration are summarised in Table 5-11. The figures suggest that open syllables are generally more variable in duration than closed syllables. Closed syllable vowel shortening causes greater differences in duration than between speaker variation (excluding outlier NT), and so it seems likely that this phenomenon plays a perceptual role in syllabification in the way proposed by Maddieson (1985). Those duration perturbations which can be regarded as universal, be they automatic or learned, are responsible for lesser differences in duration.

Table 5-11: Summary of factors influencing on vowel duration

open syllables	
between speaker variation	83(57*)
intrinsic duration	20
diphthong vs monophthong	8
Listing	7
closed syllables	
between speaker variation	73(30*)
voicing of final consonant (stop / nasal contrast)	16
diphthong vs monophthong	10
place of articulation of final consonant	8
Listing	insignificant
all syllables	
closed syllable vowel shortening	75

*excluding NT

5.1.4 DIPHTHONGS

CLASSIFICATION OF PHONETIC DIPHTHONGS

Ladefoged and Maddieson (1996) define a diphthong as a vowel for which more than one target vowel quality is specified. Rèn (1986) comments that diphthongs may be described either as dynamic events incorporating vowel quality change, or as two connected events. If three, rather than two, targets are involved, the resulting object may be termed a triphthong. Laver (1994:284) defines a diphthong as: 'a vocoid in which the medial phase explicitly consists of an articulatory trajectory across the vocoid space, giving an auditory impression of a changing quality'.

Also relevant to the classification of diphthongs is their temporal structure. Lindau et al. (1985) found cross-linguistic differences between the vowel-quality trajectory of the /ai/ and /au/ diphthongs they measured in Arabic, Hausa, Mandarin Chinese and English, both in terms of the starting and end points and in the proportion of the total vowel during which vowel quality is changing. Kent and Moll (1972) found that the transition rate of F2 increased with the magnitude of the F2 change, in other words 'the further the faster'. Lindau et al. (1985) found that another general rule 'the further the longer' applied only in certain languages or in certain diphthongs.

Diphthongs may further be classified as rising or falling. This distinction is made by identifying one of the vowel quality targets as the syllabic component of the diphthong (Rèn 1986). If the first element is syllabic, the diphthong is falling. Conventionally, falling diphthongs involve movement from open to close vowel quality such as /ai au aɯ/, though the opposite can be true (e.g. /ɨə/ in Thai or Khmer). Conversely, if the syllabic element is second, the diphthong is described as rising, typically with movement from close to open vowel quality, such as /ia ua/. The rising/falling distinction translates into a difference in phonological structure in some phonological frameworks (e.g. Government Phonology: Kaye 1989:128).

Lindau et al. (1985) estimated that diphthongs are present in the phoneme inventories of one third of the world's languages. Maddieson's (1984:161) cross-linguistic survey recognised diphthongs only if they could not, according to the distributional patterns observed in other segments in the language, be analysed as a VC, CV or VV sequence. Under this rather exclusive stipulation, diphthongs were recorded in only twenty-three out of 196 languages (Maddieson 1984:133).

ALLOPHONIC VARIATION IN DIPHTHONGS

The complex array of diphthongs in Wa is complicated still further by allophonic variation. Possible alternations are given in Table 5-12. Where the conditioning context for the variation is given as 'free', consistent dialectal variation may, in fact, be involved. Rèn (1986) notes commonly observed processes of monophthongisation, where diachronic change or synchronic variation may turn a diphthong into a monophthong located toward the centre of the movement between the two elements of the original diphthong, in terms of the vowel quadrilateral. Several of the alternations are consistent with this process.

Table 5-12: Possible allophonic variation in Wa diphthongs (Wáng and Chén 1981:51)

Diphthong	*allophonic variation*	*context*
/e/	[e] ~ [ei]	final velar, /ʔ/ or /h/
/o/	[o] ~ [ou]	final velar, /ʔ/ or /h/
/ai/	[ai] ~ [aɛ] ~ [ɛ]	Free
/oi/	[oi] ~ [oe]	Free
/ɔi/	[ɔi] ~ [ɔɛ]	Free
/ia/	[ia] ~ [iɛ] ~ [ɛ]	Free
/aɯ/	[aɯ] ~ [aɤ] ~ [ɤ]	Free
/au/	[au] ~ [ao] ~ [a] ~ [ɔ]	Free
/ua/	[ua] ~ [ue]	Free

EXPERIMENTAL ANALYSIS

This section looks at the phonetic structure of the diphthongs found in Wa irrespective of their phonological status. In this inclusive treatment, the variety of diphthongs is richer than the phonology of the language suggests. This investigation includes a full list of diphthongs recorded from a single consultant and a smaller subset of diphthongs which were included in the main wordlist, spoken by four consultants.

The full list of diphthongs is taken from Zhōu and Yán (1984:8) and Wáng and Chén (1981:44), where ample examples of real words containing each diphthong are given. The set is reproduced below in Table 5-13. Consultant SJ read each diphthong in an open syllable consisting of an initial voiceless bilabial stop /p/ followed by the diphthong, placed in a frame sentence and written in PRC orthography. Being active in both the development of the PRC orthography and in Wa language culture and education, this consultant was capable of reading nonsense words to a high degree of naturalness. For procedural reasons, the frame sentence (Table 5-14) used to elicit diphthongs from this consultant differed slightly from that used with the main wordlist.

Table 5-13: Full set of diphthongs and triphthongs

diphthongs			*triphthongs*
iu	ɯi	ui	iau
ia	ɤi	ua	uai
ei		ou	
		oi ɔi	
ai	aɯ	au	

Table 5-14: Frame sentence used to elicit full set of diphthongs from consultant SJ

ʔeʔ	*ʔah*	*lɔk*	___	*nan*
we-2PL-INCL	say	like	___	that.way

'We say ___ that way.'

The shorter list consisted of nine diphthongs which occur in the main wordlist (see Section 8.1), including centring, closing and opening diphthongs. All are clear register with one exception, and so no comment can be made on the role of the register contrast in the phonetics of diphthongs. In contrast to the list of nonsense words in which the full inventory of fifteen diphthongs were placed, the shorter list includes diphthongs in closed syllables. Three diphthongs with similar changes in vowel quality appear in both closed and open syllables. The open syllable diphthongs are marked long [:].

Table 5-15: Diphthongs in shorter list and their source words

^{n}dai	[ai:]	'skirt'
^{ŋ}gau	[au:]	'hold in collar of clothing'
paɯ	[aɯ:]	'faded'
kraɯŋ	[aɯ]	'drum'
pauʔ	[au]	'uncle'
^{n}daiʔ	[ai]	'eight'
tuih	[ui]	'conversation'
^{ŋ}gṳah	[ṳa]	'hatch'
tiam	[iɛ]	'write'

Vowel quality change in each diphthong was measured by sampling Fl and F2 from sound spectrograms and spectra. F1 and F2 were measured at the beginning and end points of each vowel only, taking care to make the beginning-point 50ms after the burst of the initial stop and the end-point measurement 50ms before the consonant which followed the diphthong to avoid distortion of the measurements by formant transitions. An additional measurement was made of Fl and F2 at the point of the F1 maximum for each of the two triphthongs.

The relationship between the magnitude of the vowel quality change and the time taken to achieve it was tested by dividing each diphthong into three phases:

a) an initial phase of unchanging vowel quality;

b) a transition phase with changing vowel quality;

c) a final phase of unchanging vowel quality.

Following the method used in Lindau *et al.* (1985), the divisions were made on the basis of F2 transitions. The boundaries between the three phases of each diphthong were judged by eye from spectrograms, taking into account prior expectations of how the formants were expected to behave in each vowel. In several of the diphthongs, however, no period of unchanging vowel quality was discernible at the beginning or end phase, in which case the beginning of vowel quality change was recorded as coinciding with the vowel onset or the end of the vowel. Formant transitions associated with consonants were ignored for the purposes of the temporal measurements. The measurement procedure is illustrated in Figure 5-18.

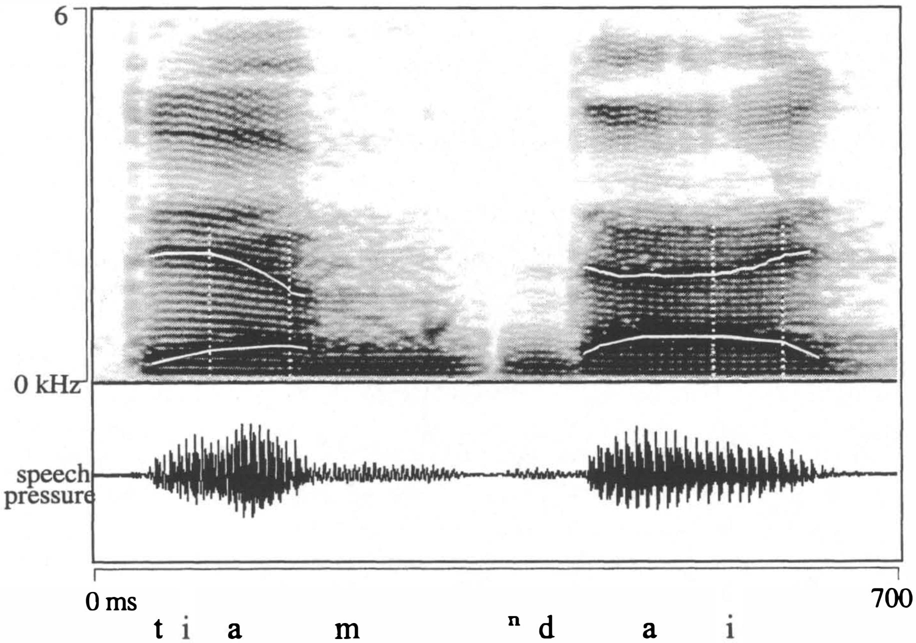

Figure 5-18: Spectrogram (100Hz bandwidth) and waveform of *tiam* 'write' and *ⁿdai* 'skirt' spoken by SRM. The initial, medial and final phases of each diphthong are divided by dotted lines; F1, F2 are marked with solid white lines.

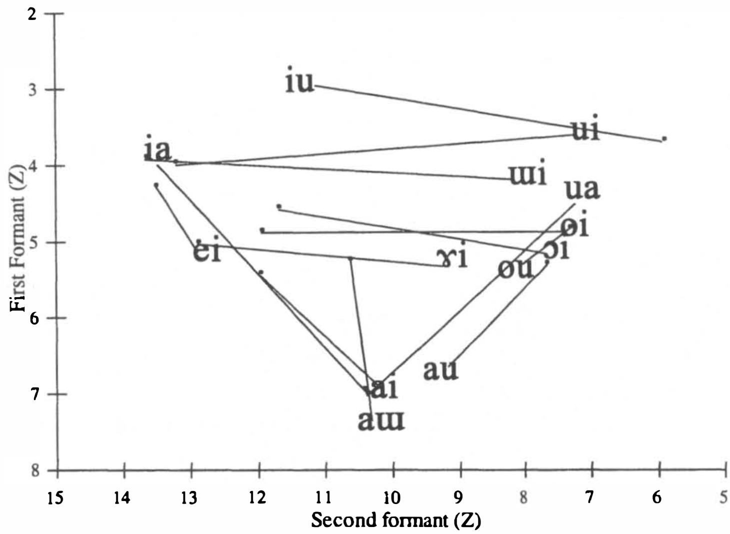

Figure 5-19: Fl and F2 of thirteen diphthongs spoken by consultant SJ. Markers represent pooled mean of four tokens, two of each register. The vowel symbol is placed at the starting-point of the trajectory of each diphthong.

The vowel quality change of each item in the full set of fifteen diphthongs, spoken by a single consultant, is illustrated in the F1/F2 plane in Figure 5-19; the two triphthongs /iau/ and /uai/ are plotted separately in Figure 5-20. The acoustic trajectory of the two triphthongs shows clearly that the low vowel /a/ target in the middle of the trajectory is more fronted [a] with higher F2 for /iau/, but backed [ɑ] with lower F2 in /uai/. These triphthongs might be narrowly transcribed [iɑɔ] and [uaɛ]. This is consistent with the allophonic alternation of diphthongs /au/ and /ai/ with [ɔ] and [ɛ] respectively (Table 5-12).

The articulatory trajectories of the smaller set of diphthongs are plotted in the F1:F2 plane in the same way as the full set of diphthongs above.

Figure 5-22 shows the breakdown of the smaller set of diphthongs into temporal phases. The difference in duration between the open and closed syllable diphthongs is both visually apparent and statistically significant ($F(1,70) = 64.30$, $p < 0.0001$).

Figure 5-22 gives the visual impression that there is a correlation between the duration of the transition phase of each diphthong and total duration of the vowel; this is corroborated by a fairly strong statistical correlation ($r = 0.623$, $n = 72$). If the temporal phases of the diphthongs are considered as percentages of the total duration (Figure 5-23), there is no statistically significant difference between open and closed syllables in the proportion of the vowel taken up by the transition phase ($F(1,70) = 2.99$, $p = 0.088$), nor is the proportion of the vowel taken up by the transition phase of any one diphthong significantly different from any other, though a just-significant effect is observed within the set ($F(8,63) = 2.25$, $p = 0.035$). On average, the transition phase is 48.34 per cent (s.d. 20.01, $n = 72$) of the total duration of the vowel. The transition phase can thus be thought of as a loosely fixed proportion of the whole vowel, lasting about half the total duration, which can 'stretch' with it.

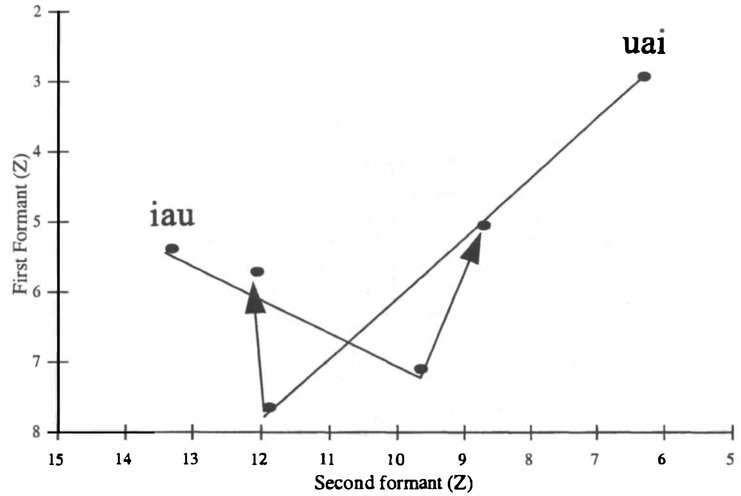

Figure 5-20: Trajectory in the F1/F2 space of triphthongs /uai/ and /iau/ for one speaker.

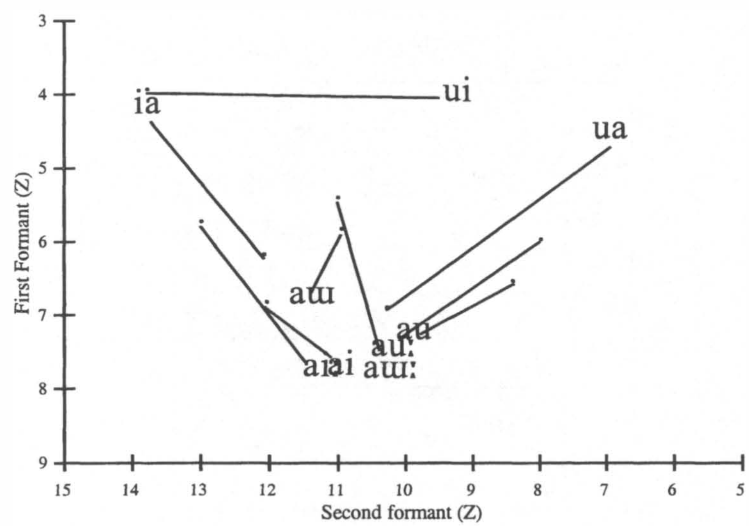

Figure 5-21: Articulatory trajectories of a subset of diphthongs. Labels are placed at beginning of trajectory. Each marker represents the mean of eight tokens (two tokens recorded from each of four speakers).

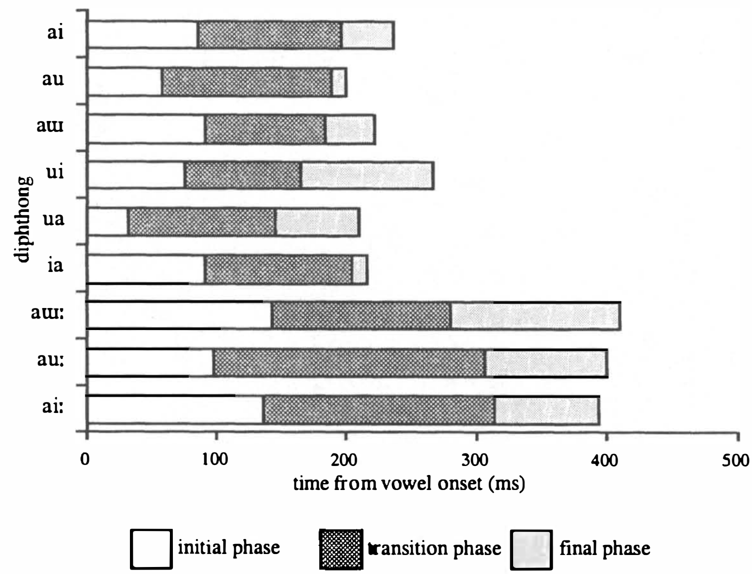

Figure 5-22: Temporal phases (ms) of a subset of diphthongs. Each marker represents the mean of eight tokens (two tokens recordedop from each of four speakers).

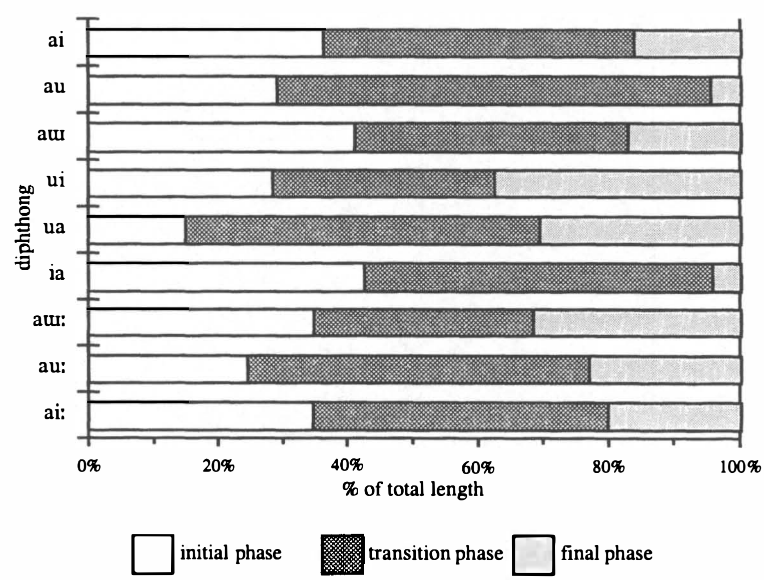

Figure 5-23: Temporal phases of diphthongs normalised as a percentage of total duration. Each marker represents the mean of eight tokens (two tokens recorded from each of four speakers).

Following Lindau et al. (1985), the acoustic distance travelled during the course of the trajectory of each diphthong was calculated as the Euclidean distance between the points in the F1:F2 plane representing the vowel quality at the beginning and end of the diphthong's transition phase. This is plotted against the duration of the transition phase in Figure 5-24, which illustrates that for the three pairs of like diphthongs which occur long in open syllables and short in closed syllables [ai ai: au au: aɯ aɯ:], the magnitude of vowel quality change correlates reasonably well with the duration of the transition phase (r = 0.512, n = 48). In the context of the 'stretching' transition phase considered above, it appears that the magnitude of vowel quality change decreases in closed syllable diphthongs to fit the time available.

By comparing the rate of vowel quality change, calculated in Barks per second (Zs^{-1}), to the magnitude of vowel quality change of each diphthong, it emerges that a linear relationship between rate and distance obtains for all the diphthongs excluding /ua/. This correlation (r = 0.721, n = 72) suggests that 'the further the faster' is true in the F1:F2 space rather than in just the F2 dimension, as in Kent and Moll's (1972) original hypothesis.

Figure 5-25 shows that /ui/ involves the greatest change in vowel quality in the shortest time, but the rate of change in /ui/ is commensurate with the distance it travels across the F1:F2 plane. The high rate of change in /ua/ remains unaccounted for.

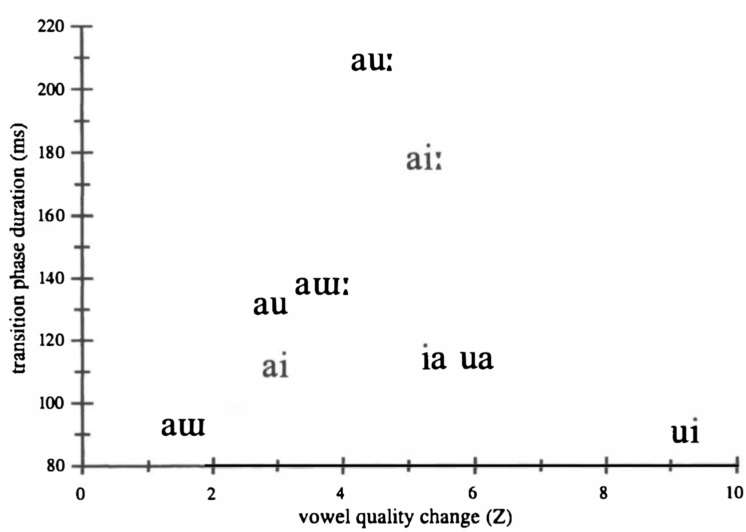

Figure 5-24: Mean magnitude of vowel quality change in Bark (Z) against duration of transition phase (ms) in diphthongs. Each marker represents the mean of eight tokens (two tokens recorded from each of four speakers).

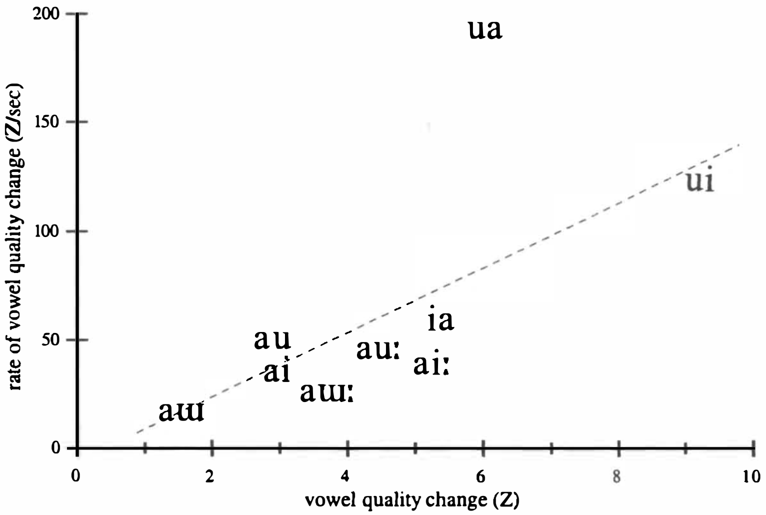

Figure 5-25: Magnitude of vowel quality change (Z) against rate of change over duration of whole diphthong (Zs^{-1}). Each marker represents the mean of eight tokens (two tokens recorded from each of four speakers).

This investigation amounts only to a brief overview of the rich array of diphthongs in Wa. A more comprehensive study, taking account of differences in the phonetic structure of diphthongs, might prompt a revision of the phonological analysis of diphthongs offered earlier. For instance, the markedly higher transition rate of /ua/ detected above could be construed as evidence that this diphthong should be analysed as a glide+vowel sequence [wa].

It is posited by Laver (1994:284) that in English, the intended target of a diphthong, inferred from the evidence of the trajectory, is perceptually more important than the end point actually reached. The allophonic variability of Wa diphthongs suggests that for the purposes of correct identification diphthongs cannot be perceptually dependent on both vocalic elements. The diphthong-to-monophthong alternations in Table 5-12 suggest that the mid-point of certain diphthongs might have more perceptual salience.

5.2 Stops

Stops are dynamic speech sounds, produced by coordinating a set of independently variable articulatory actions. These actions trigger a complex sequence of acoustic events with various sources. The acoustic components of stops are selected from a common repertoire, though not all the components are necessarily present in all stops. The apparent discontinuity of the acoustic manifestation of stops is explained by differences in articulatory activity which underlies the sequence.

The articulatory action which defines stop consonants is the formation of a blockage in the vocal tract. The articulation of the blockage necessarily entails three phases: the bringing together of the articulators to form the blockage ('closing phase'), the time during which the blockage is in place ('closure') and the release of the closure ('release phase').

Many South East Asian languages, such as Thai, Khmer or Vietnamese or others (Henderson 1965b), which have a three- or four-way contrast in initial stops place tight constraints on the voicing of stops in syllable final position. In Wa, stops at four places may occur in syllable final position, but the four-way voicing contrast is neutralised and the stops are unreleased. Initial and final stops are therefore discussed separately. In initial stops, however, air pressure increases during the closure such that when the articulators are released, air rushes out, causing an audible pressure pulse: the 'burst'. This is the only acoustic feature of (released) plosive stops which is always present.

5.2.1 PLACE CONTRASTS

The place dimension of stop articulation is not a special focus of this study. Since no laboratory techniques (such as electropalatography) were available to monitor movement of the oral articulators directly, there was no way of investigating tongue contact to establish with certainty the exact places of articulation of stops in Wa. Instead, the acoustic properties of the place contrasts of stops in Wa are considered. Further detail gathered from careful listening is also offered.

Published studies of the acoustics of stop place contrasts, and also of stop consonant perception (Liberman et al. 1952; Delattre et al. 1955; Stevens and Blumstein 1978; Blumstein and Stevens 1979; Kewley-Port 1983a and 1983b), have focused largely on two of the acoustic properties of place contrasts: burst spectra and formant transitions.

In Wa, the position of the oral blockage in the supralaryngeal vocal tract is used to discriminate between four phonological place categories of stop consonant /p t c k/, mirrored exactly in the set of nasal consonants. Bilabial, alveolar/dental and velar stops are all three present in 98.4 per cent of the languages in Maddieson's sample of 317 languages (Maddieson 1984:39). Maddieson finds that when languages have stops at a fourth category, it is most commonly between alveolar and velar, but beyond that specification there is enormous scope for variation. A fourth place of articulation is not unusual cross-linguistically: the most common addition is not a fourth plosive, but an affricate in the alveolar or palatal region, such as is the case in Wa, where the 'palatal' series of stops /c c^{h} j j^{h}/ may properly be transcribed narrowly as palato-alveolar affricates [tɕ tɕ^{h} ^{ŋ}dʑ ^{ŋ}dʑ^{h}]. True unaffricated palatal plosives are cross-linguistically much rarer (Maddieson 1984:212). In Wa, then, the label 'palatal' is therefore frequently inaccurate. Within this section only, the phonologically contrastive place categories are referred to using capitalised adjectives: Bilabial Alveolar Palatal Velar. Uncapitalised, these (and other) adjectives are used in their narrow, strictly articulatory–descriptive senses.

BURST SPECTRA

The burst spectrum is the acoustic footprint of the sound pressure pulse which accompanies the release of the oral articulators, and as such is a transient with a flat spectrum. This sound is shaped by the resonant qualities of the vocal tract in front of the closure, which are determined by place of articulation.

Abundant data are available on the acoustics of the burst spectra of stops at three places of articulation: bilabial, alveolar and velar. Blumstein and Stevens (1979) defined invariant acoustic properties of burst spectra which enabled them to identify the place of articulation of naturally produced stops from burst spectra with a high degree of accuracy. Spectral 'templates' are described as 'flat and falling' for bilabials, 'flat and rising' for alveolars and 'compact with a mid-frequency peak' for velars. These templates have some basis in acoustic theory (Johnson 1997:134). Having no front cavity, bilabial stop bursts reflect the acoustics of the sound source and so are diffuse with little formant structure. As the place of articulation moves back in the mouth, so the size of the front cavity increases, and the formant structure of the burst is more pronounced, as is evident for velars. While there is general consensus that 'falling' and 'rising' may enable consistent identification of bilabial and alveolar stops, respectively, 'compact' cannot uniquely define velar stop bursts.

Other studies (e.g. Kewley-Port 1983b) do not support the validity of static templates in stop identification, incorporating instead elements of the dynamic nature of stops, such as formant transitions. It is known that perception of the place dimension of stops combines the acoustic cues of burst spectrum with the formant structures surrounding it. Specifically, perceptual studies using synthesised stimuli (Liberman et al. 1952) suggest that correct identification of stops from burst spectra is dependent on the following vowel, especially for velars.

Comparing the burst spectra of velar and palatal stops in Hungarian, Blumstein (1986) established that the spectra of palatal stops share the 'compact' property with velar stops, in the same way that the bilabial and alveolar stops share the property 'flat' or 'diffuse'. She established further that the peaks in palatal and velar stop bursts both vary 'as a function of place of articulation and vowel context'. Her results suggest that the peaks in velar burst spectra are generally lower in frequency than those for palatals in similar phonetic contexts, and that velars and palatals pattern differently with respect to front and back vowels (Blumstein 1986:183). Keating and Lahiri (1993) found that the spectra of palatal bursts had a high-frequency emphasis, in the region of F4 of the following vowel.

FORMANT TRANSITIONS

The need for the oral articulators to move from their position during stop closure to the position required for the articulation of the following vowel (or vice versa for a VC sequence) systematically and characteristically determines the shape of the vocal tract immediately following (or preceding) a consonant. The resulting change in the resonant qualities of the vocal tract is borne out acoustically as transitional changes in the formant resonances, typically lasting no more than 50ms.

Formant transitions are the acoustic link between stop burst spectra and vowel formant structure. The removal of the obstruction as the stop is released allows the cavities in front and behind to couple acoustically. The relative sizes of these cavities and their resonant qualities are determined both by the place of articulation of stops and of the formant structure of the vowel.

The shape of the vocal tract changes as the articulators move to form the stop obstruction, causing the formant resonances to shift towards a certain point, known as the locus frequency. The point is never actually reached, since actual formation of the closure cuts off the acoustic coupling between the front and back cavities, changing the resonant characteristics of the vocal tract completely (Johnson 1997:136). Formant transitions may be described in terms of the locus frequency, the point towards which the tweaked ends of each formant band appear to point on a spectrogram.

The locus frequency is zero for F1 in stops with a place of articulation at the velum or further forward. Thus a downward-pointing F1 transition functions as an acoustic cue for stops and nasals in this region. In terms of acoustic theory, this is because there is no acoustic coupling between the front and back cavities and F1 must therefore be zero.

The F2 and F3 transitions of bilabials are characteristically downward-pointing, while the transitions associated with other places of articulation depend in part on the formant structure of the adjacent vowel, in particular F2, responsible for the 'front-back' dimension of the vowel on the vowel quadrilateral. Table 5-16 summarises the locus frequencies established in one study (Kewley-Port 1983b).

Table 5-16: Locus frequencies of F1, F2 and F3 for stops at three places of articulation as estimated by Kewley-Port (1983b)

stop place	*locus estimate*		
	F1	F2	F3
bilabial	near 0	1100–1500	2200–2400
alveolar	near 0	1800	2500–2700
velar	near 0	1500–2500	2200–3000

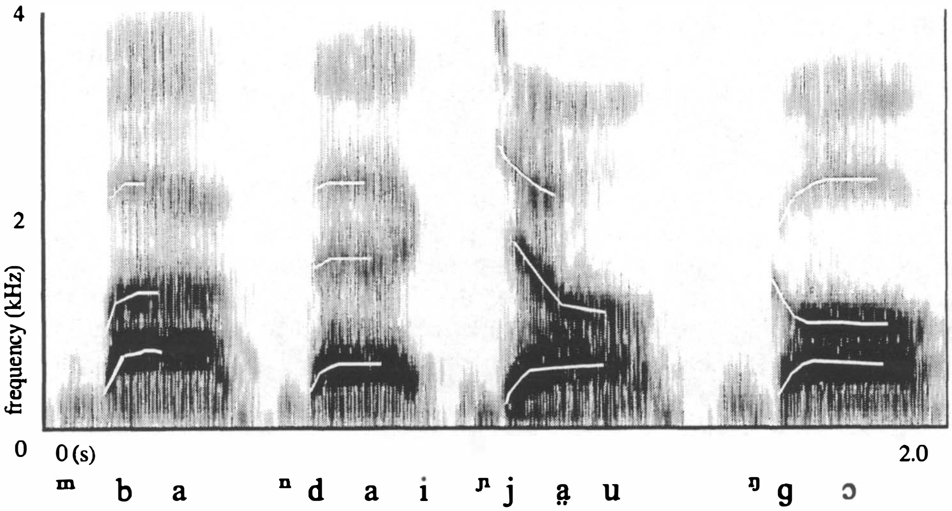

Figure 5-26: Spectrogram (150Hz bandwidth) of ^{m}*ba* 'thigh', ^{n}*dai* 'skirt', $^{\text{ɲ}}$*jau* 'reason', $^{\text{ŋ}}$*gau* (here [$^{\text{ŋ}}$gɔ]) 'hold in collar', spoken by consultant NKP, with formant transitions highlighted. Nasal formants have all but disappeared in the process of 'bleaching' the spectrum to make the vowel formants more visible.

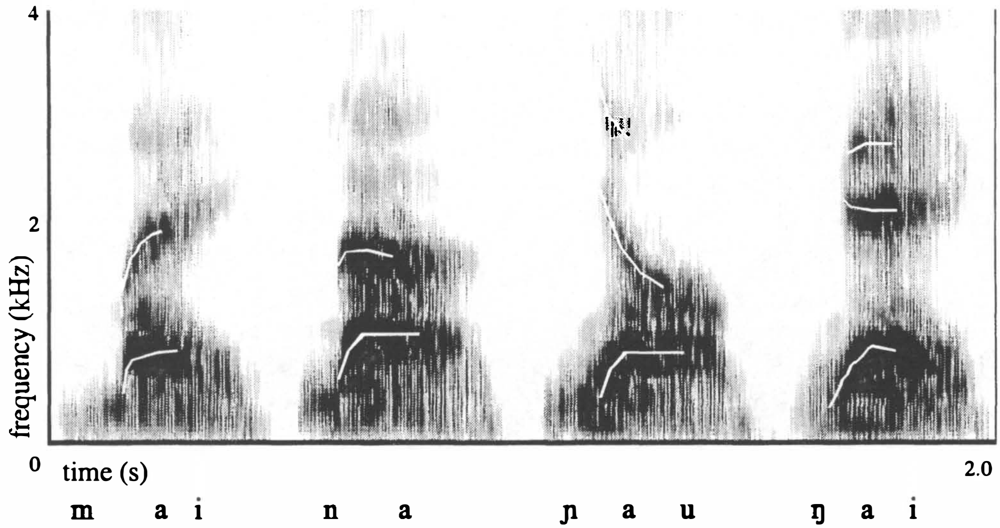

Figure 5-27: Spectrogram (150Hz bandwidth) of *mai* 'and', *na* 'lie spread out', *ɲau* 'rub clean', *ŋai* 'eye', spoken by consultant NKP, with formant transitions highlighted.

ACOUSTIC EVIDENCE OF THE PLACE CONTRASTS IN WA

While it was not ultimately possible to produce satisfactory spectra to compare the bursts of Wa stops with the established patterns described above, there was abundant acoustic evidence to illustrate the distinctive formant transitions associated with the place contrasts in Wa.

Alveolars /t t^h ^{n}d ^{n}d^h/

The F2 transitions of the Alveolar stop and nasal consonants in Figure 5-26 and Figure 5-27 point to a locus frequency in the region of 1800Hz estimate of Kewley-Port (1983b), given in Table 5-16. The impression of the author from looking and listening while making the recordings is that these stops may frequently be articulated at the dental place [t̪ t̪^{h} ^{n}d̪ ^{n}d̪^{h}], but further articulatory experimentation is necessary to determine how consistent this is.

Bilabials /p p^h ^{m}b ^{m}b^h/

The Bilabial stop in Figure 5-26 has the characteristically downward-pointing formant transitions expected with bilabials, where the formant locus frequency is lower than the vowel formant frequency for F1, F2 and F3. Similar transitions are visible after the bilabial nasal in Figure 5-27.

Velars /k kʰ ᵑg ᵑgʰ/

The F2 and F3 transitions in Figure 5-26 and Figure 5-27 both form a wedge-shape, found to be characteristic of velars (Stevens and Blumstein 1978). However, the place of articulation of final Velars is subject to considerable allophonic variation. The distribution of fronted final Velars and final Palatals preceded by /i/ was discussed earlier in Section 1. It is unclear whether Velars fronted by a preceding /i/ are articulatorily distinct from Palatals. Final Velars following open vowels appear to have a uvular place of articulation rather than velar, e.g. /ti̤ak tṳ/ [t̤i̤a̤q˺ t̤ṳ] 'open country', /lɔk/ [lɔq˺] 'for instance'. Again, more articulatory data are needed to describe this variation more precisely.

Palatals /c cʰ ᶮj ᶮjʰ/

In Wa, the Palatal stops are distributed phonologically in exactly the same way as the Bilabial, Alveolar and Velar plosives: the four-way voicing contrast applies in initial position and is neutralised in final position; there is a Palatal nasal /ɲ/ to match the nasals at the other three places /m n ŋ/. There is abundant historical evidence in Diffloth (1980) to suggest that Palatal stops were present in Proto Waic, and they are present in Mon-Khmer languages generally.

As phonetic objects, however, the Palatals diverge from the patterns which group the other stops together phonetically as well as phonologically. Firstly, the Palatals are affricates, in contrast to the simple plosive Bilabials, Alveolars and Velars. Secondly, Palatals are associated with distinctive on-glides. These two properties are examined below.

PALATAL AFFRICATES

Affricates represent a distinct manner of articulation, differing from stops in that 'the release of the constriction is modified in such a way as to produce a more prolonged period of frication after the release' (Ladefoged and Maddieson 1996:90), though the release of non-affricated stops may necessarily entail a very brief stage of frication accompanying the initial loosening and release of the closure. Stops, affricates and fricatives differ acoustically in the duration of frication noise and in 'rise time', a measurement of the time taken for the waveform amplitude to reach its maximum value (Kent and Read 1992:130). The differences are set out in Table 5-17. Both these differences are observed in Figure 5-29, in which both the duration of the friction noise and rise time are both longer in /s/ than that in /cʰ/. An affricate /c/ may be compared with two stops, /t/ and /ᵑg/, in

Figure **5-28**, in which the frication noise of /c/ is clearly visible. Slight affrication is also evident in /ᵑg/, though the frication noise it generates is lower in frequency and less prominent than that of /c/. /c/ is compared with other stops in Figure 5-26 also, though in that Figure the noise associated with the fricative component of the affricate is mostly off the frequency scale.

Table 5-17: Acoustic differences between stops, affricates and fricatives

	stop	*affricate*	*fricative*
frication duration	none or very brief	short	long
rise time	very rapid	fast	slower

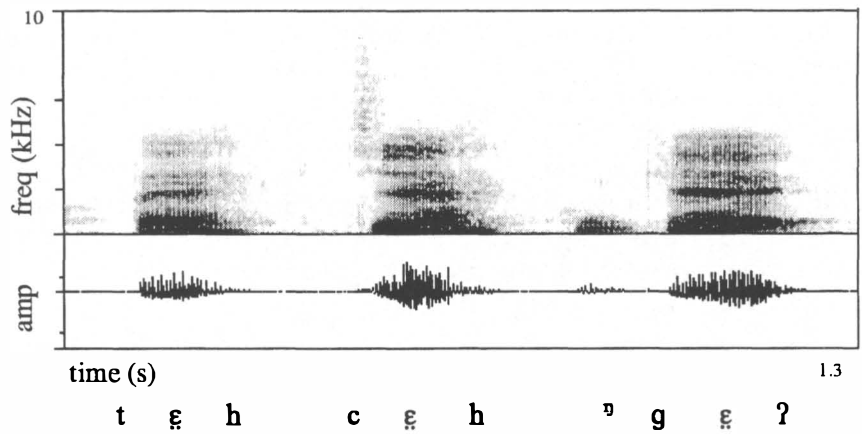

Figure 5-28: Spectrogram (150Hz b/w) and waveform of alveolar and velar plosives contrasted with an alveolo-palatal affricate, spoken by consultant NT. *tɛ̤h* 'turn over', *cɛ̤h* [tɕɛ̤h] 'pierce', *ᵑgɛ̤ʔ* 'empty-handed'.

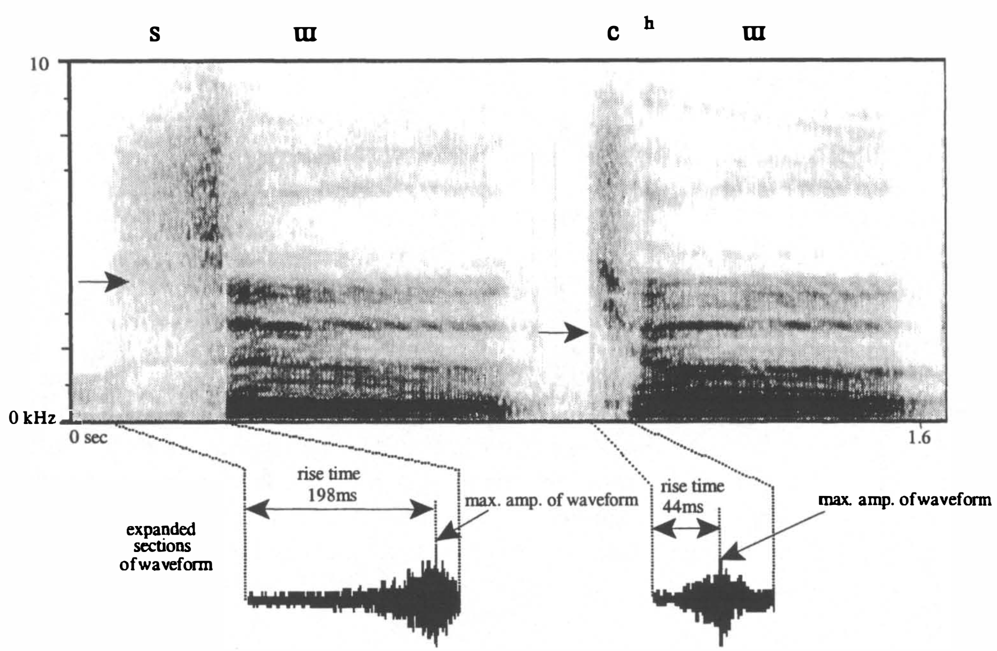

Figure 5-29: Spectrogram (150Hz b/w) and partial waveforms of *sɯ* 'pour' and *cʰɯ* [tɕʰɯ] 'sack', spoken by consultant NT. The rise time of the fricative is 198ms; of the affricate 44ms. The cut-off point of frication noise, indicated by arrows, is measured at 3890Hz for [s] and 2230Hz for [tʃʰ].

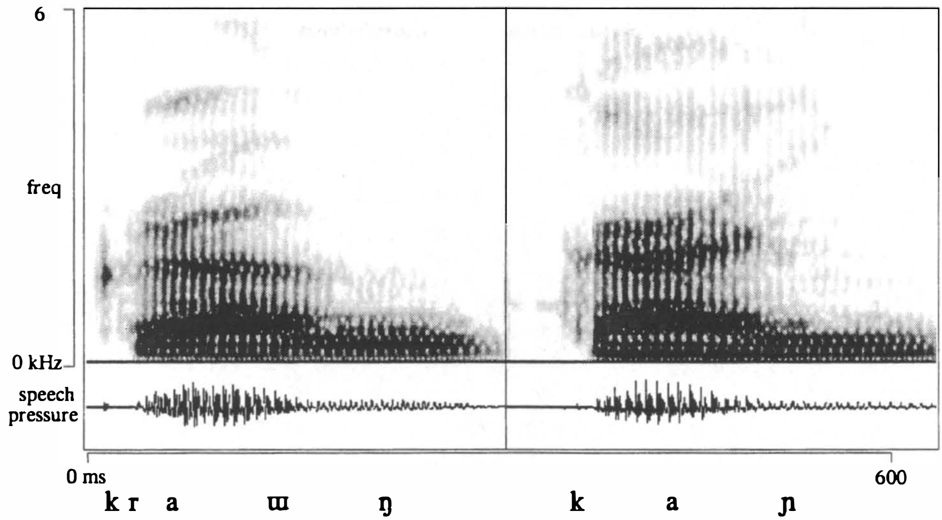

Figure 5-30: Spectrogram (150Hz bandwidth) and waveform of *krawŋ* 'drum' and *kaɲ* [kaiɲ] 'head', spoken by SJ.

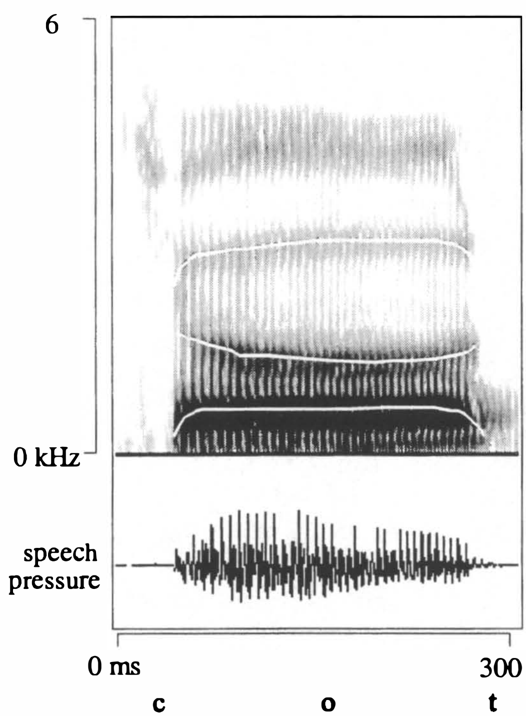

Figure 5-31: Spectrogram (120Hz bandwidth) and waveform of *cot* [coʈ˺] 'drop', spoken by consultant NT. F1, F2 and F3 are highlighted.

PALATAL ON-GLIDES

It is a common phonotactic feature of many Mon-Khmer languages for Palatal consonants to be associated with perceptible [i] on-glides marking the transition between a Palatal consonant and the vowel that precedes or follows it. In Khmer, which contrasts final stops and nasals at four places /p t c k/ and /m n ɲ ŋ/, Henderson (1952:169) finds that the palatal on-glide is one of the principal auditory features distinguishing the palatal /c ɲ/ and alveolar /t n/ finals, which are nearly always unreleased. Wa is largely consistent with this pattern: 'In Waic, as in Mon-Khmer generally, palatal finals have a distinct palatal on-glide' (Diffloth 1980:45).

The articulatory basis of palatal on-glides is the same as that of any formant transitions, but they involve more extreme perturbations of formant frequencies. Formant transitions are by definition transitory, an inevitable consequence of the reconfiguration of the vocal tract. With Palatal stops, however, the tongue body is either moving away from the hard palate following the palato-alveolar frication of an initial /c/ [tɕ], or towards the hard palate prior to the formation of the closure of a final /c/ [c˺]. Placing the tongue body in close proximity to the hard palate happens also to be the oral cavity shape which is characterised by a low first formant and a high second formant resonance, which, if maintained, defines the close front vowel [i].

Perceptual experiments have shown that formant transitions are an acoustic cue used in the perception of stop place of articulation (Delattre et al.1955), but that the transitions themselves are not independently perceived. One might speculate that palatal on-glides are readily perceptible because they are acoustically similar to a distinctive vowel quality universally present in vowel systems. In any case, none of the language's phonemically distinctive vowel qualities is so readily comparable to the formant transitions associated with any of the other stop places of articulation. The [i]-like vowel quality of the palatal transitions is unique to Palatals.

The place of articulation of Palatals involves complexities besides affrication and on-glides. The frication of a Palatal is identifiable from Figure 5-29 as post-alveolar, with friction noise absent below about 3kHz. Assuming that the stop and fricative portions of affricates are homorganic, we can say that the stop portion of the affricate must similarly be post-alveolar [t̠], and also that the nasal portion of the prenasalised post-alveolar stop is post-alveolar [n̠]. The presence of on-glides indicates palatalisation, suggesting that the articulation is laminal rather than apical. Overall, then, the place of articulation may be described as alveolo-palatal, another term for laminal palatalised post-alveolar (Ladefoged and Maddieson 1996:150–151). The appropriate articulatory label for the Wa initial Palatals is therefore alveolo-palatal affricates [tɕ tɕʰ ⁿdʑ ⁿʑʰ].

Spectrograms of palatal on-glides following an initial Palatal stop and nasal are presented in Figure 5-26 and Figure 5-27, from which it is evident that the palatal on-glide represents more extreme changes in formant structure than the formant transitions of the other three places of articulation. Final /t/ and /c/ may be compared in Figure 5-31 and Figure 5-32; final /ŋ/ and /ɲ/ are contrasted in Figure 5-30. In all cases, the displacement of F2 is particularly marked. The [i] quality of the glide associated with a Palatal final is demonstrated by the measurements of F1 and F2 in the spectrogram and derived spectral slice of Figure 5-32 and Figure 5-33.

FINAL PALATALS

While initial Velar and Alveolar stops are easily distinguishable from each other by reference to a range of acoustic cues, the same is not always true of final Palatals, and this threatens the perceptual salience of the system of place contrasts in final stops. The affrication which sets initial Palatals apart from Velars and Alveolars is unavailable as an acoustic cue in final Palatals, since they are unreleased, but the palatal glide remains available as an acoustic cue to place identification. Meanwhile, given that there is already some overlap in the locus frequencies of the F2 and F3 transitions of Alveolars and Velars, introducing final Palatals muddies the distinctions still further. These facts make a strong phonetic case for expecting that perception of final Palatals should involve reference to some other phonetic feature. The distinctive [i] glides are available as an additional acoustic cue to fulfil this role.

A further question is the phonological status of final Palatals in Wa. Some possible analyses were discussed in Section 1. In short, the decision whether or not to recognise final Palatals as distinct from final Velars depends on whether or not there is a fronted velar place of articulation which is distinct from the palatal place of articulation. This study takes the view that this is not the case.

A similar problem in Vietnamese is discussed in Henderson (1965a). The stop consonant inventory of Vietnamese, a Mon-Khmer cousin of Wa, contrasts velar and palatal places of articulation in initial voiceless plosives and initial nasals. The implication of the writing system, based on 17th century pronunciation of Northern Vietnamese, is that final stops preserve the four-way contrast found in initials, using the same spelling conventions for both, shown in Table 5-18.

Table 5-18: Spelling of Vietnamese stops (adapted from Nguyễn 1990:55)

	palatal	*velar*
voiceless stop	ch	c
nasal	nh	ng*

* 'ngh-' before front vowels.

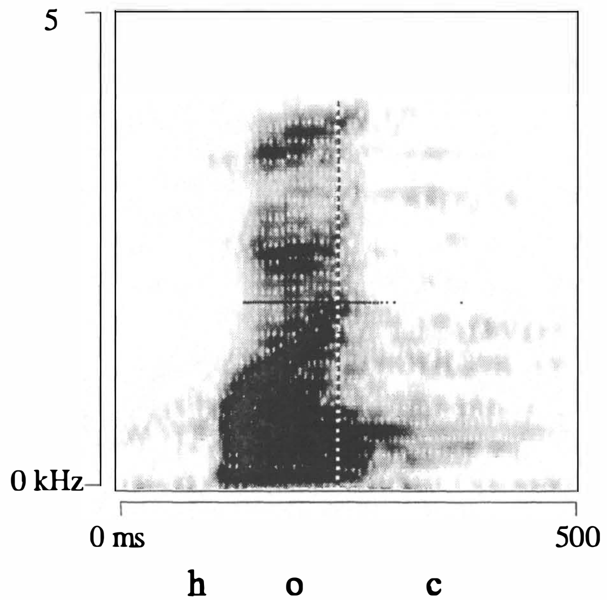

Figure 5-32: Spectrogram (120Hz bandwidth) of *hɔc* [hɔⁱc˺] 'already' spoken by NT. The spectral slice in the following figure is centred on the vertical dotted line, indicating the [i]-quality of the palatal on-glide.

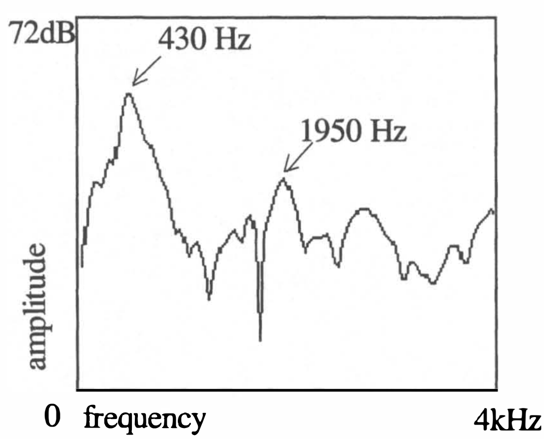

Figure 5-33: Spectral slice (150Hz bandwidth) through final stages of /i/-coloured palatal on-glide in *hɔc* [hɔⁱc˺] 'already', centred on cursor in the previous figure.

Using wipe-off palatograms, Henderson showed that Vietnamese final '-ch' and '-nh' were, in fact, fronted velar [k̟ ŋ̟], distinct from both initial 'ch-' and 'nh-' [c ɲ] and from final '-c' and '-ng' [k ŋ] . Henderson's assessment of the phonemic status of final '-ch' and '-nh' is that '...final "nh" and "ch" are clearly the allophones after front vowels of the phonemes written "ng" and "c" in other contexts,' and that 'the final consonantal alternance, whether of nasals or of stops, is one of three terms, not of four' (Henderson 1965a:351). In South Vietnamese, however, final (written) '-ch' and '-nh' merge after front vowels with final post-alveolar stops and after central or back vowels with velar stops.

The situation in Wa is parallel to that of Vietnamese in a number of ways. Diffloth's (1980) historical phonology predicts that final palatal stops and nasals will be distinct from both the alveolars and velars in all contexts, in a system parallel to that represented in the Vietnamese orthography, but not in Henderson's phonological analysis. In the analysis which informs the PRC writing system for Wa, velar and palatal final stops and nasals have merged phonemically, but are complementarily distributed allophones, in a pattern mirroring Henderson's appraisal of Northern Vietnamese. Finally, the Bible orthography represents a third position, in which Wa final palatals are analysed as either alveolars or velars, as in Southern Vietnamese. This comparison is dulled by the lack of any obvious factor conditioning the assignment of palatals to one category or the other. A further complication is that the alveolar and velar stops and nasals are themselves subject to allophonic variation (as noted in Section 5.2.1), such that there is no firm articulatory basis on which to discriminate between final Alveolars and Palatals and between final Palatals and Velars.

SUMMARY

The analysis here finds that the four phonological categories (Bilabial, Alveolar, Palatal and Velar) make use of six distinct places of articulation: bilabial, dental-alveolar, alveolo-palatal, palatal, velar and uvular. Of these, the alveolo-palatal and palatal categories, and the velar and uvular categories, are complementarily distributed allophones of Palatal and Velar stops, respectively, as discussed above. The Palatals are accompanied by palatal on-glides, which may avoid potential perceptual difficulties in distinguishing palatal articulations from velar and alveolar in certain vocalic contexts.

5.2.2 VOICING CONTRASTS

The release of a stop may be described in terms of the movement of air through the glottis and the vocal tract relative to the three phases of movement of the supralaryngeal articulators: 'closing phase', 'closure' and 'release phase'. In Wa, the airstream associated with stops is egressive and pulmonic. Stops accompanied by identical supralaryngeal articulations are differentiated by the intervention of the larynx on the airstream in the form of voiced phonation and the ensuing aerodynamic conditions within the oral cavity. A four-way categorisation may be applied to Wa stops, arising from two distinctive and potentially co-occurring articulatory actions. The first of these involves either introducing and maintaining voicing during the closure or delaying the onset of voicing until after the release. The second involves delaying the onset of vowel nucleus voicing after the burst.

Linguistic phonetic descriptions are frequently hampered by the problems encountered in the segmentation of speech sounds. For instance, the register contrast, manifested as a complex of phonetic features, smears itself across the boundary between consonants and vowels. The segmentation of stops presents some particular problems. It was, after all, the close relationship and interplay between the laryngeal articulation of stops and the vowels following them that gave rise to the register contrast. Fundamental frequency and phonation type are two phonetic properties which are particularly likely not to be confined by segment boundaries. The articulatory and acoustic correlates of the four-way contrast in stops or the aspirated–unaspirated contrast in sonorants are likewise not contained within those consonants but spill over into neighbouring vowels. The blurred boundaries between consonants and vowels are an inevitable consequence of their being produced by the same articulatory machinery: both stops and vowels involve articulatory activity both at the larynx and in the supralaryngeal tract.

These observations are also the primary motivation for the non-linear phonological organisation of speech sounds in a number of theories. While this study is not primarily concerned with the development of a formal theoretical analysis of either the phonological patterning of Wa speech sounds or of the coarticulatory processes observed in their production, the facts presented here may certainly contribute to both.

Systems of stops with a four-way contrast may be found in approximately 8 per cent of the sample surveyed by Maddieson (1984:26), though most of these involve some 'glottalic' feature, that is, either ejective or implosive consonants. Only five of the languages in Maddieson's (1984:29) database make use of a four-way voicing contrast like that observed in Wa, with plain voiceless, aspirated voiceless, plain voiced and voiced aspirated stops.

The phonetic details of a similar system of contrasts in Hindi are presented in Dixit (1989), Schiefer (1992) and Davis (1994). A widely accepted and attractively simple phonological analysis of the facts in Hindi is of two features [voiced] and [aspirated]. These may be thought of as a 2 x 2 matrix, as in Table 5-19.

Table 5-19: Using two binary stop consonant features to account for a four-way contrast

	[–ASPIRATED]	[+ASPIRATED]
[–VOICED]	p	p^h
[+VOICED]	b	b^h

The Wa stops fit well into this type of analysis in many respects. This study presents experimental evidence to support this, but also focuses on ways in which the phonetic detail of the Wa stops may diverge from the Hindi pattern.

The term 'voiced' is used throughout this section to refer to vocal fold vibration prior to the release burst in stops. This term is equivalent to the 'voice lead' referred to in other studies of stops.

EXPERIMENTAL ANALYSIS OF VOICING CONTRASTS

The quantity of data to be processed was reduced by looking at the voicing contrasts of stops at one place of articulation only, and it is assumed that the results obtained for the Alveolars here could be replicated for the other places of articulation, except for certain universal phonetic differences. In particular, voice onset time has been found to be longer with more back articulations (see Byrd 1993 for English data), though the pattern is not uniform (Maddieson 1997:631). This pattern of voice onset time variability conditioned by place of articulation apparently operates in a trading relationship, with more back articulations having shorter closure duration (Maddieson 1997:622, 630). Closure duration was not measured in this study.

Measurements were made of a set of eighteen syllables with initial alveolar stops, set out in Table 5-20. This set was chosen to illustrate the effects of juxtaposing different segments involving a range of phonetic features. The phonological contrasts in this matrix of syllables may be divided into three categories:

- voicing contrasts in initial stop consonants;
- the register contrast;
- laryngeal final consonants.

Table 5-20: Phonological contrasts maintained by laryngeal articulations in eighteen Wa syllables

<table>
<tr><td colspan="2" rowspan="4"></td><td colspan="6">initial consonant</td></tr>
<tr><td colspan="4">unaspirated</td><td colspan="2">aspirated</td></tr>
<tr><td colspan="2">voiceless
/t/-</td><td colspan="2">voiced
/^{n}d/-</td><td>voiceless
/t^{h}/-</td><td>voiced
/$^{n}d^{h}$/-</td></tr>
<tr><td>clear register</td><td>breathy register</td><td>clear register</td><td>breathy register</td><td>†</td><td>†</td></tr>
<tr><td rowspan="3">final consonant</td><td>(none)</td><td>tɛ
‘sweet’</td><td>tɛ̤
‘peach’</td><td>^{n}dai</i>
‘skirt’</td><td><i>^{n}dɛ̤
‘finish’</td><td>t^{h}a</i>
‘wait’</td><td><i>$^{n}d^{h}$a
‘beforehand’</td></tr>
<tr><td>glottal fricative /h/</td><td>tɛh
‘lessen’</td><td>tɛ̤h
‘turn over’</td><td>^{n}dɛh</i>
‘tie’</td><td><i>$^{n}d^{h}$ɛ̤h
‘clap’</td><td>t^{h}ah</i>
‘cut wood’</td><td><i>$^{n}d^{h}$ah
‘long’</td></tr>
<tr><td>glottal stop /ʔ/</td><td>tɛʔ
‘earth’</td><td>tɛ̤ʔ
‘wager’</td><td>^{n}dɤʔ</i>
‘stupid’</td><td><i>^{n}de̤ʔ
‘nearby’</td><td>t^{h}ɯʔ</i>
‘shove’</td><td><i>$^{n}d^{h}$uʔ
‘gobble food’</td></tr>
</table>

† no register contrast after aspirated initials

In particular, they maximally exploit the system of laryngeally articulated phonological contrasts in Wa. Ignoring vowel quality differences, the words in Table 5-20 are differentiated by laryngeal activity alone. The experimental procedure outlined here concentrates on the laryngeal accompaniment of stop consonants and their interaction with the vowels following them. The final laryngeal consonants /h/ and /ʔ/ are discussed in Section 5.3 and Section 6.7.3.

Measurements were made as outlined, with notes, below. The numbers correspond to those in Figure 5-34. Two further measurements (iv) and (v) are explained in Table 7.25.

Timing measurements:

1 onset of voicing;
2 offset of prenasalisation voicing in syllables with pre-burst voicing cut-out;
3 onset of vowel phonation (see Section 5.2.3).

Fundamental frequency (F0) and closed quotient (CQ) measurements:

(i) F0 and CQ in the 1st period of voicing onset;

(ii) F0 and CQ in the 4th period of voicing onset;

(iii) F0 and CQ of vowel phonation (see Section 5.2.3).

The burst was the reference point for all the temporal measurements. In some cases, the final consonant /k/ of the preceding word *lɔk* in the frame sentence was voiced [g], such that there was no break in vocal fold vibration observed in the laryngograph trace between the preceding word in the wordlist and the prenasalisation voicing of the test word. In such cases, the beginning of the stop voicing was determined by the appearance on the spectrogram of nasal formants if there was prenasalisation. In some cases, weak transients signalling the release of the velar closure of the preceding [g] could be used to define the boundary. Since voicing did not always have cut-out at any point before the burst, the cessation of prenasalisation voicing before the burst was not measurable for all voiced stops.

Since adjacent segments may exert competing and sometimes contradictory influence on the fundamental frequency and phonation type (measured here as closed quotient) of their immediate phonetic environment, there are few single points in these syllables at which the experimenter can sample fundamental frequency and closed quotient and be confident of detecting the influence on these phonetic parameters of any particular segment. The following strategies were employed.

Measurements (i) and (ii) were intended to reflect the type of F0 and CQ change during the vowel onset. They were also used as a reference point in calculating the overall F0 or CQ pattern for each vowel.

Measurement (iii) of F0 and CQ in the vowel nucleus was straightforward in most cases. By comparing spectrograms with laryngograph traces, it was possible to identify a plateau in both the F0 and CQ traces which came after the onset of vowel phonation (see Section 5.2.3) but preceded the effects of any final laryngeal consonant. However, in certain syllables, most often those combining either an aspirated consonant or a breathy register vowel with a final glottal stop, closed quotient was observed to rise consistently, with no such plateau visible. In these and similar cases, the values of F0 and CQ were recorded at the midpoint of the vowel.

NB: The measurements of fundamental frequency in vowel onset are not reported in detail in this section (though the measurements are used in Section 6.7). It was expected that a low rising F0 contour would distinguish vowel onset in voiced stops from a high falling contour of the voiceless ones, the perturbations observed and linked to tonogenetic processes by Hombert et al. (1979). No such effect was generally observed in the data.

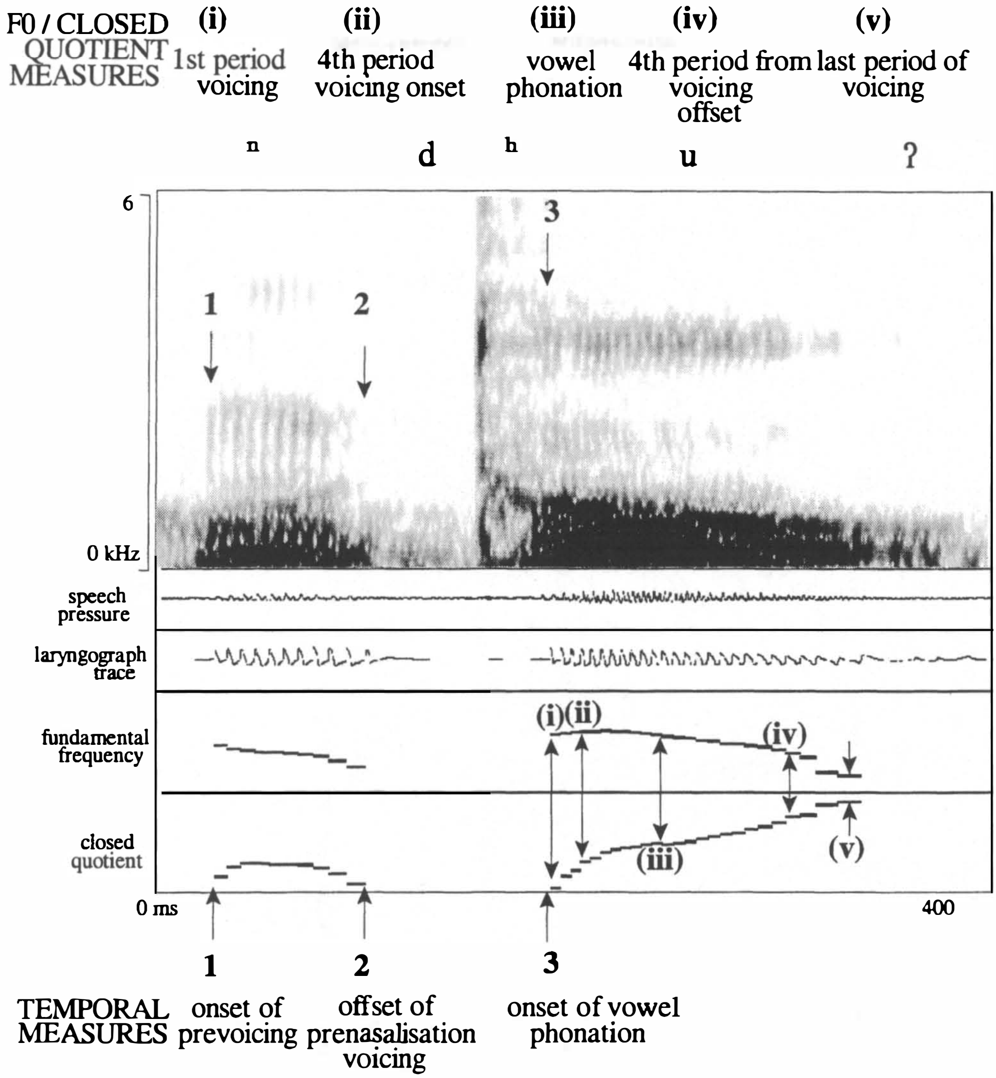

Figure 5-34: Spectrogram (120Hz bandwidth), waveform, laryngograph trace, fundamental frequency and closed quotient of *ⁿdʰuʔ* 'gobble', spoken by NT. Numerals refer to the measurement schema in the text.

VOICE ONSET TIME (VOT)

A considerable body of literature has accumulated on the subject voice onset time (VOT) since the classic experiments of Lisker and Abramson (1964). They measured voice onset time as 'the interval between the release of the stop and the onset of glottal vibration, that is, voicing' (Lisker and Abramson 1964:389). Lisker and Abramson demonstrated that voice onset time may be thought of as a continuum which languages carve up in different ways for the purposes of stop consonant perception. They showed further that the number of perceptual categories into which the continuum may be divided also varies cross-linguistically, thus while English and Spanish speakers impose a single perceptual boundary along the continuum (albeit at different places), Thai speakers impose two boundaries, dividing the continuum to enable the three-way contrast in stop-voicing found in that language (Lisker and Abramson 1970). Unfortunately, the apparent simplicity of these findings invited exploitation of the VOT measurement. Abramson (1977:297) was prompted to remind VOT enthusiasts that:

> Since this work [Abramson and Lisker 1970, 1973, Lisker and Abramson 1964, 1970] has stimulated many studies on the part of others, gratifyingly too numerous to mention, it is important to stress that psychological and linguistic discussions of VOT should not give the impression that it is an acoustically simple dimension. It is radically different from many other continua in the literature in that there is an abrupt qualitative discontinuity at the point of stop release.

The frequency distribution of the VOT measurements of the alveolar stops in Wa is displayed as a histogram in Figure 5-35. VOT clearly distinguishes voiced stops from voiceless stops. There are no stops with VOT between –20ms and 0ms. On the basis of these measurements, it can be stated that there is vocal fold vibration prior to the burst in all stops which are classified here as phonologically 'voiced'.

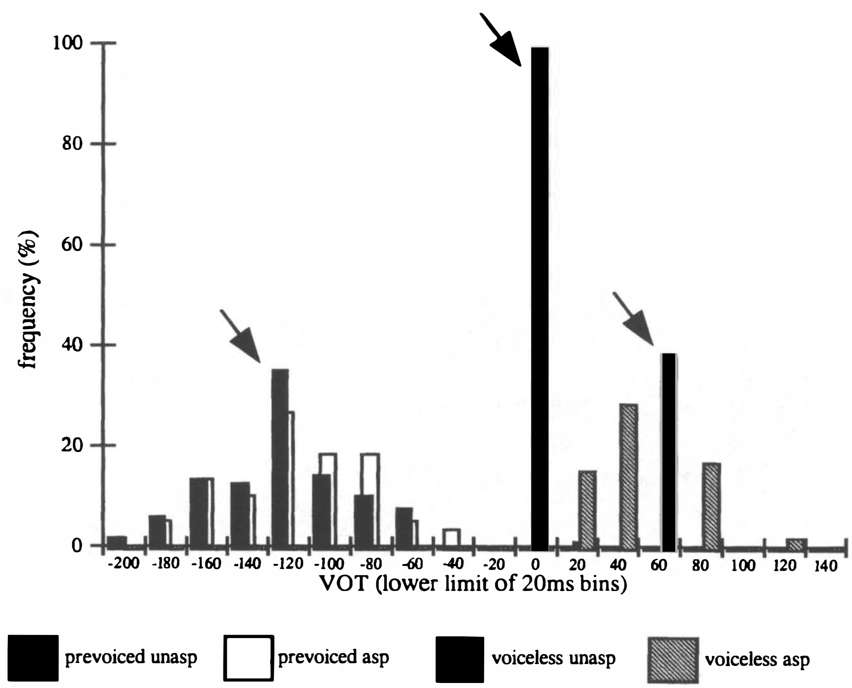

Figure 5-35: Histogram of voice onset time in Wa stops. /t/ and /ⁿd/ 120 tokens each; /tʰ/ and /ⁿdʰ/ sixty tokens each = 360 tokens total. Bars are weighted to percentages of total in each category.

PHONETIC VARIABILITY OF VOICED STOPS

Voicing in Wa differs from the Hindi pattern, where [+VOICE] is uniformly represented by at least 70ms of voicing before the release (Davis 1994:184), after which the vocal folds continue vibrating uninterrupted into the vowel. In Wa, the phonetic implementation of [+VOICE] follows one of four patterns, all of which may be observed in both aspirated and unaspirated voiced stops. They are described and given narrow transcriptions in Table 5-21. Example spectrograms of each type are given in Figure 6.36 and Figure 6.37.

Table 5-21: Variation in phonetic detail of voiced stops

Description	*prenasalised*	*voicing cut-out*	*narrow transcription*	
			unaspirated	*aspirated*
voicing is not nasalised; vocal fold vibration continues through the stop release	no	no	[d]	[dɦ]
prenasalisation; vocal fold vibration continues through the stop release	yes	no	[nd]	[ndɦ]
prenasalisation; vocal fold vibration cuts out before the stop release	yes	yes	[nt]	[nth] or [ntɦ]*
voicing is not nasalised; vocal fold vibration cuts out before the stop release	no	yes	[dˋt]	[dˋth] or [dˋtɦ]*

- see Section 5.2.3.

The symbols in Table 5-21 are used to imply the following:

[d] portion of closure phase (and release**) accompanied by vocal fold vibration

[t] portion of closure phase (and release**) with no vocal fold vibration

[n] portion of closure phase accompanied by vocal fold vibration and lowered velum

[h] voiceless aspiration: vocal folds not vibrating between release and onset of vowel phonation (see Section 5.2.3)

[ɦ] voiced aspiration: vocal folds vibrating between release of a onset of vowel phonation

**unless followed by 'unreleased' symbol [ˋ]

[d] Vocal fold vibration is maintained without prenasalisation, despite the increase in air pressure in the oral cavity and pharynx which cancels out the transglottal pressure difference in [nt] and [d^{n}t]. With neither nasalisation nor voicing cut-out, this variety of voice lead is most likely of all four to involve cavity expansion.

[nd] Cavity expansion is less likely to be necessary in this type of voicing, which employs the velum-lowering voice preservation strategy. Opening the naso-pharyngeal

port allows air to escape from the cavity behind the stop closure out through the nose. Raising of the velum again prior to the burst does not bring about a cessation of voicing.

[nt] This variety is the same as [^{n}d] in all respects except that when the velum is raised prior to the burst, the transglottal pressure drop decreases and vocal fold vibration cuts out.

[d˺t] This combination illustrates the likely course of events if the velum remains raised throughout the stop. If voicing is to be maintained during the closure, it must be done by cavity expansion alone, the same as in [d]-type non-nasalised stops with no voicing cut-out. In this case, the oral cavity reaches a limit beyond which it will not expand further and voicing cuts out, as in the experiment conducted by Bickley and Stevens (1986). The last cycles of vocal fold vibration before cut-out are characteristically breathy. This is observed as a falling closed quotient trace in the four periods of vocal fold vibration in the voicing of *^{n}d^{h}u?* [d˺tuʔ] in Figure 6.37.

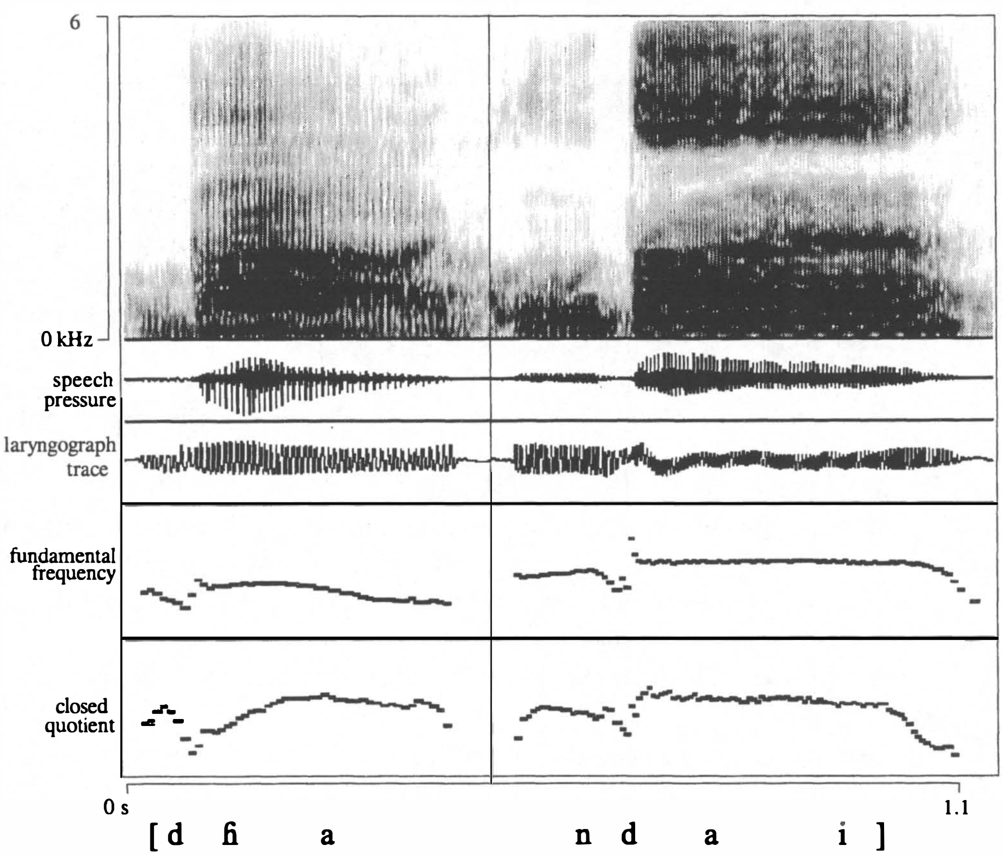

Figure 5-36: Voiced alveolar stops with vocal fold vibration uninterrupted over the release, without and with spectrographically evident nasalisation prior to the release burst. Spectrogram (150Hz bandwidth), waveform laryngograph trace, fundamental frequency and closed quotient of *^{n}d^{h}a* 'beforehand' and *^{n}dai* 'skirt' (different speakers).

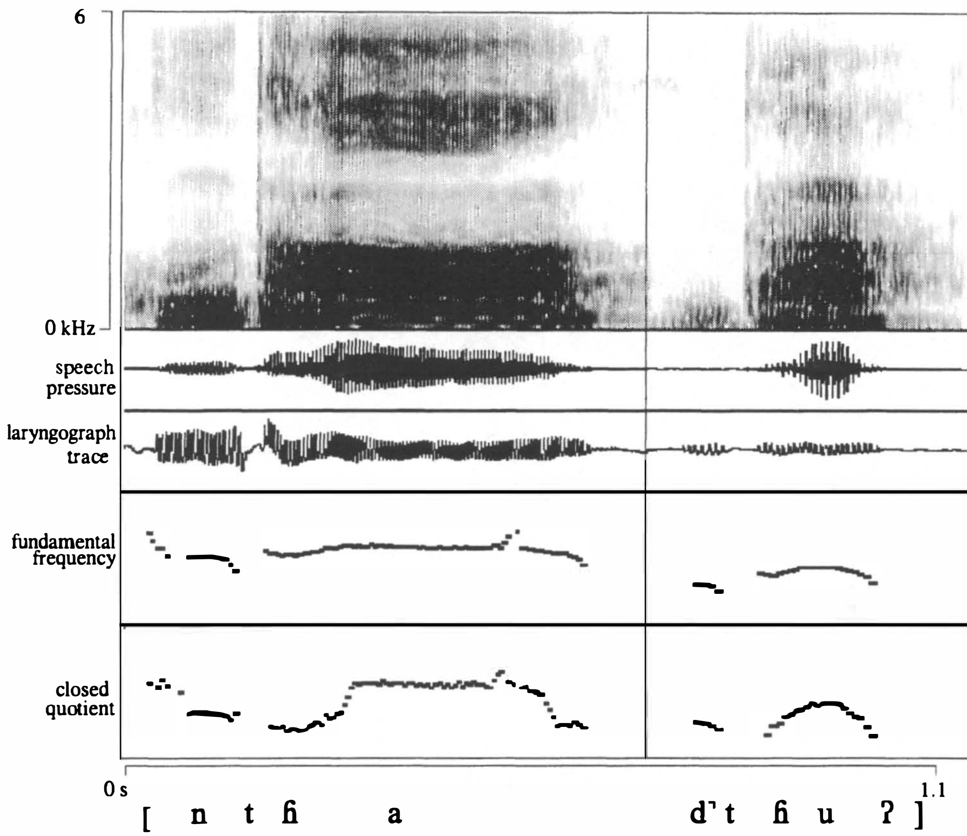

Figure 5-37: Voiced alveolar stops with voicing cut-out during the release, with and without spectrographically evident nasalisation prior to the burst. Spectrogram (150Hz bandwidth), waveform laryngograph trace, fundamental frequency and closed quotient of *ⁿdʱa* 'beforehand' and *ⁿdʱuʔ* 'gobble food' (different speakers).

The phonetic variation of voiced stops may be accounted for by considering the aerodynamics of phonation. The VOT measurements established that voiced stops may be defined by the presence of vocal fold vibration prior to the release of the closure formed by the oral articulators. The closure seals off the oral cavity, preventing the air coming up from the lungs and through the glottis, passing out through the mouth. As pulmonic air flows up into the oral cavity, pressure builds up. Even if subglottal pressure stays the same, the increased supraglottal pressure will cancel out the transglottal pressure drop which drives phonation, and the vibratory cycle of the vocal folds peters out (Bickley and Stevens 1986). If voicing is to continue throughout the closure, some articulatory strategy has to be implemented to maintain the transglottal pressure drop (Ohala 1983, 1990). Two such strategies are considered here.

The first strategy entails lowering the velum, allowing air to pass through the naso-pharyngeal opening and out through the nose, and preventing supraglottal pressure from building up. Voicing may be maintained indefinitely by this strategy, or at least as long as the subglottal pressure is kept up, though this is clearly not necessary or desirable in the voicing of stops. The velum must be raised again prior to the release of the oral articulators, to enable the pressure build-up which provides the energy for the release burst. While the velum is lowered, the vocal tract is effectively reconfigured into the shape adopted for nasal stops, with the corresponding change in resonance which that configuration of the vocal tract implies. Nasalisation during stop voicing was determined from spectrograms by the presence of nasal resonances and anti-resonances. If the low-frequency voice bar was the only periodic resonance visible in the spectrogram, then the voicing was judged to be non-nasalised. The judgements of whether nasal resonance was or was not spectrographically evident were, inevitably, partially subjective.

This is simplistic, given that there is in fact a continuum of possibilities for varying degrees of velic opening, from slight nasal leak to a fully lowered velum (Rothenberg 1968:99ff.). For this reason, and because of the variability of the computer spectrogram's sensitivity to low levels of nasal resonance, it was possible for nasalised stop voicing to be wrongly categorised as non-nasalised, though probably not vice-versa. The nasal/non-nasal categorisation had to be made subjectively.

The second strategy involves allowing the pharyngeal and oral cavities to expand, increasing the volume of the space into which the air emerging through the glottis may flow. Since the walls of the mouth and pharynx are soft and compliant, the expansion may take place passively. The scope for expansion is finite, so this strategy can prolong phonation only for a limited time, but this is sufficient for the purposes of maintaining voicing during stop closure. The physiological structure of the vocal tract offers less scope for passive expansion in back articulations, such as velars and uvulars, than in front articulations, such as bilabials. This is a possible explanation for the relative rarity, cross-linguistically, of voiced back stops compared to voiced front stops (Maddieson 1984).

Lowering the larynx is another way of enlarging the pharyngeal and oral cavities to enable phonation to continue (Lindau 1984). Vertical movement of the larynx may be evident in the DC component of the laryngograph trace (Marasek 1997), but monitoring it by this method is generally unreliable and was not attempted in this study.

Estimates of the actual duration of voicing that these strategies might enable were calculated by Rothenberg (1968:):

> Without any special adjustment, equalization of transglottal air pressure would occur in 4ms. ...with passive expansion of the pharyngeal walls, voiced closures could be accommodated up to 20–30ms ... Active expansion of the pharynx might give voiced closure durations of 80–90ms. ... even longer closure durations might be explained by incomplete velar closure.

The distribution of the phonetic varieties of voiced stops is explored in Table 5-22 and Table 5-23. The varied phonetic detail of stop voicing is, at least in part, a function of speaker variation ($F(9,178) = 8.149$, $p < 0.0001$). The effect of aspiration on the type of voicing is also significant ($F(1,178) = 6.503$, $p = 0.012$), though a significant interaction in the same ANOVA test between the effects of aspiration and speaker ($F(9,178) = 1.396$, $p = 0.003$) suggests that, for some speakers at least, whether or not the stop is pronounced with or without prenasalisation and/or voicing cut-off is dependent in part on whether or not the stop is aspirated. Speaker variation is explored in more detail in

Table 5-24. It is hard to say with certainty, but it is likely that dialect and/or accent are one source of variation.

Thirty of the 179 (16.8 per cent) voiced stops examined in this study are phonetically [d]-type stops, while less that 10 per cent are of the [dˋt] type. These types of voicing stop are the least common and are about as likely to occur with aspirated stops as with unaspirated. Just over one quarter of the stops in the sample are [nt] type. Stops with [nt] type voicing are more likely to be aspirated than not. [nd] is the most common type of voicing, accounting for nearly half the sample and generally associated with unaspirated stops rather than aspirated ones.

The observation that the [nt] type of voicing is less frequent than the [nd] type is predicted by the voice-preserving articulatory strategies described above. The vocal tract, having resorted to prenasalisation in order to preserve voicing, is not obliged to loosen for cavity expansion, as is the case in the [d]-type non-nasalised stops. The walls of the pharyngeal and oral cavities may be left at normal 'stiffness', or at least are not loosened, and so may be expected to have less capacity for passive expansion, with the effect that the transglottal pressure-drop is rapidly cancelled out and vocal fold vibration ceases.

Table 5-22: Co-occurrence of nasalisation and voice cut-off in stop voicing

Total: 178 stops	*no voice cut-off*		*with voice cut-off*	
	type	*n*	*type*	*N*
voice lead not nasalised	[d]	29 (16.8 per cent)	[dˋt]	15 (8.4 per cent)
voice lead nasalised	[nd]	87 (48.6 per cent)	[nt]	47 (26.3 per cent)

Table 5-23: Speaker variation in distribution of voicing varieties

speaker	[d]	[nd]	[nt]	[dˋt]	
RM	0	4	14	0	
NT	2	16	0	0	
YH	5	1	8	4	
JN	0	6	12	0	
ST	4	12	0	0	
NKP	6	12	0	0	
SRM	0	14	4	0	
APP	7	0	0	11	
AP	6	10	3	0	
SJ	0	12	6	0	
totals	30	87	47	15	= 179
per cent of total	16.76	48.60	26.26	8.38	= 100 per cent

Table 5-24: Speaker variation in distribution of voicing varieties, accounting for aspiration

	[d]			[nd]			[nt]			[d˺t]		
speaker	*unasp*	*asp**	*n*	*unasp*	*asp**	*n*	*unasp*	*asp**	*n*	*unasp*	*asp**	*n*
RM	0	0		3	2		9	10		0	0	
NT	2	0		10	12		0	0		0	0	
YH	5	0		1	0		5	6		3	2	
JN	0	0		6	0		6	12		0	0	
ST	2	4		10	4		0	0		0	0	
NKP	0	12		12	0		0	0		0	0	
SRM	0	0		12	4		0	8		0	0	
APP	5	4		0	0		0	0		7	8	
AP	5	2		8	4		0	6		0	0	
SJ	0	0		12	0		0	12		0	0	
Totals	19	22	41	74	26	100	20	54	74	10	10	20
per cent of total	46.34	53.66		74.00	26.00		27.03	72.97		50.00	50.00	

* As the sample contains half as many aspirated tokens as aspirated, the numbers of aspirated tokens have been weighted by double for comparison.

A possible explanation for the phonetic variability of voiced stops in Wa is the fact that they are the reflexes of clusters in an earlier stage of the language. Generally, nasalisation of stop voicing may represent an intermediate stage in a phonetically driven model of the development of prenasalised stops from voiced stops, when devoicing during stop closure might otherwise threaten the contrast between voiced and unvoiced stops. Voiced stops evolved from Proto Waic homorganic nasal+ voiceless stop clusters, the Proto Waic voiced-voiceless stop contrast having become redundant once the register contrast had developed. The phonetic differences between voiced stops described here are sub-phonemic, since the presence of nasalisation *per se* is not essential for maintaining the phonemic contrast.

DURATION OF VOICE LEAD IN VOICED STOPS

The factors affecting the duration of the voicing lead in stops were explored with an ANOVA test (Table 5-25). The results suggest that the duration of voicing prior to the burst release is significantly influenced by cross-speaker variation. Two more factors influencing voice lead duration are the type of voicing and whether or not the stop is aspirated. These effects are explored in Table 5-26 and Figure 5-38.

Table 5-25: Design and results of ANOVA test for factors in duration of voice lead

Dependent variable: duration of voice lead
Independent variables:

	d.f	*F*	*p*	*sig*
aspiration	178	1.5	0.22	
voicing cut-off	178	18.397	< 0.0001	•
prenasalisation	178	6.719	0.01	○

The effects on duration of voice lead are consistent with the aerodynamically motivated account of the four types of voiced stop above. Voice lead is generally longer if it is nasalised, other things being equal: [nd] and [nt]-type voicing is observed to be longer than [d] and [d̚t] respectively. Lowering the velum to maintain the transglottal pressure drop is not only a voice-maintaining strategy but is also associated with longer voice leads.

Conversely, the two types of voiced stop with voicing cut-out, [nt] and [d̚t], are longer than their counterparts with uninterrupted vocal fold vibration, [nd] and [d]. This suggests that voicing cut-off is more likely as voice lead duration increases, since the longer phonation is maintained, the more likely the transglottal pressure drop is to fall below the critical threshold beyond which vocal fold vibration can no longer be powered. A further effect on voice lead duration is that of aspiration: within each category, voicing is slightly longer in unaspirated stops and shorter in aspirated ones.

Table 5-26: Duration of stop voice lead by voicing type and aspiration (See also Figure 6.38)

phonetic detail of voice lead		*mean duration (ms)*	*s.d.*	*n*
[d]	all	91.2	27.94	29
	unasp	97.1	29.58	18
	asp	81.5	23.11	11
[nd]	all	107.7	31.74	87
	unasp	110.6	32.90	74
	asp	91.1	16.79	13
[nt]	all	123.3	33.00	47
	unasp	127.5	29.27	18
	asp	120.7	35.37	29
[d˺t]	all	112.8	20.25	15
	unasp	115.4	15.71	10
	asp	107.6	28.78	5
all		109.5	32.20	178

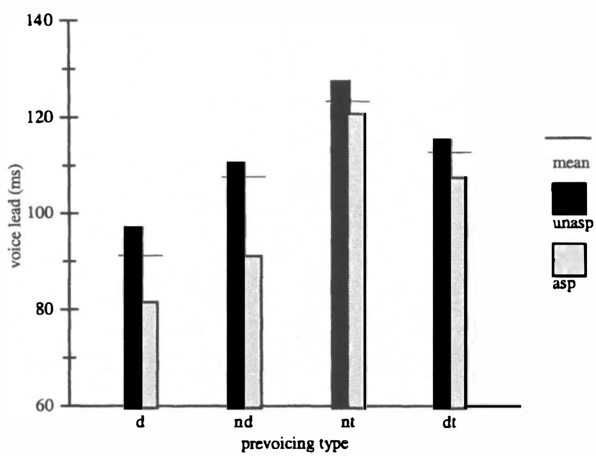

Figure 5-38: Effect of nasalisation and voicing cut-out on mean voice lead of voiced stops. Number of tokens represented shown on top of each bar. Figures given in Table 5-26.

VOICELESS STOPS

Stops without voice lead are distinguished from voiced stops by the fact that vocal fold vibration is inhibited throughout the closure until at least the time of the burst. This is accomplished by implementing articulatory strategies which suppress voicing, in direct opposition to the voice-maintaining strategies discussed above. These strategies diminish one or more of the prerequisites of vocal fold vibration: sufficient airflow, sufficient narrowing of the glottis or sufficient compliance of the vocal folds.

The first strategy entails tensing the walls of the pharyngeal and oral cavities to inhibit their passive expansion. This prevents the transglottal pressure drop from building up, cutting off the power supply for the airflow necessary for phonation. Without expansion, and as long as the oral closure is maintained, supralaryngeal air pressure rises to match subglottal pressure, cancelling out the transglottal pressure difference.

The second strategy is to configure the larynx so that vocal fold vibration does not occur even when the pressure drop across the larynx is sufficient to enable vibration to occur, by stiffening the vocal folds and/or abducting them.

In unaspirated stops the vocal folds have to be adducted and in a vibration-prone position ready for vocal fold vibration to begin within a few milliseconds (see VOT measurements in Figure 5-39) of the burst, and the restoration of a transglottal pressure drop thereafter. In aspirated stops, however, the vocal folds are abducted at the time of the burst as part of the ongoing sequence of glottal abduction and adduction. Widening the glottal aperture reduces the acceleration of air at the glottis and diminishes the Bernoulli effect, either preventing vocal fold vibration or making it more breathy, but not precluding it absolutely since vibration may be maintained by other means.

5.2.3 ASPIRATION

The aim of this section is to investigate the acoustic and/or articulatory correlates of the phonological category [ASPIRATED]. The principle difficulty which arises is deciding what to measure.

It was shown above that the [VOICE] contrast /t t^h/ vs /^{n}d $^n d^h$/ depends on the prevention or enablement of vocal fold vibration before the burst. The [ASPIRATED] contrast, on the other hand, is based on delaying the onset of the vowel until some time after the release of the closure. In the Hindi model, aspiration is defined as the 'duration from the point of articulatory release to the onset of the vowel following word-initial ... plosives' (Dixit 1989:218) or as the 'duration of the noise ... between the stop consonant release and the following vowel' (Davis 1994:177).

VOT, discussed in Section 5.2.2 above, is one method of assessing this duration and will be looked at first. From the measurements of VOT illustrated earlier in Figure 5-35, it is clear that VOT does not help us to distinguish between aspirated and unaspirated voiced stops. However, voiced stops with voicing cut-out before the release have, effectively, two instances of voicing onset and therefore, arguably, two voice onset times also. This second, post-release voice onset was ignored for the purposes of the VOT measures discussed above. The histogram in Figure 5-39 includes all instances of post-release onset of vocal fold vibration, regardless of the presence or absence of voice lead, therefore including all voiceless stops and all voiced stops in which there is voicing cut-out before the release, but excluding voiced stops in which vocal fold vibration continues uninterrupted through the burst.

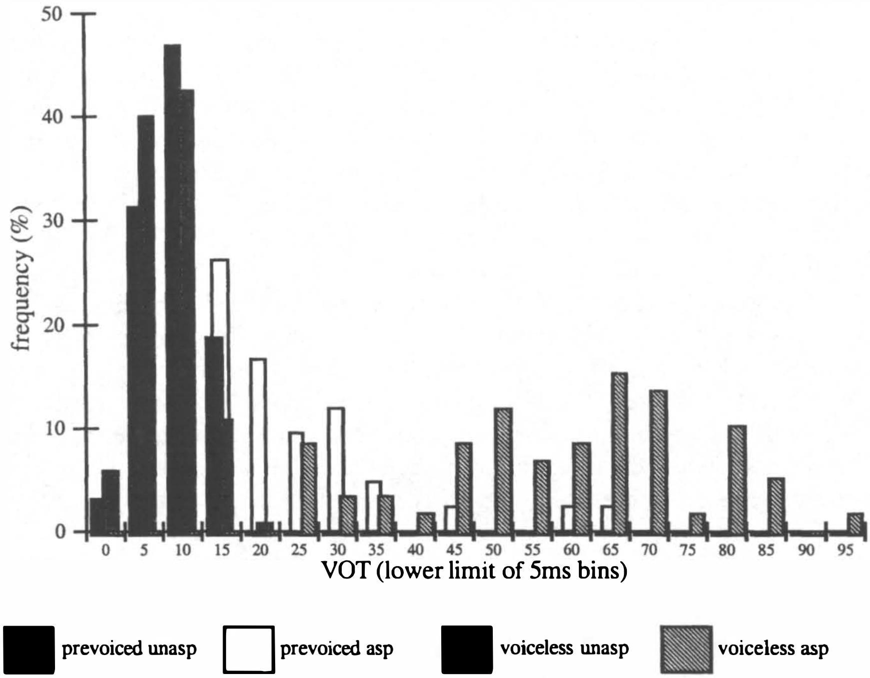

Figure 5-39: Histogram of post-release VOT in Wa stops, including that of voiced stops with voicing cut-out before the release. /t/ 120 tokens; $/^{n}d/$ 32 tokens; $/t^{h}/$ 59 tokens; $/^{n}d^{h}/$ 42 tokens = 253 tokens total. Frequency is normalised to a percentage of the total in each category.

In Figure 5-39 the unaspirated stops may be easily identified, though their distribution overlaps somewhat with the voiced aspirates. The relatively flat distribution of post-release VOT in voiced aspirated stops with voicing cut-out blurs the boundary between the voiced aspirated and voiced unaspirated categories. VOT, measured in this way, clearly fails to capture the aspirated/unaspirated contrast in voiced stops.

The relevance of measuring post-release VOT in aspirates is questionable because it is of doubtful perceptual salience. Davis (1994:183), citing Lisker and Abramson (1967), comments that the earliest measurable periodicity in the signal is typically low-amplitude and not necessarily perceptually salient. It seems risky, therefore, to assign post-release VOT a major role in preserving the contrast between aspirated and unaspirated stops in Wa.

Post-release VOT does not characterise aspiration, because the beginning of vocal fold vibration does not necessarily coincide with the end of aspiration noise. This is obviously the case in voiced stops with uninterrupted vocal fold vibration. Lisker and Abramson (1964:419) describe a similar situation with regard to the voiced aspirates of Hindi and Marathi: 'Instead of the time of onset of voicing it is the kind of voicing that distinguishes the voiced aspirates.' The crux of the problem is how best to define the point in time where aspiration noise ends and the vowel begins. Davis (1994) uses an acoustic 'noise offset measurement', defined as

> the beginning of the second formant of the following vowel, [of which the] onset nearly always coincides with the offset of post-release noise ... because its appearance represents the full attainment of vowel onset. (Davis 1994:182)

She further asserts that her noise offset measurement is consistently accurate by comparing it with VOT in voiceless aspirated syllables, in which the two are identical. This method, while attractively simple, is not possible for all data, and in any event not suited to the Wa data here.

An alternative approach is to avoid the acoustic domain altogether and to look directly to the larynx. Evidence from studies of other languages with voiced aspirated stops suggests that a gestural analysis is appropriate for stops. Rothenberg (1968:102) refers to this as a 'ballistic cyclic opening movement of the glottis'. In their study of Hindi, Benguerel and Bhatia (1980) determined the onset of vocal fold approximation by fibreoptic laryngoscopy, using the distance between the vocal processes of the arytenoid cartilages as their measure. These studies lead us to expect that voiced aspirates will be accompanied by a glottal abduction-adduction gesture ending with adducted vocal folds some time after the release of the oral articulators.

In the present study, the presence and nature of such a gesture was tracked by its effect on closed quotient. The end of the gesture involves an abrupt change in the gradient of the closed quotient trace which will be referred to here as the point of 'vowel phonation onset'. The label 'vowel phonation' is chosen above 'modal phonation' since vowels are not necessarily modal in Wa because of the register contrast.

The sequence of events immediately following the release varies both within the data of individual speakers and between speakers. The variation is examined by considering two temporal factors: the absolute beginning of vocal fold vibration (VOT) and the onset of vowel phonation, as defined above. Three possible sequences are observed:

- no vocal fold vibration at stop release, first vocal fold vibration is that of vowel phonation. Only VOT measurable, coincides with vowel phonation onset;
- No vocal fold vibration at stop release, first vocal fold vibration occurs between release and vowel phonation. Both VOT and CQ gradient change are measurable; but the point of vowel phonation onset is indicated by the latter only;
- Beginning of vocal fold vibration precedes stop release or is simultaneous with it, onset of vowel phonation follows. Vowel phonation onset measurable only as a change in phonation type.

It is to be expected that if the vocal folds vibrate through all or part of the abduction-adduction gesture, then the adductive tension of the vocal folds is minimal, the result will be breathy phonation. If the vocal folds are held apart, they may still be induced to vibrate, but the open phase of each glottal cycle increases with the degree of abduction, measurable as a drop in the laryngographically derived closed quotient trace.

However, the closed quotient trace is useful for more than simply detecting the breathy phonation in aspiration. Inspection of the closed quotient traces shows that it gives a clear indication of the termination of the glottal abduction-adduction gesture. The glottal gesture concludes with the restoration of the phonation type of the vowel (shown in Section 6.7 to be similar to that of clear register but slightly breathier). During the adduction phase of the gesture, closed quotient increases. The gesture ends when the glottis reaches the width which will subsequently be maintained for the rest of the vowel. The end of the gesture may be read from the closed quotient trace as sharp change in gradient. Experimentation showed that, where necessary, the closed quotient trace could be used to identify the vowel phonation onset consistently. The histogram in Figure 6.40 illustrates the frequency distribution of vowel phonation onset time, using all syllables for which this was measurable. This involved a larger subset of the stop syllables than could be included for VOT before, since it included voiced aspirated stops with no voice cut out, for which no post-release VOT measure had been possible but to which the vowel phonation measure could be applied.

The distribution is clearly bimodal. A summary of the measurements is given in Table 5-27. An ANOVA test with post-hoc Scheffé comparisons confirmed the impression given by the histogram that the vowel phonation onset times of the aspirated stops are statistically different from the unaspirated stops ($F(3,247) = 17.414$, $p < 0.00005$), but that there is no significant difference between voiced and voiceless stops of either category. The greater spread on the histogram of vowel phonation onset times in aspirated consonants may be an artefact of the crudeness of the vowel phonation onset measurement.

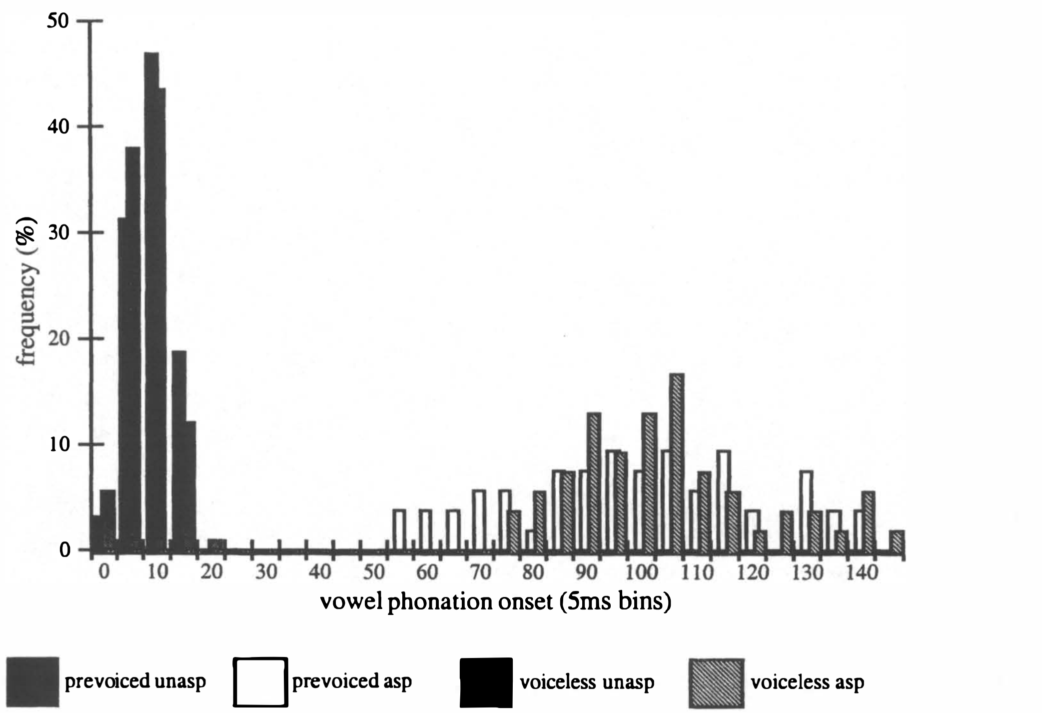

Figure 5-40: Histogram of vowel phonation onset time in Wa stops.

Table 5-27: Summary of vowel phonation onset times (ms)

voicing category	*mean*	*s.d.*	*n*
voiceless unaspirated	10.31	3.74	108
voiced unaspirated	11.50	3.45	32
voiced aspirated	101.63	25.38	54
voiceless aspirated	104.69	17.11	54

The vowel phonation onset measure demonstrates that the feature [ASPIRATION] in all aspirated Wa stops may be identified phonetically. It is possible also that the abrupt change in closed quotient in voiced aspirated stops with no voicing cut-out may have perceptual salience as a sharp change in phonation type.

When there is voicing cut out before the release, the part of a voiced stop which precedes the release is easily segmentable in acoustic terms from the remaining part of the stop. This is consistent with their origins as (nasal + stop) clusters (Section 4.2.2). After voicing cut-out, there is little, if anything, to distinguish the remaining stop from a voiceless one. On the other hand, many voiced stops have uninterrupted vocal fold vibration throughout and cannot be segmented in the same way.

5.2.4 UNRELEASED FINAL STOPS

Voicing contrasts are neutralised in final stops. Zhōu and Yán (1984) describe final stops as voiceless, implying that vibration of the vocal folds ceases at the formation of the stop closure. The experimental data presented here do not support this assertion.

Final stops in Thai also represent a restricted class compared to the inventory of initial stops, which (except for velars) have a three-way contrast in voicing: voiced, voiceless unaspirated or voiceless aspirated. Despite some debate[18] on the topic, 'the overall finding through acoustic analysis is that the closures of word-final stops [in Thai] are silent, i.e., they show no glottal pulsing' (Abramson 1972 and pers. comm.).

Only a small number of final stops are included in the corpus of recordings. The material presented here comprises a small number of final stops at four places of articulation read by one consultant only, listed in Table 5-28. These are all Dai loanword numerals simply because no other final stops were included in the wordlist. There is no reason to expect that words of Waic origin would behave any differently. Additionally, two words with final palatals from the main wordlist, read by eleven consultants, were examined: /hoc/ 'come' and /hɔc/ 'already'.

For each stop, one measurement was made of the time from the formation of the closure to the cessation of vocal fold vibration. The formation of the closure was identified on the spectrogram as the end of vowel formant structure and on the waveform as an abrupt drop in amplitude; the cessation of vocal fold vibration was measured as the last well-formed peak on the simultaneous laryngograph waveform. Time measurements were, therefore, accurate only to the nearest 10ms or so.

[18] A lively discussion on the *Sealang* mailing list concerning the use of voiced symbols /b d g/ for final stops in Mary Haas's (1964) Thai-English Dictionary is archived on the Internet at: *ftp://ftp.nectec.or.th/pub/info/mailing-lists/sealang-l/sealang-l.9505* and *.9506*.

Table 5-28: Dai loan numerals with final stops

ʔet	'one'
r^h^ok	'six'
pɛt	'eight'
sip	'ten'

The measurements are displayed graphically in Figure 5-41 and Figure 5-42. Figure 5-41 shows a high degree of between-speaker variability in the coordination of voicing with final palatals. The palatal stops of consultants RM, NT, JN and possibly also YH, may be described as voiceless, since the inaccuracy of the measurement procedure meant that cessation of voicing about 10ms or less after the closure may be described as simultaneous with the closure. The same cannot be said for the other subjects' stops, however, which are clearly voiced. The mean duration for the sample is 24ms (s.d. 17ms). Vocal fold vibration continued until the closure in all cases, so no negative measurements were recorded.

The measurements of the single consultant, SJ, reading the stops at all four places of articulation are displayed in Figure 5-42. Although the sample is too small to draw firm conclusions, there is little evidence here that there is a simple relationship between the place of articulation of a final stop and the duration of vocal fold vibration after the formation of the stop closure. One pattern that might have been expected is longer voicing with more front articulations, in which the capacity for voice preservation by cavity expansion is greatest (Ohala 1983:197).

5.2.5 CONSONANT CLUSTERS

The initial consonant clusters which may occur in Wa are highly restricted. Liquids /r/ or /l/ may follow bilabial or velar initial stops /p p^h ^mb $^mb^h$ k k^h ^ŋg $^ŋg^h$/, yielding sixteen possibilities in total (see Zhōu and Yán 1984:6 for examples). Spectrograms of clusters involving both liquids are shown in Figure **5-43** and Figure **5-44**. The temporal coordination of aspiration is unaffected by the presence of a liquid as C2 in a cluster. Devoicing of /l/ or /r/ in C2 in position following a voiceless aspirated stop is noted by Wáng and Chén (1981:49–50): partial devoicing of /l/ in *$^mb^hla$ʔ* is evident in Figure **5-44**.

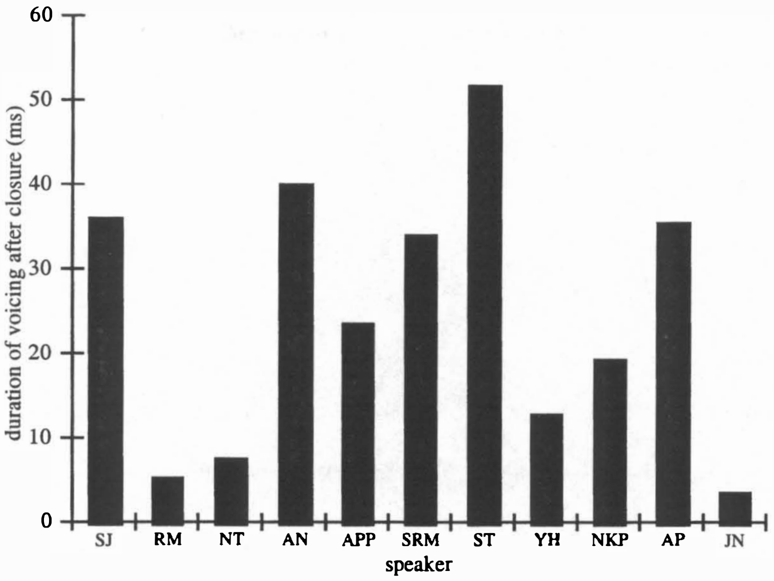

Figure 5-41: Duration of voicing after final palatal stop closure for eleven speakers. Each bar represents the mean of four tokens.

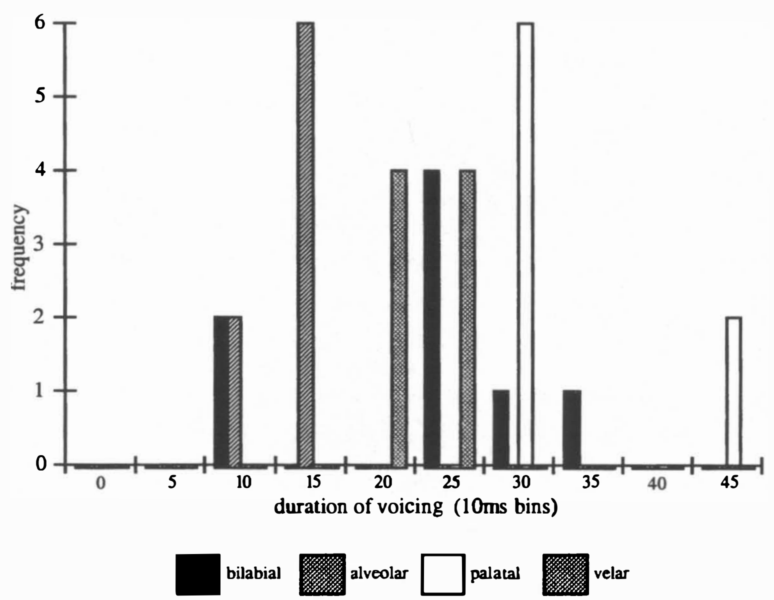

Figure 5-42: Frequency distribution histogram of voicing duration in eight final stops at each of four places of articulation, as spoken by consultant SJ.

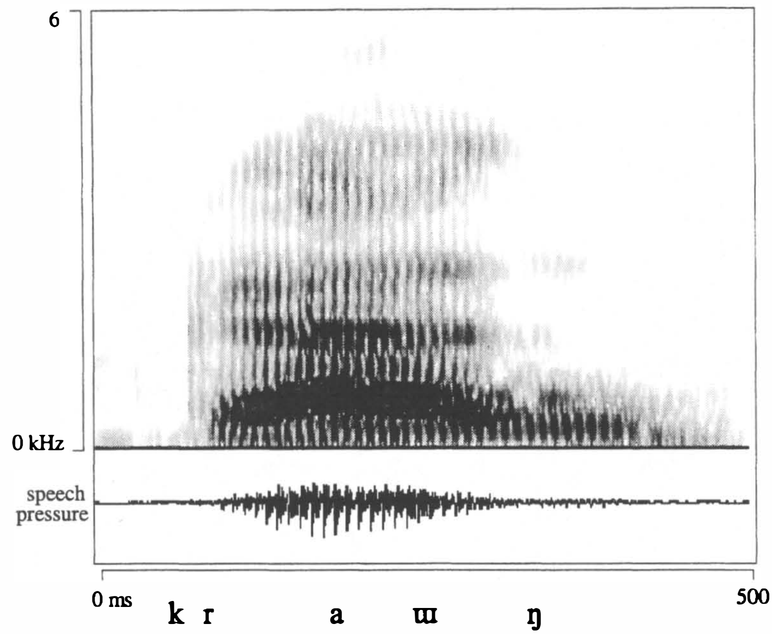

Figure 5-43: Spectrogram (150Hz bandwidth) and waveform of *kraɯŋ* 'drum' spoken by NKP.

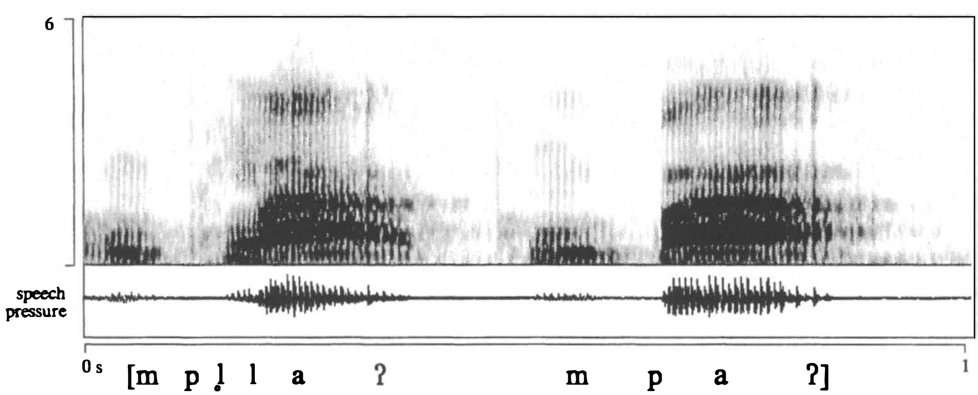

Figure 5-44: Spectrogram (150Hz bandwidth) and waveform of *$^{m}b^{h}$laʔ* '(a kind of tobacco)' and *^{m}baʔ* 'invite' spoken by JN. Both initial stops are phonetically [mp]-.

5.3 Laryngeal consonants

The stops discussed above involve articulatory activity both in the larynx and in the supralaryngeal vocal tract. In contrast, the articulation of laryngeal consonants /h/ and /ʔ/ is confined to the larynx, and the configuration of the supralaryngeal vocal tract is unspecified. Ladefoged and Maddieson (1996:326) have suggested that it is 'appropriate to regard [h] and [ɦ] as segments that have only a laryngeal setting'. The stricture is formed at the glottis in both consonants, leaving the shape of the vocal tract at the release to be determined by adjacent segments. For this reason, laryngeal consonants have no characteristic formant transitions (Kent and Read 1992:142). It is evident, for instance, in Figure 5-47 that neither the offset of /i/ nor the onset of /a/ in the sequence /kiʔ ʔah/ is disrupted by the intervening double glottal stop; there is a smooth transition from one to the other.

Initial laryngeal consonants may be thought of as differences in the initiation of vocal fold vibration, also known as vocal attack. Orlikoff and Kahane (1995:146) refer to work by P. Moore who identified three types of vocal attack, outlined in Table 5-29. In order for the glottis to be in these states when airflow is initiated, the larynx must be prepared as much as 500ms in advance. The preparatory laryngeal activity is known as 'prephonatory adjustment'.

Table 5-29: Types of glottal attack (Orlikoff and Kahane 1995:146)

type of attack	*state of glottis at initiation of airflow*
normal	vocal folds adducted to glottal midline with moderate medial compression
hard	vocal folds adducted and with high medial compression
breathy	vocal folds abducted

Initial /ʔ/ is articulated as hard glottal attack. The prephonatory adjustment necessary for this entails adduction and compression of the vocal folds, both of which increase closed quotient. Initial /h/ consists of a breathy attack, for which the vocal folds must first be abducted. To enable them to vibrate in this state, they must also be slackened. Both these actions lower closed quotient. Initial /ʔ/ and /h/ are illustrated in Figure 5-45 and Figure 5-46.

Few initial glottal stops occurred in the corpus of recordings. Some examples were recorded from consultant SJ, who read the flash card numbers using the Dai loanword numerals.[19] In this counting system, an initial glottal stop plays an important role in telling apart the minimal pair *-sip pɛt* '...-ty-eight' and *-sip ʔet* '...-ty-one'. Instrumental evidence of this minimal pair may be compared in Figure 5-45. The duration of the bilabial closure of the unreleased final [p̚] followed by an initial /p/ in *-sip pɛt* is longer than in the string *-sip ʔet*, where the bilabial closure is released silently some time before the initial glottal stop. The initial glottal stop in Figure 5-45 is accompanied by a sharp increase in closed quotient (marked * on the closed quotient trace), followed by low frequency, high closed quotient vocal fold vibration. The glottal stop ends with the restoration of the vowel phonation at the point indicated by the arrow on the closed quotient trace and on the spectrogram.

[19] This system of counting is explained in Zhōu and Yán (1984:41).

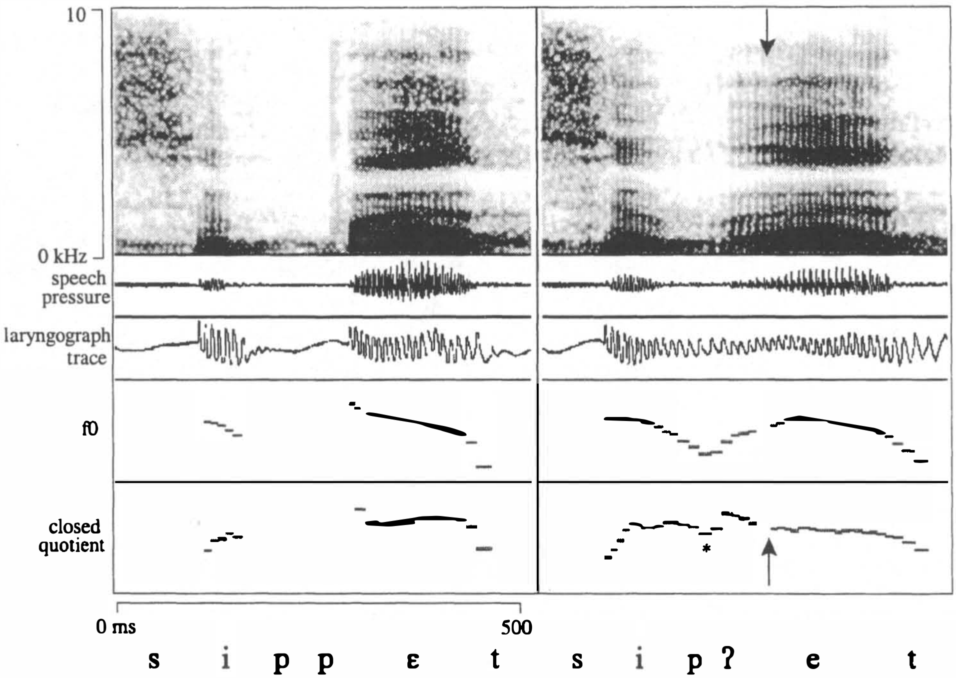

Figure 5-45: Spectrogram (150Hz bandwidth), waveform, laryngograph trace, fundamental frequency and closed quotient of *-sip pɛt/* '...-ty-eight' and *-sip ʔet* '...-ty-one' spoken by SJ. The asterisk on the closed quotient trace indicates the beginning of preparatory vocal fold tensing; the arrow marks the end of creaky phonation associated with the glottal stop and the onset of vowel phonation (the gap at that point in the closed quotient trace is an artefact).

Initial /h/ was included in two words in the main wordlist. Two utterances of *hoc* [ɦoⁱc˺] 'come' are illustrated in Figure 5-46. As /h/ is preceded by silence in both utterances, the preparatory activity which precedes the voiced glottal fricative [ɦ] must be deduced from the very low closed quotient which accompanies the breathy phonation at the onset of vocal fold vibration. The initial of the first utterance in Figure 5-46 is much longer than the second. The onset of vowel phonation is especially clearly visible on the closed quotient trace of the second utterance in Figure 5-46, indicated by the arrow on the closed quotient trace.

The breathy attack of initial /h/ is similar to the onset of voicing in aspirated consonants. The hard glottal attack of /ʔ/ is not the same as the vocal attack in a stop consonant. This is evident from a comparison of *-sip pɛt* and *-sip ʔet* in Figure 5-45, where the perturbation of fundamental frequency and closed quotient at voicing onset in the sequence ...[ʔe]... is much more dramatic than in the sequence [pɛ].

Ladefoged and Maddieson (1996:74–75) comment on the variability of the phonetic realisation of glottal stops: 'glottal stops are apt to fall short of complete closure, especially in intervocalic positions. In place of a true stop, a very compressed form of creaky voice ... may be superimposed on the vocalic stream.' This is borne out in the phonetic realisation of final glottal stops in Wa. Final /ʔ/ is realised as a short period of true creaky phonation, characterised by aperiodicity and/or high closed quotient. Vocal fold vibration does not necessarily come to a complete stop in utterance-medial position; in utterance-final position the vocal folds are obviously bound to stop vibrating eventually.

Final /h/ is realised as a period of breathy phonation, which may be accompanied and/or followed by friction noise generated at the glottis and in the vocal tract by high airflow through an abducted glottis.

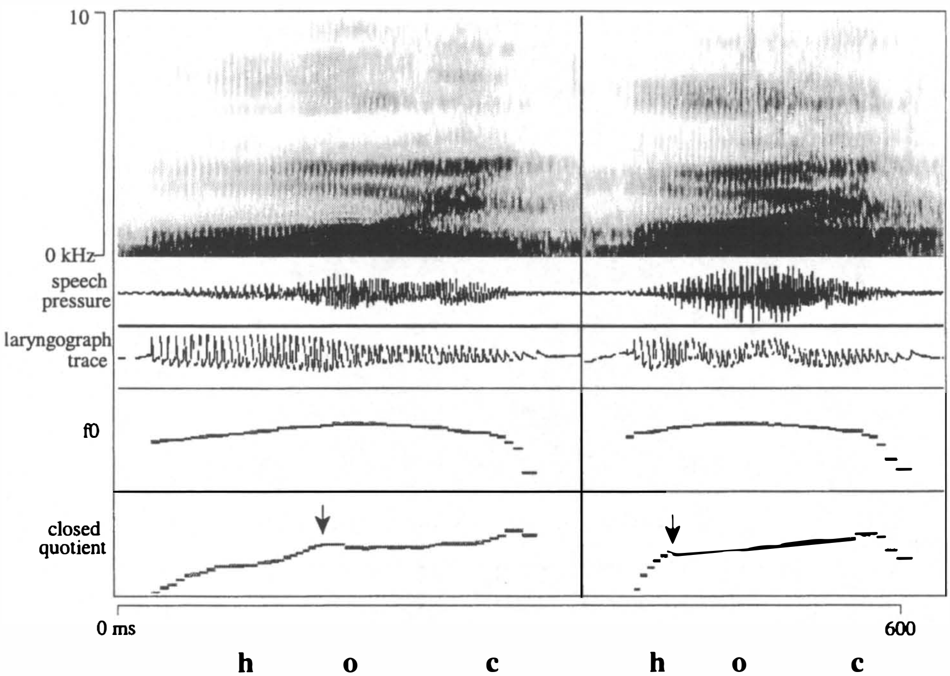

Figure 5-46: Spectrogram (150Hz bandwidth), waveform, laryngograph trace, fundamental frequency and closed quotient of ***hoc*** [ɦoⁱc˺] 'come' spoken twice by SJ. Arrows on the closed quotient trace indicate the onset of vowel phonation.

Examples of final and initial /ʔ/ and final /h/ occur in the frame sentence in the sequence *kiʔ ʔah nan* 'they say (it) like that'. The phonetic implementation of this phrase is illustrated in Figure 5-47. The presence of an initial laryngeal consonant is signalled by a shift from either creaky or breathy phonation towards the phonation type of the vowel. Conversely, a final laryngeal consonant involves a transition in the opposite direction from vowel phonation towards either breathy or creaky phonation. Both types of consonant are dynamic in nature. Thus the sequence of final /ʔ/ + initial /ʔ/ is represented as a pronounced peak in the closed quotient trace of Figure 5-45. One might segment this sequence by considering the left hand side of the peak to be the final /ʔ/ of *kiʔ* and the right hand the initial /ʔ/ of *ʔah.* Alternatively, the sequence may be thought of as two overlapping glottal stops, superimposed on one another. The final glottal stop involves a shift from the vowel towards creaky phonation, from which position the phonation type then shifts back towards modal phonation for the next vowel; the initial glottal stop involves a tense glottal attack, a shift from creaky phonation towards the phonation type of the vowel, for which the larynx must implement some preparatory glottal tensing gesture in advance. The closed quotient peak is aligned with the mid-point between the two neighbouring vowels, and is visible as a patch of reduced resonance on the spectrogram.

The final /h/ is represented by a dip in the closed quotient trace, the trough of which occurs just before the onset of the following nasal consonant. This trough is followed by an increase in closed quotient, effecting the return to vowel phonation type. The shift in phonation type is completed within the duration of the nasal consonant. The coordination of this laryngeal activity with the supralaryngeal articulation is different from that observed in aspirated nasals, where there is a similar trough in closed quotient, with the lowest value aligned with the end rather than the beginning of the nasal consonant (see Section 6.7.1).

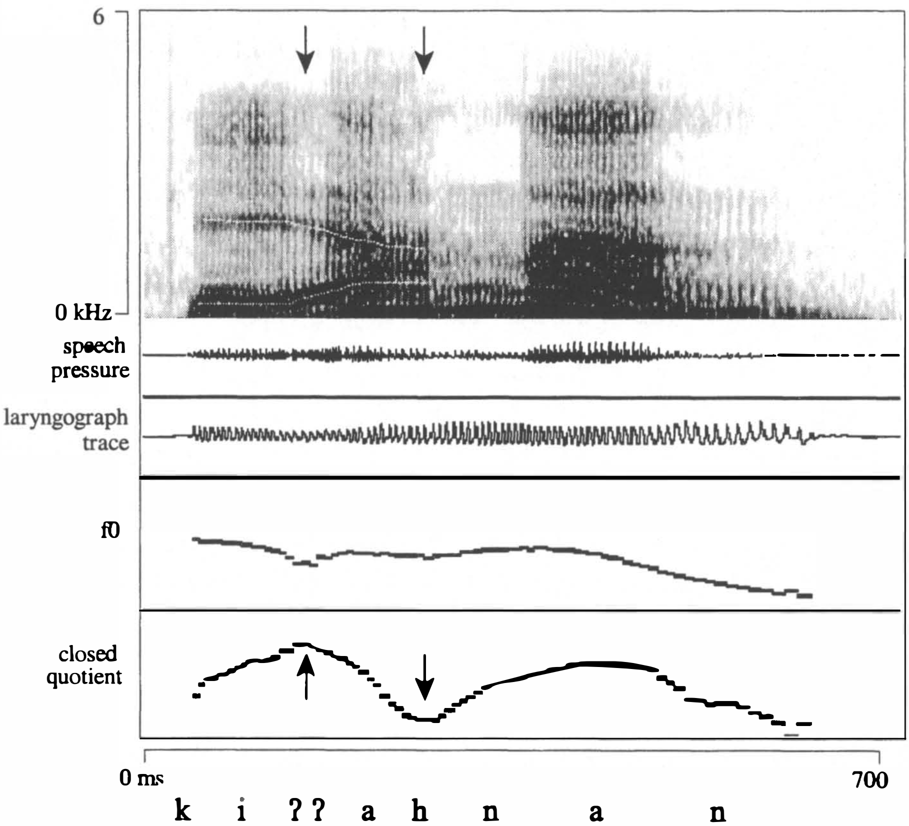

Figure 5-47: Spectrogram (120Hz bandwidth), waveform, laryngograph trace, fundamental frequency and closed quotient of *kiʔ ʔah nan* 'they say (it) like that' spoken by JN. Arrows on the closed quotient trace and the spectrogram indicate the instants of the closed quotient peak associated with /ʔ/ and the trough associated with /h/. F1 and F2 are traced in white through the sequence *kiʔ ʔah*.

5.4 FRICATIVES

Wa contains few fricative consonants and those which do occur in the language do not form a natural class. Nevertheless, they are discussed as a group of sounds here because they share similarities of articulation and acoustic representation. /h/, in some senses also a fricative, was investigated more fully in the previous section. Fricatives which occur as allophonic variants of approximants, for instance /r/ and /y/, are discussed alongside those sounds.

[s] is by far the most common fricative cross-linguistically. In general, the presence of a voiced fricative in the sound system of a language usually implies the presence of its voiceless counterpart (Maddieson 1984:47). However, the appearance of a voiceless labiodental fricative [v] with no voiceless partner [f] is not uncommon in sound systems generally because [v] may develop diachronically from a voiced approximant [w] rather than in association with a homorganic voiceless counterpart [f] (Maddieson 1984:48). This is precisely the situation in Wa.

ACOUSTICS OF FRICATIVES

Fricatives are produced by forcing air through a constriction in the vocal tract, causing turbulent airflow. Studies modelling fricative production (Shadle 1991) have distinguished between 'wall' fricatives and 'obstacle' fricatives according to the way in which the turbulence is generated. Other writers (e.g. Ladefoged and Maddieson 1996:138, 180) have used this categorisation to underpin a widely-observed distinction between non-strident and strident (or sibilant) fricatives, which may also form the basis of two phonological classes of fricatives.

In non-strident fricatives, the noise source is the turbulence caused by air escaping through a narrow constriction formed by the articulators. The noise thus generated may be filtered further by the shape of the vocal tract in front of the place of the constriction. In general, formant peaks of friction noise at higher frequencies result from shorter front cavities. In the case of glottal fricative /h/, the front cavity is effectively the whole of the supralaryngeal tract, giving /h/ the potential to have a formant structure like that of any vowel.

In strident fricatives, a high velocity jet of air is forced through a groove formed between the tongue and a passive articulator. This jet is aimed at an obstacle further forward in the mouth, typically the teeth, and the collision of the air jet with the obstacle disrupts the high velocity laminar flow of the jet, creating the turbulence which is the source of sound in this variety of fricatives. The noise is markedly higher in frequency and greater in intensity than the noise of non-strident fricatives. It has been suggested (Kent and Read 1992:125) that strident fricatives may be classified by the cut-off frequency below which there is no turbulence. This frequency can be identified by its proximity to one or other of the higher formants.

VOICED LABIO-DENTAL FRICATIVE /v v^h/

The vocal fold vibration in a voiced fricative may vary in phonation type. This possibility is exploited by voiced labio-dental fricatives /v v^h/, which form an unaspirated/aspirated pair like the stops and nasals. /v/ and /v^h/ are omitted from the study of aspiration in continuant consonants (Section 6.7.1) because the items in the word list in which this sound occurred proved to be problematic for a number of recording subjects, and the recordings had to be discarded. In those few examples of /v^h/ which did emerge, the laryngeal gesture associated with aspiration was similar to that of the other continuant consonants, the nasals and approximants.

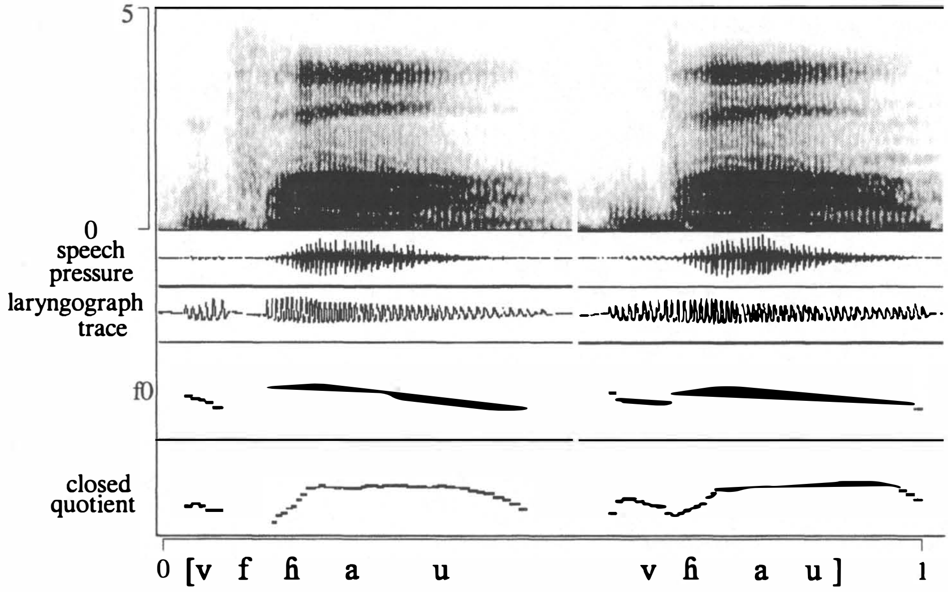

Figure 5-48: Spectrogram (100Hz bandwidth), waveform, fundamental frequency and closed quotient of *v^{h}au* 'burn' spoken twice by NKP. /v^h/ is realised as [vfɦ] and [vɦ] respectively.

As with several of the other sonorants, in some cases the phonation type shift associated with the laryngeal abduction-adduction gesture caused vocal fold vibration to cut out. The result of such a devoicing process can be observed as a short period of voicelessness during the first example of /v^h/ illustrated in Figure 5-48, visible as a short gap in the waveform of the laryngograph trace. The increased airflow during this voicelessness causes an increase in friction noise, phonetically [f], evident as a dense 'cloud' on the spectrogram. Adding vocal fold vibration to fricatives causes a reduction in glottal airflow, which in turn cuts down the intensity of turbulence noise. This is evident, for instance, from a comparison of the voiced and voiceless allophones of /v^h/ in Figure 5-48.

VOICELESS ALVEOLAR STRIDENT FRICATIVE /S/

The Wa phoneme inventory contains only one strident fricative phoneme, voiceless alveolar /s/. It may be compared to the voiceless alveolo-palatal strident fricative component of the alveolo-palatal affricate /c/. Figure 5-29 shows that for the consultant whose speech that spectrogram illustrates, the cut-off frequency for [s] is in the region of F4 at 3890Hz, while the cut-off frequency for the [ɕ] part of /c^h/ is nearer F3, at approximately 2230Hz.

Zhōu and Yán (1984) refer to an aspirated allophone of the alveolar fricative /s/ which occurs preceding clear register vowels. No evidence of such a systematic alternation was found in the recordings, which included the minimal pair /sɯ/ 'pour' /sɯ̤/ 'straight'.

In this analysis, /s/ occurs only as an initial consonant. The option of recognising a phoneme |s| in syllable-final position was discussed in Section 4.2.4. This approach was adopted by Diffloth (1980) to account for a sound he describes as an alveolo-palatal fricative [ɕ]. The putative |s| phoneme is transcribed /ih/ in the phonological analysis adopted in this study. In the light of the description of /h/ in the preceding section, /h/ preceded by /i/ implies a shift from the vowel towards voicelessness via breathy phonation, entailing high airflow and friction noise, with the formant characteristics of /i/ superimposed. Catford (1977:250) notes that:

> [h] may be thought of as either a glottal fricative or a voiceless vowel ... Any voiceless vowel with an articulatory stricture narrower than the glottal stricture (certainly [i]- and [u]-type vowels, and possibly [e]- and [o]-types) will be an (oral) approximant and will have turbulent flow through the oral channel. Any vowel with an oral channel more open than the glottal channel will not generate turbulent flow at that point.

Thus the articulation of [ih] has much in common with [ɕ], or perhaps a slightly lowered variety of it [ɕ̞].

5.4.1 PRESYLLABIC /s./

The sibilant alveolar fricative [s] occurs also as a presyllable /s./, the reflex of phonologically more elaborate clusters and prefixes discussed in a diachronic context in chapter 1. The phonetic realisation of presyllable /s./ varies considerably.

The /s./ presyllable has received various treatments in the hands of Mon-Khmerists, both in phonetic descriptions and orthographical representations. Shorto (1963:53–54) transcribes the Wa[20] /s./ presyllable as containing a vowel /i/ and makes no comment on its phonetic variability or instability. Diffloth (1980) transcribes the presyllable /s./ consistently as /sə/ from the PRC Wa spelling 'si' which is his source of Wa data, though he does not use the same symbol /ə/ for any other vowel in Wa. Wáng and Chén (1981:55) cite Luó Jìguāng's description of the vowel in the presyllable as: 'frequently vague, a somewhat unfixed high vowel'[21]. They also indicate that the presyllable may contain no vowel, a suggestion echoed by Zhōu and Yán (1984:15), who transcribe the prefix as ' s' ', though without stating explicitly the intended value of the apostrophe. Orthographical representations of the presyllable may be compared in Table 8.12. The differences between these descriptions raise the following questions:

(i) Does /s./ contain a vowel or not?

(ii) Does the quality of the vowel, if any, match one of the nine vowel qualities found otherwise in Wa?

(iii) What is the exact phonetic nature of the fricative?

[20] Praok in his nomenclature.

[21] This quotation is translated from Chinese.

EXPERIMENTAL ANALYSIS OF /s./

Six instances of the /s./ prefix occurring in recordings by four speakers of the Wa translation of the Parable of the Sower (see 8.2.2) were examined, yielding twenty-four examples of /s./ in total. The source words are given in Table 5-30.

Table 5-30: Words with prefix /s./

s.mɛ̤	'seed'
s.ŋaiʔ	'sun'
s.naʔ	'between'

These tokens were taken from a longer text which was read continuously rather than from frame sentences. The following measurements were made from the speech waveform, spectra and spectrograms:

1. duration of fricaton;
2. time between end of frication noise and onset of nasal formants;
3. Fl and F2 of any epenthetic vowel, if discernible.

ANOVA tests were used to determine significant effects on the four measures of the /s./ presyllable, as set out in Table 5-31.

Table 5-31: Design and results of ANOVA test for effects on phonetic properties of /s./

independent variable: speaker (1,4)			
dependent variables	*F*	*p*	*sig*
duration of [s] frication	3.1773	0.0464	○
duration of epenthetic vowel	5.4764	0.007	○
Fl of epenthetic vowel	1.3489	0.3089	
F2 of epenthetic vowel	0.945	0.4522	

The means and standard deviations of the temporal measurements are explored in Table 5-32 and illustrated in Figure 5-49 and Figure 5-50. The ANOVA tests suggest that there was significance between-speaker variation in the duration of the [s] and vowel segments of the presyllable. This finding is explained, at least in part, by the different speeds at which the four consultants read the source passage. Concealed in the figures in Table 5-32 is the fact that the recorded vowel duration was zero for five tokens in which the [s] frication abutted the nasal consonant with no detectable gap between the two. Fl and F2 were measured for only fifteen tokens (62.5 per cent of the sample). In the remaining four a gap was visible on the spectrogram between the end of the [s] frication and the onset of the nasal consonant, but no formant structure was in evidence. Spectrograms and speech waveforms of two presyllables are shown in Figure 5-52, on which F1 and F2 of the epenthetic vowel are highlighted.

Table 5-32: Duration (ms) of [s] and vowel segments of /s./ presyllable

speaker	[s]		Vowel		n
	mean	s.d.	Mean	s.d.	
YS	142.67	13.63	48.33	13.54	6
RM	123.67	19.75	23.00	13.17	6
NT	111.83	17.55	12.33	18.20	6
YH	133.00	14.40	22.33	13.15	6
All	127.79	20.07	26.50	19.80	24

There was no evidence in the ANOVA tests that the epenthetic vowel was of significantly different quality in the speech of the four consultants. The epenthetic vowels are plotted in the F1:F2 plane in Figure 5-51.

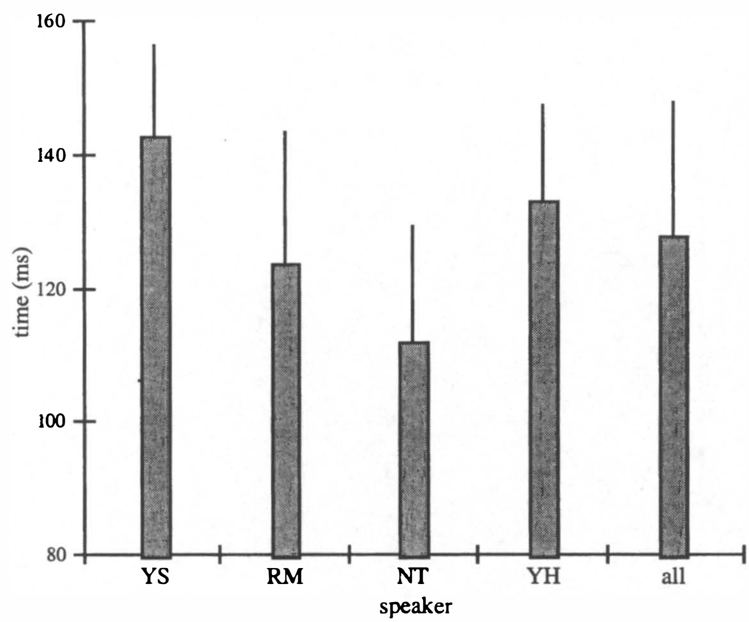

Figure 5-49: Duration of [s] friction in /s./ presyllable. Mean + 1 s.d. (n = 6).

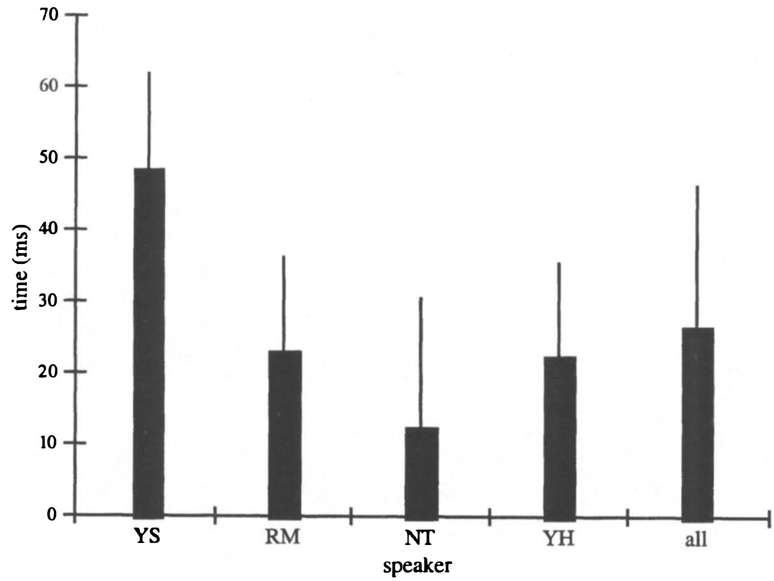

Figure 5-50: Duration of epenthetic vowel in /s./ presyllable. Mean + 1 s.d. (n = 6).

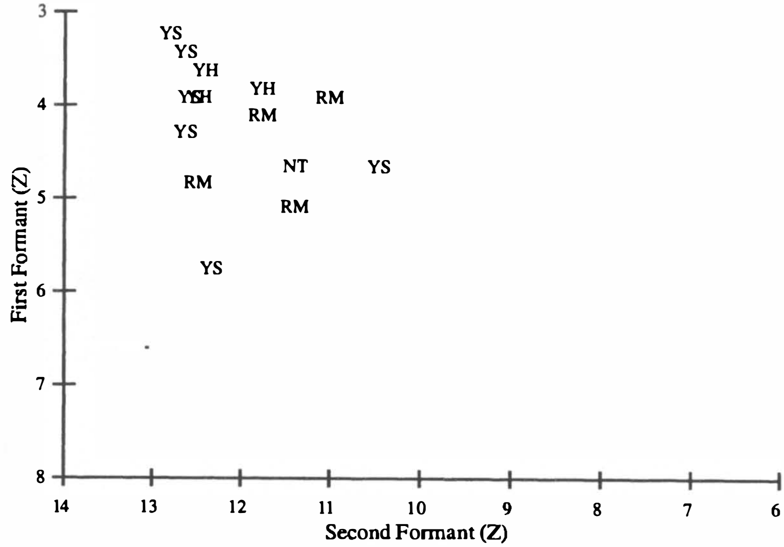

Figure 5-51: Fl and F2 of epenthetic vowel in /s./ presyllable. Fifteen tokens, each identified by its speaker. Superimposed on a template of the mean F1 and F2 values of /i e ɛ a ɔ o u/ for the whole set of consultants.

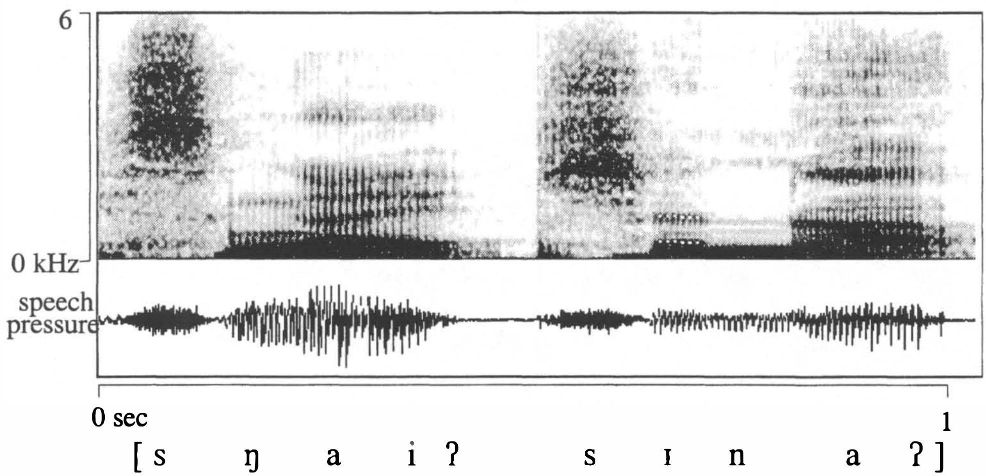

Figure 5-52: Spectrograms (120Hz bandwidth) and speech pressure waveforms of *s.ŋaiʔ* 'sun', *s.naʔ* 'between' spoken by NT and YS respectively. F1 (600Hz) and F2 (1810Hz) of epenthetic vowel in [sⁱnaʔ] are marked with dotted white lines.

A comparison of the two spectrograms of /s./ in Figure 5-52 helps to answer the third question raised above, regarding the nature of the fricative. The /s/ friction extends to lower frequencies in *s.naʔ* (about 2kHz) than in *s.naiʔ* (about 3kHz). As discussed above (Section 5.4), this is one acoustic indicator of differences in sibilant fricative articulation. It proved impossible to quantify this clearly visible difference by measuring spectra, but through impressionistic spectral analysis, and careful listening, the consonant in each /s./ presyllable could be classified as either alveolar [s] or palato-alveolar [ɕ]. Three tokens of a single consultant (YS) contain alveolo-palatal fricatives [ɕ] such as that visible in *s.naʔ* in Figure 5-52; all remaining twenty-one tokens are correctly described as alveolar fricatives [s]. The variation may be described as a freely distributed continuum [s] ~ [sʲ] ~ [ɕ].

In the light of these judgments, it is reasonable to posit a link between the place of articulation of the fricative and the quality of the vowel. In Figure 5-51 it is seen that the vowels in the presyllables spoken by YS, whose /s./ presyllable fricatives tend towards [ɕ], are closer and more front in quality, suggesting that the more palatal the articulation of the fricative in the presyllable, the more the quality of the vowel tends towards [i]. A similar parallel between [i] and palatal articulations was drawn in Section 5.4.

The presyllable is transcribed /s./ (i.e. with no vowel) for two reasons. Firstly, no vowel is present in a substantial number of cases; secondly, when there is a vowel, it is of indeterminate quality. In the instances where a vowel is discernible, it is most commonly a non-peripheral high front vowel [ɪ].

Wáng and Chén (1981:54) distinguish between clear and breathy register in the vowels of presyllables; for Zhōu and Yán (1984:15) the presyllable vowel is consistently clear register. The presyllables studied here were recorded without a laryngograph, so no phonation type data are available to confirm or contradict Zhōu and Yán's analysis. Given the anticipatory coarticulation both in sonorants and in the voicing of stops of the phonation type of the following vowel, explored in Section 6.7, it seems likely that phonation type contrasts would carry forward into the vowels (if any) of presyllables preceding sonorants or stops.

5.5 Sonorants

5.5.1 Nasals

Nasals share with plosives the same four-way place distinction in the formation of a closure in the vocal tract. Like plosives, nasals may be aspirated, accompanied by a glottal abduction–adduction gesture. Nasals also bear a distributional similarity to stops, occurring as initial and final consonants. As final consonants, they shorten preceding vowels as do final stops. Cross-linguistically, the presence in a phonological system of four nasals at the same places of articulation as a series of stops is very common. Breathy-aspirated nasals are, however, rare, occurring only in a single language (Hindi) in the survey of Maddieson (1984).

Nasals differ in articulation from plosives in that the velum is lowered while the closure in the oral cavity is in place. The aerodynamic consequences of this were discussed in connection with stop voicing in Section 5.2.2. In that context, nasalisation of stop voicing was determined by the presence of nasal formants. Lowering the velum alters the resonant qualities of the vocal tract. In this configuration, the vocal tract has been modelled as a tube consisting of the pharyngeal and nasal cavities combined, with a side-branch comprising the oral cavity, which varies in length depending on the position of the oral occlusion. Acoustic theory (Fant 1960) enables the filtering function of the vocal tract in this state to be calculated first in terms of the naso-pharyngeal tube, which produces four evenly spaced formants below 3kHz, though these cannot be predicted with great accuracy due to between-speaker and within-speaker variation in the shape of the nasal cavity (Johnson 1997:144). The oral side-branch shapes this spectrum further by contributing a zero or anti-formant at its resonant frequency, which increases as the position of the oral closure moves back in the mouth and the size of the oral side-branch decreases. Spectrograms of initial nasals at the four places of articulation are illustrated in Figure 5.53.

Duration of initial nasals

The oral articulation of nasals is essentially the same as that of their plosive stop counterparts, involving a 'closed phase'. While measuring the duration of the closed phase of initial plosives is problematic because the formation of the closure is usually silent, measuring the duration of nasals is much easier, because the nasal resonance which is associated with the configuration of the oral and nasal cavities, combining oral closure with lowered velum while the vocal folds are vibrating, is acoustically distinctive, involving an abrupt increase and decrease in resonance energy.

Syllables with all twelve possible nasal consonants in initial position, reproduced in Table 5-33 were used to assess the duration of initial nasals. Each nasal appears once unaspirated with clear register, once unaspirated with breathy register and once aspirated. These syllables are also used in Section 6.7.1 to describe the laryngeal activity which accompanies sonorants.

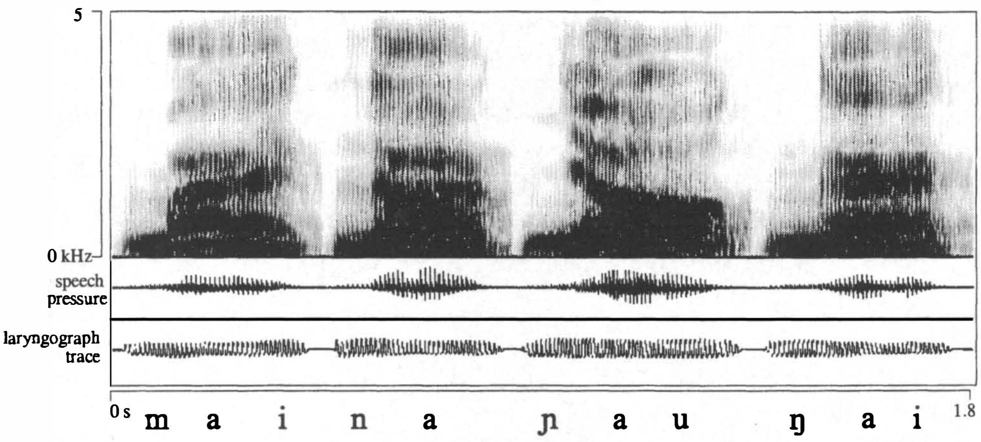

Figure 5-53: Spectrogram (150Hz bandwidth), waveform and laryngograph trace of nasal initial consonants. ***mai*** 'and', ***na*** 'lie spread out', ***ɲau*** 'rub clean', ***ŋai*** [ŋɛ] 'eye' spoken by SRM.

Table 5-33: Syllables measured for investigation of duration of initial nasals

		bilabial	alveolar	palatal	velar
unaspirated	clear	*mai*	*na*	*ɲau*	*ŋai*
	breathy	*m̤ai*	*n̤a*	*ɲ̤au*	*ŋ̤ɔ*
aspirated		*m*^{h}*ai*	*n*^{h}*a*	*ɲ*^{h}*au*	*ŋ*^{h}*a*

An ANOVA test (Table 5-34) was performed to investigate the factors influencing initial nasal duration; the measurements are summarised in Table 5-35 and illustrated in Figure 5-54.

Table 5-34: Design and results of ANOVA test for effects on duration of initial nasals

Dependent variable: initial nasal duration

Independent variables	*d.f*	*F*	*p*	*sig*
speaker (10)	9224	24.283	< 0.0005	•
place of articulation (bilabial, alveolar, palatal, velar)	3224	9.389	< 0.0005	•
register (clear, breathy, post-aspirated)	2224	2.047	0.132	
recitation order (first or second)	1224	5.699	0.018	○

The source of the highly significant effect of between-speaker differences ($F(10,539) = 147.89$, $p < 0.0005$) is illustrated in Figure 5-54, in which the speakers have been ranked for mean nasal duration, with the longest first. Four speakers who rank in the top five for vowel duration in Section 5.1.3 also rank in the top five for duration of initial nasals. This suggests that the duration of vowel and nasal are not mutually compensatory, a case of 'the longer the nasal the shorter the vowel', but rather that there is a steady ratio of nasal:vowel duration. The effects of between-speaker variation (and perhaps also of recitation order) can probably be explained in the same way as the effects on vowel duration.

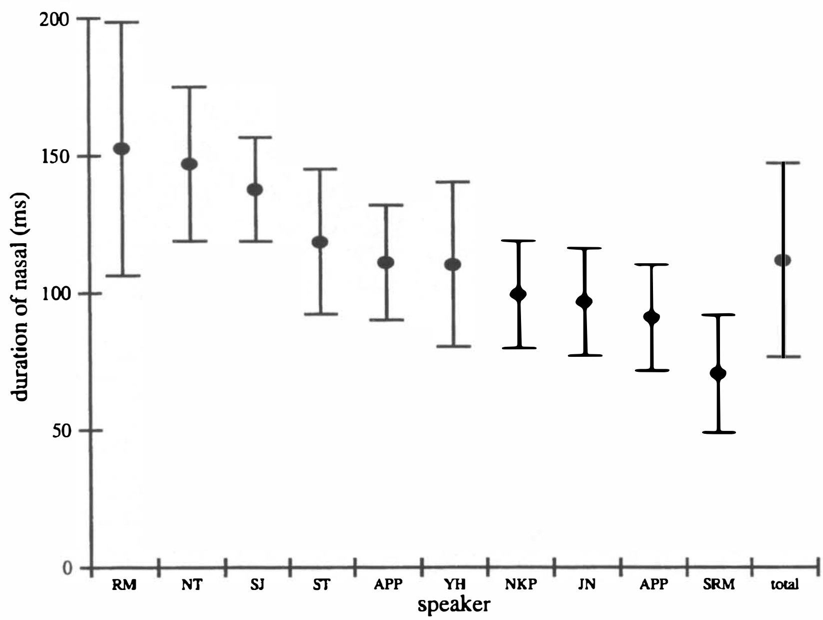

Figure 5-54: Duration of initial nasals by speaker. Markers represent the mean (+/– 1 s.d.) of twenty-four tokens.

Table 5-35: Duration of initial nasals by speaker (see Figure 5-54)

	mean	*s.d.*	*n*
RM	152.5417	46.017	24
NT	147	27.9903	12
SJ	137.75	18.797	24
ST	118.6667	26.4701	24
APP	111.125	21.0244	24
YH	110.375	30.0128	24
NKP	99.625	19.5444	24
JN	96.8571	19.6984	21
APP	90.9167	19.4309	24
SRM	70.3333	21.3188	24
total	111.9556	35.3658	225

The effect on nasal duration of place of articulation was also statistically significant. A post-hoc Scheffé test found that the initial palatals were significantly shorter than nasals at the three other places of articulation, none of which were significantly longer or shorter than each other, so it seems that the effect may be due to the shorter palatals alone. The figures are set out in Table 5-36 and illustrated in Figure 5-55.

Table 5-36: Duration of initial nasals by place of articulation (see Figure 5-55)

	mean	*s.d.*	*n*
alveolar	119.15	38.29	54
velar	116.98	35.00	60
bilabial	114.23	35.55	53
palatal	97.98	29.20	58
total	111.96	35.37	225

It was established earlier that the juncture between initial palatal stops and vowel is distinguished from combinations of vowels with consonants at other places of articulation by the presence of palatal on-glides. In that context, the acoustic markedness of palatal glides was discussed. Here, we have evidence of durational differences which set palatals apart. The shorter palatal nasal resonance may be thought of as a 'universal' phonetic effect if we consider the physical shape of the articulators involved. The tongue body has further to travel to make contact with the domed surface of the hard palate. The shorter contact compensates for the extra time taken moving the tongue towards and away from its target position.

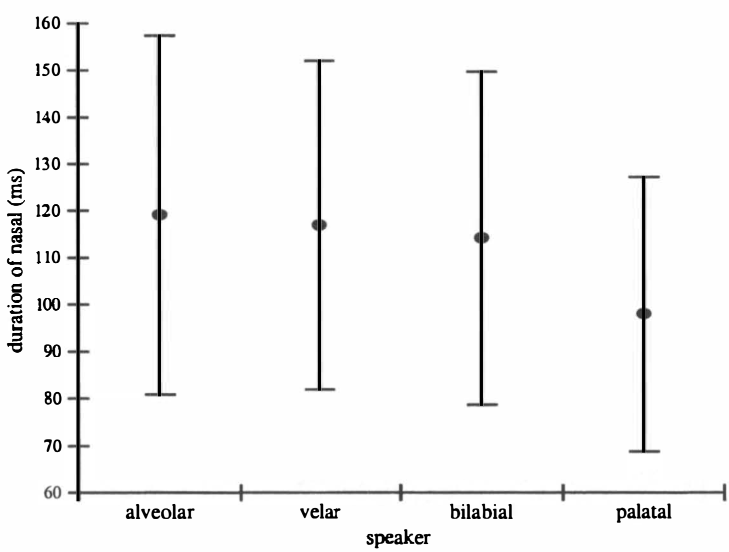

Figure 5-55: Duration of initial nasals by place of articulation. Markers represent the mean (+/– 1 s.d.) of twenty-four tokens.

5.5.2 LATERALS /l lʰ/

Johnson (1997:153) likens the configuration of the vocal tract for laterals to that of nasals. The tongue is held in a position such that air can flow round the sides, and this creates a pocket of air above the tongue which may be compared to the side-branch formed by the oral cavity when the velum is lowered for nasals. There is typically an abrupt switching between lateral resonance and the formant structure of an adjacent vowel if the articulation is made with the tongue tip, which is capable of rapid movements (Ladefoged and Maddieson 1996:193). An abrupt change in resonance of this kind is evident in all the lateral-vowel boundaries in Figure 5-57 and Figure 5-58.

Two laterals feature in Wa: unaspirated /l/ and aspirated /lʰ/, which occur in three words in the corpus of recordings: A number of allophones of these two items were observed in the corpus of recordings, in the context of the following three words: *lai* 'why', *la̤i* 'writing' and *lʰai* 'crooked'. Narrow transcriptions of the allophones are set out in Table 5-37, alongside an indication of the number of consultants who pronounced them.

Table 5-37: Allophones of Wa laterals

phoneme	/l/	/lʰ/	no. of speakers (out of 11)
	[l]	[l̤ɦ]	6
allophones	[l]	[l̥]	1
	[ɫ]	[ɫ̤ɦ]	4

An impressionistic judgement of the 'darkness' of laterals was followed by a small-scale experiment to assess the degree of velarisation, in which the frequency of the second formant was measured. F2 frequency has been proposed as an indicator of the degree of velarisation of alveolar laterals (Ladefoged and Maddieson 1996:196) since it is inversely related to the volume of the oral–pharyngeal cavity behind the articulatory occlusion (Bladon 1979). Although this method is better suited to comparison of different laterals by the same speaker rather than between-speaker comparisons, the F2 measurements plotted in Figure 5-56 confirm the auditory impressions: the four speakers with the lowest F2 are those whose laterals were classified auditorily as velarised.

One speaker produced a voiceless allophone of /lʰ/, a spectrogram of which is shown in Figure 5-57. This illustrates clearly the contrast between /l/, with reduced lateral resonance but no friction noise evident in the spectrogram, and the voiceless allophone of /lʰ/, in which friction noise is clearly visible until the beginning of vocal fold vibration, signalled by the beginning of undulations on the laryngograph trace. This example of voiceless /lʰ/ is considered especially interesting because the onset of vocal fold vibration is abrupt, with no evidence of breathy phonation. A more typical production of /lʰ/ is shown in Figure 5-58, where the dip in the closed quotient trace indicates breathy phonation.

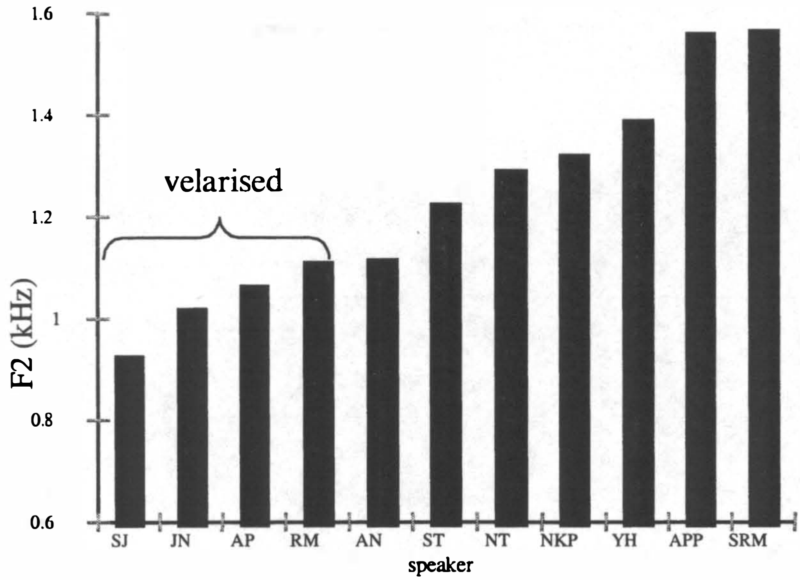

Figure 5-56: Mean (n = 4) F2 of voiced alveolar lateral approximants for eleven speakers. Those with auditorily evident velarisation are indicated.

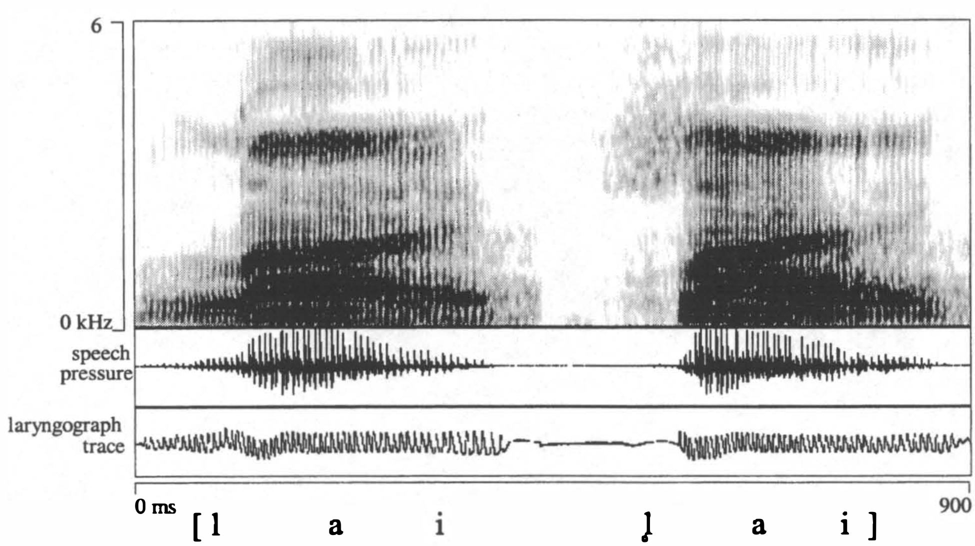

Figure 5-57: Spectrogram (120Hz bandwidth), waveform and laryngograph trace of voiced alveolar lateral approximant [l]in *lai* 'why', and voiceless allophone [l̥] in *lʰai* 'crooked' spoken by AN.

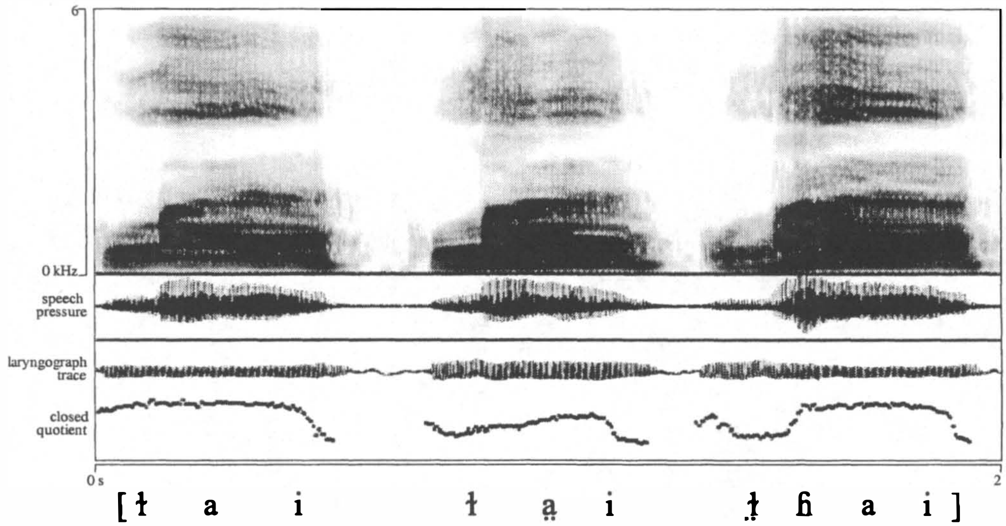

Figure 5-58: Spectrogram (120Hz bandwidth), waveform, laryngograph trace, and closed quotient of velarised voiced alveolar lateral approximant [ɫ] followed by clear and breathy register vowels in *lai* 'why' and *la̤i* 'writing', and breathy–aspirated velarised voiced alveolar lateral approximant [ɫ̤ɦ] in *l*^{h}*ai* 'crooked' spoken by SJ.

5.5.3 RHOTICS /ɾ r^{h}/

The heterogeneous class of rhotics or r-sounds has often defied description. Maddieson (1984:79ff) found that languages are more likely to have a single rhotic than none or more than one, that rhotics are overwhelmingly voiced, and that 'interrupted' r-sounds (i.e. trills, taps or flaps) are much more common than continuant r-sounds (approximants or fricatives). Mona Lindau (1985) sought acoustic correlates to link the wide range of articulatory variation found in the r-sounds in the thirteen diverse languages she investigated. She concluded (Lindau 1985:167) that rhotics are a family within which every member resembles some other member with respect to one or more of the following acoustic parameters:

- pulse pattern (trills);
- closure duration;
- presence of formants (sonorants);
- presence of noise;
- distribution of spectral energy (shared place of articulation).

Wa has two rhotic phonemes, one unaspirated /r/ and one aspirated /r^{h}/, represented in the corpus of recordings by the five words in Table 5-38.

Table 5-38: Words containing rhotics

rɤ	'pull'
ra	'two'
rɤ̤	'boat'
r^{h}a	'snow'
r^{h}aŋ	'tooth'

Observed allophones of these sounds, and an indication of the number of consultants who used them, are set out in Table 5-39.

Table 5-39: Allophones of Wa rhotics

phoneme	/r/	/r^h /	no. of speakers
allophones	[ɹ]	[ɹ̤ɦ]	7
	[ɹ]	[ɹ̥]	3
	[ʁ̞]	[ɹ̤ɦ]	1

The rhotic of the standard language is an alveolar approximant [ɹ], with aspirated counterparts [ɹ̤ɦ] or, more rarely [ɹ̥] (Figure 5-60). This is a group of r-sounds for which a lowered F3 is identifiable as a common acoustic correlate (Lindau 1985). The downward-pointing F3 transitions are clearly visible in Figure 5-59 and Figure 5-60.

A single consultant (NT) uses a uvular approximant [ʁ̞], shown in Figure 5-62. NT produced a uvular for unaspirated /r/ only; for aspirated /r^h/ in *r^{h}a* 'snow' he reverted to the breathy–aspirated alveolar approximant of the standard, similar to the one illustrated in Figure 5-61. The uvular variety of /r/ is most likely a dialectal feature of NT's mother tongue, Meung Yang Wa, a dialect known not to be mutually intelligible with the standard language. The speech NT used in recording sessions, while ostensibly standard Wa, apparently has a mixed accent.

In contrast with the alveolar approximant [ɹ], F3 of uvular [ʁ̞] is not lowered. F3 of NT's uvular was in the region of 3000Hz, compared to an F3 of about 1800Hz for his alveolar approximants. F3 was measured as 2265Hz for the [ʁ̞] illustrated in Figure 5-62.

Further varieties of /r/ observed were occasionally heard from some consultants, including alveolar taps [ɾ] or trills [r], though neither of these allophones was captured on tape. While the alveolar approximant remains the norm, the possibility of a greater variety of /r/ allophones conforms with Lindau's (1985) finding that rhoticity can be defined only in terms of a diverse set of features.

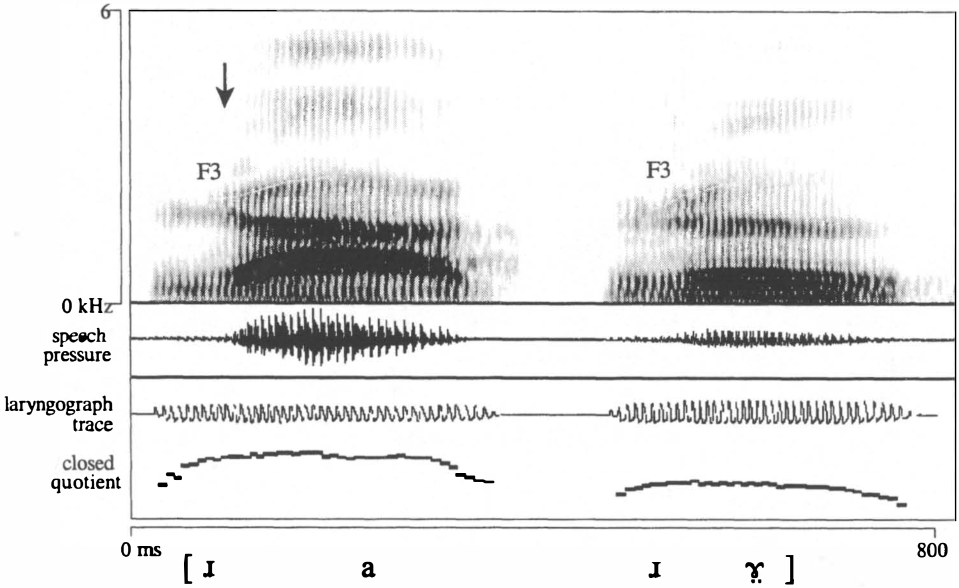

Figure 5-59: Spectrogram (100Hz bandwidth), waveform, laryngograph trace and closed quotient of /r/ followed by clear and breathy register vowels in *ra* 'two' and *rɤ̤* 'boat', spoken by SRM. Peak closed quotient is 53.5 per cent and 38.7 per cent respectively. The arrow marks where the vowel is judged to begin.

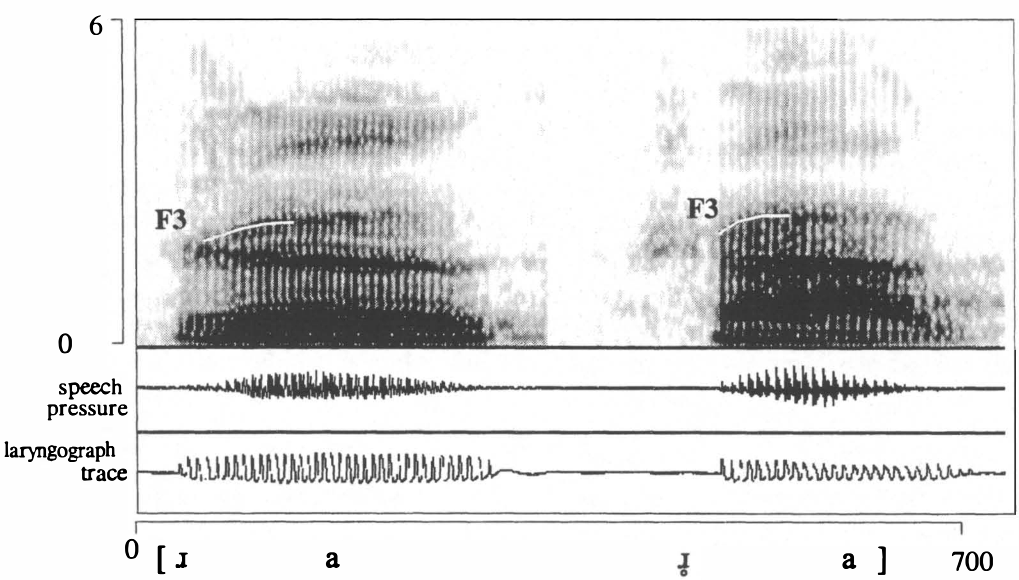

Figure 5-60: Spectrogram (100Hz bandwidth), waveform and laryngograph trace of voiced alveolar approximant [ɹ] and voiceless alveolar fricative [ɹ̥] in SRM's pronunciation of *ra* 'two' and *r*^{h}*a* 'snow'.

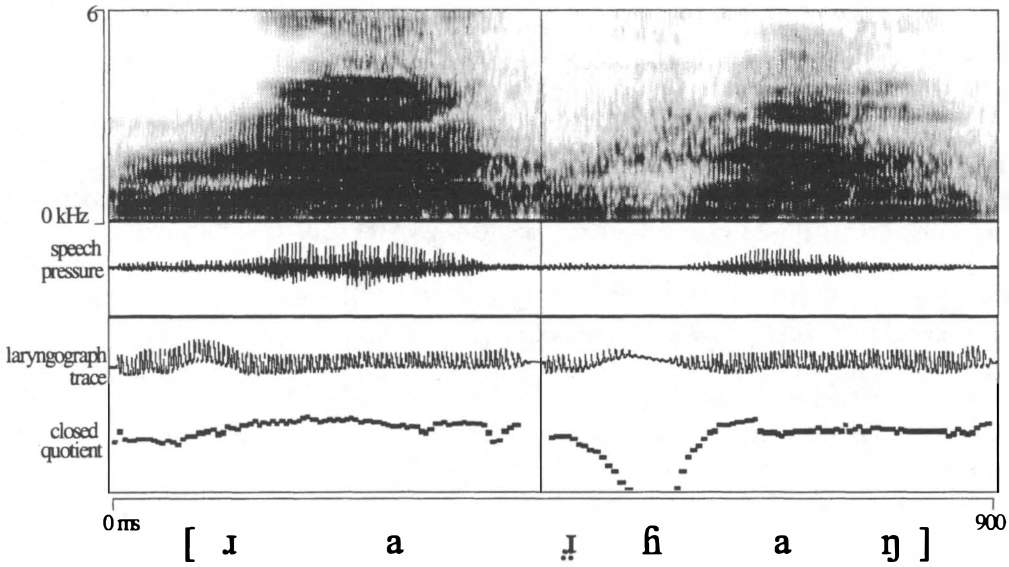

Figure 5-61: Spectrogram (100Hz bandwidth), waveform, laryngograph trace and closed quotient of aspirated and unaspirated /r/ in *ra* 'two' and *r*ʰ*aŋ* 'tooth', spoken by female consultant APP. Peak closed quotient in *ra* is 46.9 per cent; in *r*ʰ*aŋ* closed quotient falls below the apparatus minimum of 20 per cent.

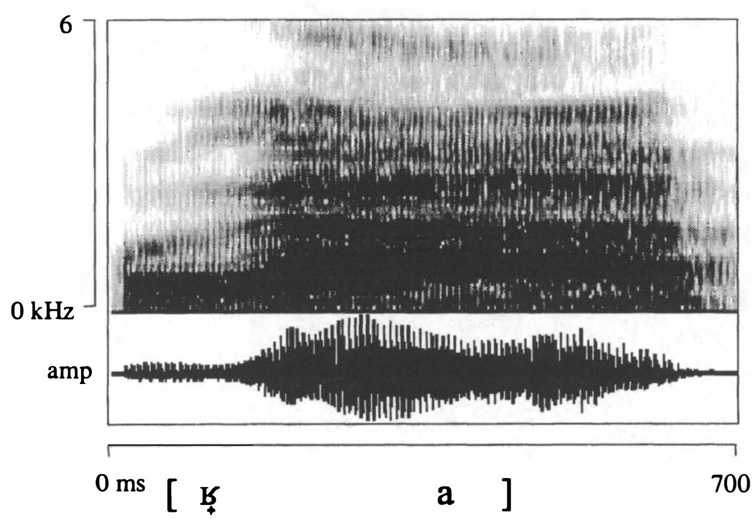

Figure 5-62: Spectrogram (100Hz bandwidth) and waveform of voiced uvular approximant [ʁ̞] in NT's pronunciation of *ra* 'two'. F3 is measured as 2265Hz.

5.5.4 PALATAL APPROXIMANTS /y yʰ/

In Chinese descriptions (Zhōu and Yán 1984; Wáng and Chén 1981) /y/ is transcribed as a voiced alveolo-palatal fricative [ʑ] when it occurs as an initial consonant. Within this set of recordings, the most frequent realisation of /y/ is voiced palatal approximant [j], such as is illustrated in the first and second syllables in Figure 5-63. Reduced resonance is evident in these spectrograms of /y/, apparently to a degree similar to that observed in other sonorants /r l/ (see Figure 5-58 and Figure 5-59).

Aspirated /yʰ/ has a variety of allophonic realisations, a sample of which is given below in Figure 5-64 and Figure 5-65. The second token in Figure 5-64 is comparable to the voiceless allophone [ɹ̥] of /r/ in Figure 5-60 and the voiceless allophone [l̥] of /l/ in Figure 5-57. The first token in Figure 5-60 and the second in Figure 5-61 are rather more typical examples, in which breathy phonation during the sonorant consonant reverts to vowel phonation after the articulators have moved away from the position they held for the consonant.

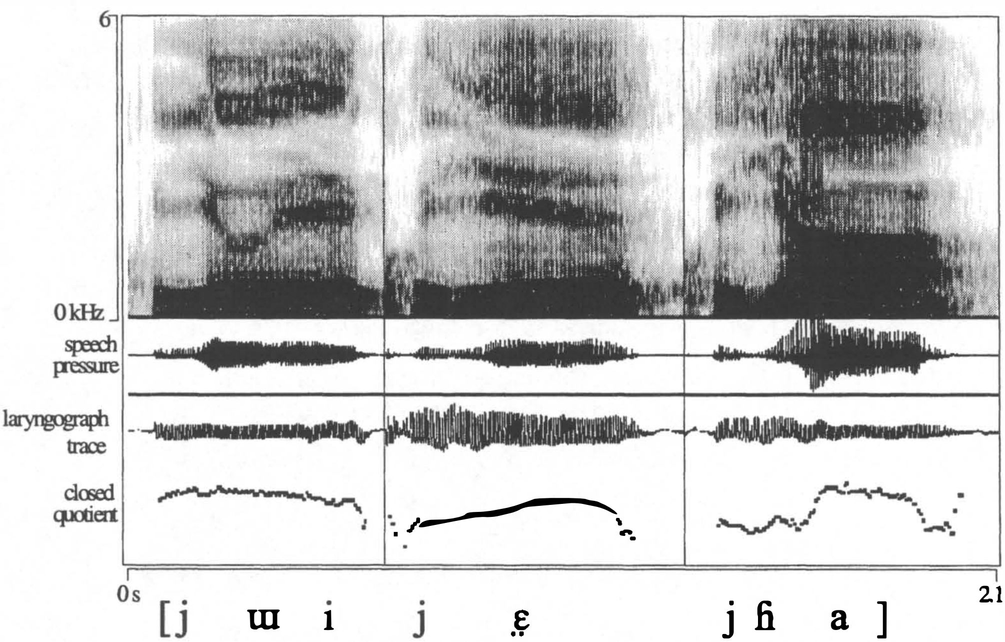

Figure 5-63: Spectrogram (150Hz bandwidth), waveform, laryngograph trace and closed quotient of *yɯi* 'fly (n.)', *yɛ̤* 'easy', *yʰa* 'give birth (of animals)' spoken by consultant SJ. Average closed quotient is 52.3 per cent and 44.4 per cent in the clear and breathy syllables respectively; CQ rises from 35.1 per cent to 54.6 per cent in *yʰa*.

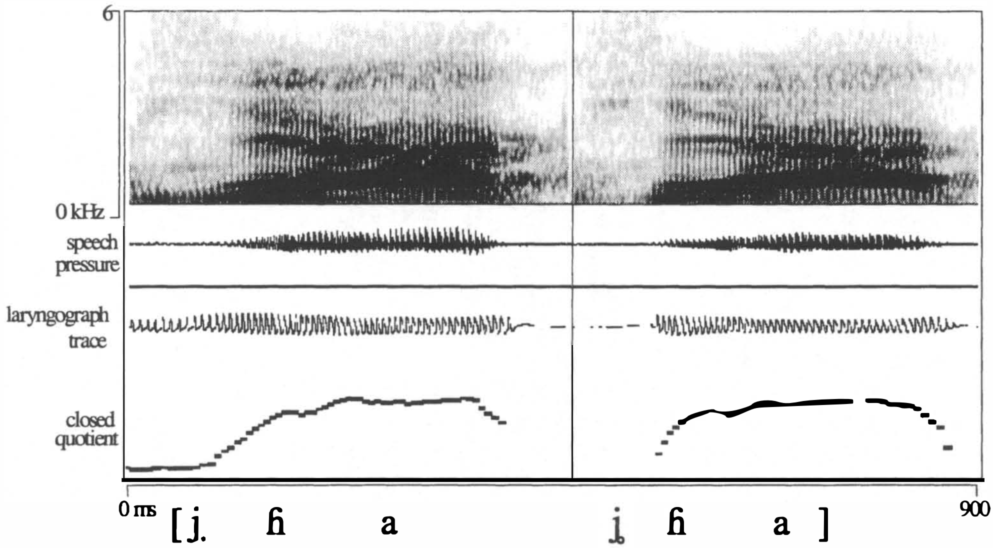

Figure 5-64: Spectrogram (150Hz bandwidth), waveform, laryngograph trace and closed quotient of /y^{h}/ in *y*^{h}*a* 'give birth (of animals)' spoken twice by consultant JH. Closed quotient rises from 23.1 to 54 per cent and from less than 20 to 52.3 per cent in the two tokens respectively.

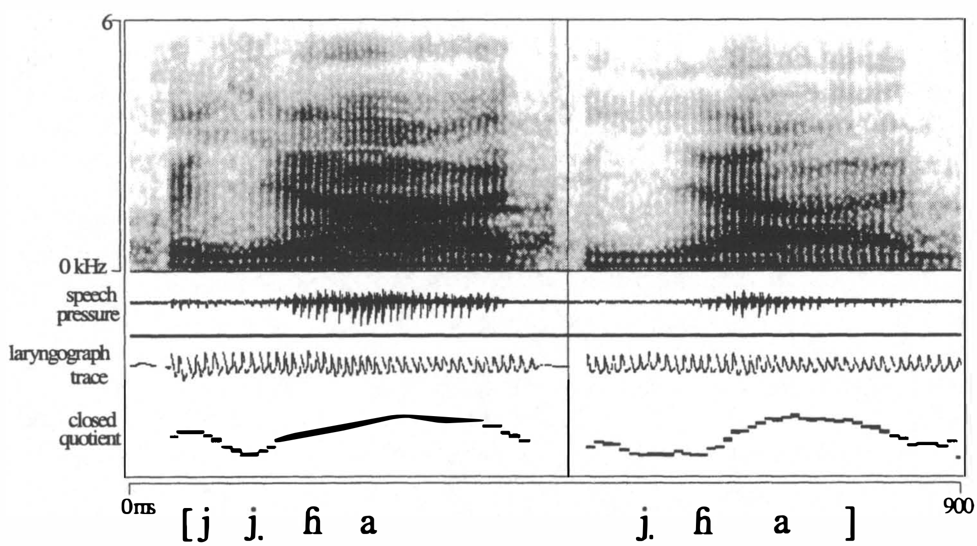

Figure 5-65: Spectrogram (150Hz bandwidth), waveform, laryngograph trace and closed quotient of /y^{h}/ in *y*^{h}*a* 'give birth (of animals)' spoken twice by consultant AP. Closed quotient rises from 32.0 to 53.8 per cent and from 31 to 54.3 per cent in the two tokens respectively.

5.5.5 ALTERNATIONS BETWEEN VOICED APPROXIMANT AND VOICELESS FRICATIVE

The laryngeal activity which accompanies the initial approximants /y/, /r/ and /l/ is discussed further in Section 6.7.1, where it is demonstrated that the aspiration of approximants and nasals consists of a laryngeal gesture which is observable as a marked dip in laryngographically derived closed quotient. Changes in phonation type have further effects which are explored here.

When the oral articulators are held in the position for an approximant, the vocal tract is at no point narrowed sufficiently to generate turbulence while the vocal folds are vibrating and the rate of airflow through the larynx is low. The formant resonances of approximants are characteristic of the shapes and sizes and acoustic interaction of the cavities formed by the narrowing in the vocal tract.

If the vocal folds stop vibrating and subglottal pressure remains constant, airflow through the open glottis increases such that the velocity of the air passing through the narrowing in the vocal tract may increase to a point where laminar flow is no longer possible. Beyond this point, airflow becomes turbulent and the resulting frication is a new source of sound. The same phenomenon may occur during aspiration of a sonorant consonant: the aspiration gesture involves a laryngeal abduction-adduction gesture which widens the glottis, resulting in vocal fold vibration with a much lower closed quotient. A longer open phase in the cycle of vibration allows more air to pass through the glottis. If the widening of the glottis combined with increased airflow causes vocal fold vibration to cut out altogether, as with the devoiced example of /v^h/ in Figure 5-48, friction noise may be present in the acoustic output.

In the language of articulatory phonetics, the effect is that, all things being equal, (voiced) sonorants may become fricatives when there is no vocal fold vibration. Catford (1977:120 ff) uses this alternation as the defining feature of approximants. In his definition, approximants are described as a category distinct from vowels (or 'resonants' in Catford's terminology), in which the oral stricture is by definition wide enough so that turbulent airflow does not ensue even with the increased airflow of voicelessness, and distinct from fricatives, in which the oral stricture is sufficiently narrow to cause turbulent airflow even with reduced airflow when the vocal folds are vibrating. Catford includes nasals in the category of approximants in this schema, labelling them 'nareal approximants', since there is audible friction resulting from turbulent airflow within the nasal cavity if vocal fold vibration is turned off. Ladefoged and Maddieson (1996:189–199), however, distinguish between fricative and non-fricative voiceless counterparts of voiced approximants: 'voiceless [lateral] approximants typically have a lower amplitude of noise...than the voiceless fricative laterals do'.

In Wa, the alternation just described may take place to a partial extent: intermediate stages are possible where the vibration of the vocal folds continues and some frication may be observed alongside the approximant formant structure, although, as with voiced fricatives, the friction noise is likely to be less intense. This effect is not especially common in Wa, but was observed sufficiently often in the corpus of recordings to be worthy of comment.

5.5.6 ASPIRATED, BREATHY-VOICED OR VOICELESS?

Phonetic variation, attributed to between-speaker variation, has been noted in all the aspirated continuants examined in this section. In a phonological account, it seems reasonable to apply the term 'aspirated' to continuants and stops alike, given their similar development from previous (consonant + h) clusters in an earlier stage of the language.

In phonetic terms, however, the label 'aspirated' seems quite inappropriate for several of the variants. In Section 5.2.3, aspiration was described in terms of a ballistic glottal abduction-adduction gesture, with the implication that glottal width is constantly changing for the duration of the gesture.

Silverman's analysis of Jalapa Mazatec breathy vowels (Silverman 1997:238) seems to describe a phonetic situation which matches this gestural analysis very closely, with a limited period of breathy phonation located across the boundary between a sonorant consonant and the following vowel. This is made explicit in his transcriptions, for example: [n͡n̤a̤a].

Invoking a glottal abduction-adduction gesture to account for the articulation of aspirated continuants in Wa implies also that gesture-like closed quotient contours should be evident. Examples where this is arguably the case may be observed for the second example of /v^h/ in Figure 5-48 or /r^h/ in Figure 5-61, in which the closed quotient trace dips down and up.

However, a gestural dip is not always evident in the closed quotient trace. /y^h/ in Figure 5-63 and Figure 5-64 shows a distinctly different pattern. Here, closed quotient is consistently low for the duration of the consonant and then rises during vowel onset to a level which is subsequently maintained for the rest of the vowel. This situation is rather more reminiscent of the phonologically breathy nasals of Tsonga, described by Traill and Jackson (1988:389):

> Airflow gradually increases during both normal voiced and breathy voiced nasals, reaching greater flows in the latter part of the nasal, with the greatest flows being in the breathy nasals. There is also significantly greater oral flow during the first 25ms of the vowel following a breathy voiced nasal.

A third phonetic variety of aspirated continuants in Wa are the voiceless ones, which may be compared with the voiceless sonorants of Burmese, in which a high volume of nasal airflow suggests that they are produced with a wide glottis (Ladefoged and Maddieson 1996:113). They are not completely voiceless, as the vocal folds start vibrating just before the release of the oral articulators. The voiceless example of /l^h/ in Figure 5-57 is consistent with this description.

6 *Suprasegmental phonetics*

The only area of linguistic phonetics in which Wa has previously featured with any prominence is the study of the linguistic use of phonation types. Research on this topic owes much to Peter Ladefoged and the UCLA phonetics laboratory: Ladefoged (1983); Maddieson and Ladefoged (1985); Ladefoged et al. (1988), Thongkum (1988b).

In the Wa vowel system, as in other Mon-Khmer languages, the potential number of vocalic phonological contrasts is doubled, because each vowel can occur in either of two registers, 'clear' and 'breathy'. This section discusses the concept of register generally and then in a specifically Mon-Khmer context. Then follows an experimental investigation of the register contrast in Wa, comprising acoustic measures of fundamental frequency, phonation type and vowel quality. The effect of register on vowel duration is also assessed. Register is assessed using the by now familiar measure of laryngographically derived closed quotient. Lastly there is some discussion of the way in which the various phonetic correlates of register combine.

6.1 'Register' and 'voice quality'

The term 'register' is widely used in several areas of linguistics. In each, it implies the grouping of diverse features into broad but discrete categories. Thus registers in discourse analysis may entail the classification of phonological processes, syntactic constructions or lexical items into categories which imply similar levels of formality. Grammatical gender in inflected languages may be thought of as abstract registers, triggering diverse agreement phenomena in a range of syntactic categories. In a phonetic context, Kenneth Pike (1948) used the term register to describe suprasegmental tonal features.

In a tonological context, register is commonly applied to tone languages in which the tonal space is divided into two pitch ranges. The diachronic development of tone systems of this kind is commonly conditioned by the loss of a voicing contrast in initial obstruents. Asian examples of this pattern are Vietnamese (Haudricourt 1954, Matisoff 1973:74–76) and a number of Chinese languages (Norman 1988:53), where an earlier tone system yields a high and a low set of tones, conditioned by the loss of initial consonant voicing.

The term 'register' is used somewhat differently in an African context to describe intonational tunes or to subdivide lexical tone systems. The phonetic interpretation of register is discussed further in Hayward et al. (1998).

Much of the literature on register makes use of the term 'voice quality' in the sense of (and frequently with direct reference to) John Laver's (1980:1) definition of voice quality: 'Voice quality is conceived here in a broad sense, as the characteristic auditory colouring of an individual speaker's voice, and not in the more narrow sense of the quality deriving solely from laryngeal activity.'

In Laver's definition, voice quality is an umbrella term which groups together phonetic features which may be involved in register systems in languages, such as larynx height, tongue root position and phonation type, but also a number of articulations which are not known to contribute to the phonetic features of register systems, such as the position of the lips, jaw or velum. Laver's objective in describing voice quality is, in any case, not primarily concerned with linguistic uses of voice quality. The term 'voice quality' is avoided here, since to use it would entail carving out a sense for it which is narrower than Laver's broad definition, but broader than simply laryngeal activity.

6.2 REGISTER IN MON-KHMER

Laver's (1980:94) comment in the context of Mon-Khmer languages is consistent with the use of the term 'register' here: '...as a linguistic concept, 'register' often now refers not solely to laryngeal behaviour, but rather to a constellation of activities at various levels of the vocal tract'.

Mon-Khmer register is a binary phonological contrast which is associated with a variety of phonetic phenomena. Some of the published work on the phonetic correlates of Mon-Khmer register is summarised in Table 6-1, including both instrumental work and general descriptions.

Table 6-1: Published work on Mon-Khmer register

language	*experimenters*
Bulang	Zhōu and Yán (1983)
Chong	Edmondson (1996)
Kammu	Svantesson (1983a)
Khmer	Henderson (1952)
Mon	Thongkum (1988b); Diffloth (1985)
Standard Wa	Svantesson (1983b, 1993); Zhōu and Yán (1984); Maddieson and Ladefoged (1985); Maddieson and Hess (1986)
Xīmĕng Wa	Zhōu and Yán (1984:109)

A number of other Mon-Khmer languages, spoken mostly in Vietnam, are described by Gregerson (1976); Thongkum (1988b) presents instrumental data from a variety of Mon-Khmer languages besides Mon.

Some Mon-Khmer languages have suprasegmental contrasts which are better described simply as tone systems, since pitch appears to be the overriding phonetic contrast. These include Kammu (Svantesson 1983a), Bulang (Zhōu and Yán 1983), U (Svantesson 1988), Hu (Svantesson 1991a), Vietnamese (Nguyễn 1987). Phonation type or other phonetic correlates may nonetheless feature in such systems as inherent properties of particular tones, both in Mon-Khmer and other tonal Asian languages, such as Thai (Hudak 1987) or Burmese (Bradley 1982).

It emerges from the studies listed in Table 6-1 that the principal phonetic correlates of Mon-Khmer register are pitch-based tone (Kammu, Bulang); phonation type (standard Wa, Mon, Chong) or vowel quality (Khmer, īmĕng Wa), or some amalgam of these and other features. Eugénie Henderson (1952:151), perhaps the first to apply the term 'register' to

Mon-Khmer languages, describes the registers of Cambodian in terms of voice quality, pitch and larynx height.[22]

The articulatory domain of the Mon-Khmer register contrast is primarily the larynx. Diachronically, it is the laryngeally articulated voicing contrasts of stop consonants which are phonologised as a register contrast. The laryngeal articulatory basis of register may subsequently be abandoned, as in Xīmĕng Wa (Zhōu and Yán 1984:109), where the phonological contrast cognate with register survives as differences in vowel quality only.

The tongue root and the pharynx form an anatomical link between the larynx, the primary articulator of phonation type, and the tongue body, the primary articulator of vowel quality. Since this connection is a physiological one, it is not surprising that configuration of the larynx cannot be altered completely independently of the pharynx and tongue root. Raising and tensing of the larynx necessarily entails tensing of the pharynx and tongue root, in turn affecting the position of the tongue, and suggesting that the configuration of the larynx is likely to influence vowel quality.

Kenneth Gregerson (1976) suggested a systematic connection between Mon-Khmer register and tongue-root position by pointing out similarities between the phonetic features which split the vowel systems of Mon-Khmer and the binary tongue root position feature [±ATR]. Tongue root advancement has been adduced to account for the doubling of vowel systems in Akan (Stewart 1967) and a number of West Nilotic African languages, for instance DhoLuo, Shilluk, Nuer and Dinka (Jacobson 1980). The concept of register is described in terms of two contrasting 'laryngeal attitudes' by Matisoff (1973:76), which he names 'tense-larynx syndrome' and 'lax-larynx syndrome'. These 'syndromes' involve the tongue root and supra-glottal cavity as well as the larynx.

Since Mon-Khmer register involves a variety of phonetic and phonological contrasts and distinctions, it is not surprising that numerous terms have been used to refer to and describe it. Even the terms 'first' and 'second' register are rendered ambiguous by inconsistencies in the ordering of the two registers, though the order in Table 6-2 emerges as the conventional one.

In the name of consistency, this study follows the example of Gérard Diffloth (1980:37) and Theraphan Thongkum (1988b) in using the terms 'clear' and 'breathy' to refer to the registers of Wa.

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[22] The diversity of phonetic features involved in Mon-Khmer register should not be underestimated. Eugénie Henderson (1952:151) notes that the second register of Khmer is 'frequently accompanied by a flaring of the nostrils,' an articulatory extra which perhaps enhances the impression of 'breathiness' by generating turbulence noise.

Table 6-2: Labels for the Mon-Khmer register contrast

'first' register	*'second' register*	*Usage and implications*
head	chest	Used of Khmer by Henderson (1952); removed from terminology in current instrumental phonetic literature; more usually used in singing technology (Sundberg 1987).
tense	lax	Generally applicable to most manifestations of register in South East Asia, viz. tense/lax 'laryngeal attitudes' (Matisoff 1973); phonetically vague; also used to refer to stop consonant articulations, e.g. in Korean (Shin 1997). 'Tense' and 'lax' are also used to describe pairs of vowels distinguished by tongue root position or other features (Ladefoged and Maddieson 1996:302) and laryngeal contrasts in stop consonants (Ladefoged and Maddieson 1996:96).
jǐn 紧 'tight, taut'	*sōng* 松 'loose, slack'	Chinese terms very similar to 'tense' and 'lax': (Wáng and Chén 1981:49; Zhōu and Yán 1984:7).
creaky	breathy	Opposite ends of the phonation type 'continuum' (see Section 6.8); misrepresentative of the phonetic facts in Wa because canonically creaky voice is not involved.
clear	breathy	Partly subjective, suggestive of more than simply phonation type; arguably also analogous to 'creaky' and 'breathy' in describing contrasting phonation types.

6.3 EXPERIMENTAL INVESTIGATION OF THE REGISTER CONTRAST

6.3.1 EXPERIMENTAL DESIGN

A number of caveats needed to be considered in deciding how to tease out the phonetic correlates of the register contrast. Fundamental frequency, phonation type and vowel quality are all subject to a wide range of influences, of which register is only one. Intonation (specifically, the intonation used when reciting the reading lists) and coarticulatory effects of neighbouring consonants (for example stops or laryngeal consonants) may also affect these measures. Another problem is that spectral measures of phonation type are not consistent at different vowel heights. To minimise skewing of the results by non-registral effects, the measures made here were of the same open syllables used in the description of monophthongs in Table 5-2, Section 5.1.2, since these syllables are in data sets which allow pairwise comparison. All measurements and tests were conducted on 396 tokens, or 198 pairs of syllables containing one clear register and one breathy register syllable.

The following tables summarise some of the measurements which are discussed subsequently. Table 6-4 summarises measurements with respect to register; Table 6-5 with respect to recitation order. Table 6-4 and Table 6-5 summarise the register contrast measurements by displaying the information as in Table 6-3.

Table 6-3: Summary of contents of Tables 7.4 – 7.7

sample mean and s.d.	*mean and s.d. of the entire set of 396 tokens*
clear/breathy mean	mean of 198 measurements of syllables of each register (of each repetition in Table 7.5)
difference	mean and s.d. of the difference between each of the 198 pairs of data, calculated as the clear register value less the breathy register value (1st rep – 2nd rep in Table 7.5)
t-test	probability that the set of clear register values are different from the set of breathy register values, calculated using a paired, two-tailed t-test
Sig	a visual key to the significance of the t-test probability

Table 6-4: Summary of measurements of six phonetic variables with reference to the register contrast

n = 396 (198 pairs)	*Sample*		*clear*	*breathy*	*difference*		*t-test*	*sig*
	mean	*s.d.*	*mean*	*mean*	*mean*	*s.d.*		
F0 (Hz)	162.87	33.42	166.80	158.94	7.86	15.63	< 0.0001	●
CQ (per cent)	47.37	6.38	51.22	43.51	7.70	5.58	< 0.0001	●
duration (ms)	342.37	43.51	343.54	341.21	2.33	54.14	0.2734	●
H2–H1 (dB)	5.06	5.07	6.41	3.69	2.69	5.05	< 0.0001	●
F1–F0 (dB)	10.87	7.27	12.76	8.90	4.09	6.51	< 0.0001	●
resonance balance (dB)	29.00	9.71	27.83	30.18	–2.35	9.4	0.0003	●

Table 6-5: Summary of measurements of three phonetic variables with reference to recitation order

n = 396 (198 pairs)	*sample*		*1st rep*	*2nd rep*	*difference*		*t test*	*sig*
	mean	*s.d.*	*mean*	*mean*	*mean*	*s.d.*		
F0 (Hz)	162.87	33.42	166.49	159.24	7.25	8.47	< 0.0001	●
CQ (per cent)	47.37	6.38	47.10	47.63	–0.54	3.09	0.0154	○
duration (ms)	342.37	97.35	353.69	331.06	22.63	41.12	< 0.0001	●

Table 6-6: Summary of between-speaker variation in the register effect on fundamental frequency, closed quotient and vowel duration

speaker	*sample*		*clear mean*	*breathy mean*	*mean difference*	*t-test*	*sig*
	mean	*s.d.*					
fundamental frequency (Hz)							
RM	129.33	10.79	131.06	127.61	3.44	0.114	
NT	193.94	14.54	202.06	185.83	16.22	< 0.0001	●
YH	147.61	12.09	151.56	143.67	7.89	0.001	●
AN	147.89	10.68	150.06	145.72	4.33	0.109	
JN	148.11	13.12	154.67	141.56	13.11	0.001	●
ST	168.83	14.86	176.39	161.28	15.11	< 0.0001	●
NKP	154.61	16.97	164.67	144.56	20.11	< 0.0001	●
SRM	137.81	16.80	145.67	129.94	15.72	0.003	○
APP	237.72	13.14	238.28	237.17	1.11	0.328	
AP	138.19	10.56	135.22	141.17	–5.94	0.008	○
SJ	187.50	11.61	185.17	189.83	–4.67	0.060	
closed quotient (per cent)							
RM	45.99	4.44	48.78	43.20	5.58	< 0.0001	●
NT	48.42	4.25	51.67	45.17	6.50	< 0.0001	●
YH	44.72	4.82	48.11	41.33	6.78	< 0.0001	●
AN	47.81	3.73	49.39	46.22	3.17	0.001	○
JN	52.36	4.41	55.00	49.72	5.28	< 0.0001	●
ST	51.17	7.17	56.11	46.22	9.89	< 0.0001	●
NKP	46.33	6.70	51.11	41.56	9.56	< 0.0001	●
SRM	45.00	7.09	50.44	39.56	10.89	< 0.0001	●
APP	41.33	5.82	44.83	37.83	7.00	< 0.0001	●
AP	47.78	7.45	54.17	41.39	12.78	< 0.0001	●
SJ	50.11	4.10	53.78	46.44	7.33	< 0.0001	●
vowel duration (ms)							
RM	400.28	64.66	390.83	407.67	–16.83	0.032	○
NT	516.67	51.37	518.50	514.11	4.39	0.378	
YH	422.50	58.90	430.00	415.00	15.00	0.196	
AN	288.89	39.57	297.78	280.00	17.78	0.059	
JN	285.83	61.75	290.22	280.89	9.33	0.309	
ST	319.44	43.65	313.39	325.56	–12.17	0.116	
NKP	337.50	51.34	357.22	317.78	39.44	0.001	●
SRM	234.17	28.81	232.22	236.11	–3.89	0.311	
APP	263.19	21.14	261.94	264.44	–2.50	0.345	
AP	270.56	67.98	255.00	286.11	–31.11	0.034	○
SJ	429.17	34.43	431.78	425.61	6.17	0.282	

Table 6-7: Summary of between-speaker variation the register effect on H2–H1, F1–F0 and the resonance balance measure

speaker	*sample mean*		*clear*	*breathy*	*mean*	*t-test*	*sig*
	mean	*s.d.*	*mean*	*mean*	*difference*		
H2–H1 phonation measure (dB)							
RM	5.64	2.26	6.22	5.06	1.17	0.003	○
NT	5.25	4.6	8.06	3.53	4.53	< 0.0001	●
YH	2.28	4.62	5.47	–0.53	6	< .0001	●
AN	5.61	3.33	7.39	4.35	3.04	0.001	●
JN	5.36	2.97	7.11	4.68	2.42	< 0.0001	●
ST	8.64	4.1	9.44	7.83	1.61	0.061	
NKP	4.53	4.94	4.33	4.72	–0.39	0.407	
SRM	3.69	4.82	5.28	2.11	3.17	0.018	○
APP	4.58	6.9	6.69	4.71	1.98	0.204	
AP	–1.08	3.65	–0.44	–2.24	1.8	0.031	○
SJ	8.08	4.33	10.17	6	4.17	0.003	○
F1–F0 phonation measure (dB)							
RM	13.92	5.23	17.28	10.56	6.72	< 0.0001	●
NT	10.31	6.16	13.72	9.44	4.28	< 0.0001	●
YH	6.75	5.41	10.44	4.31	6.13	< 0.0001	●
AN	11.17	5.36	13.5	9.65	3.85	0.001	●
JN	14.56	4.8	15.44	13.67	1.78	0.053	
ST	13.5	6.63	14.56	12.44	2.11	0.022	○
NKP	12	6.94	11	13	–2	0.169	
SRM	10.89	5.44	12.67	9.11	3.56	0.009	○
APP	6.31	6.23	10.88	8.73	2.14	0.118	
AP	8.31	5.8	12.5	8	4.5	0.014	
SJ	3.31	11.41	8.17	–1.56	9.72	< 0.0001	●
resonance balance (dB)							
RM	23.53	8.97	23.28	23.78	0.5	0.368	
NT	38.08	11.87	36.44	39.72	3.28	0.181	
YH	27	7.44	27.78	26.22	–1.56	0.224	
AN	29.72	7.71	29.06	30.39	1.33	0.247	
JN	28.36	8.01	27.11	29.61	2.5	0.030	○
ST	33.5	6.72	31.78	35.22	3.44	0.028	○
NKP	32.91	11.43	31.88	33.94	2.07	0.263	
SRM	30.72	5.69	32.5	28.94	–3.56	0.028	○
APP	24.85	9.23	22.37	27.33	4.96	0.003	○
AP	26.97	8.15	24.94	29	4.06	0.049	○
SJ	23.39	8.27	19	27.78	8.78	< 0.0001	●

6.3.2 STATISTICAL TEST DESIGN

For each of the six dependent variables in Table 6-8, an ANOVA test was used to determine the influence of the four independent variables. Significant results are reported and discussed in the section concerning each variable.

Table 6-8: Variables included in statistical test design for evaluation of phonetic correlates of the register contrast

dependent variables	fundamental frequency closed quotient duration H2–H1 F1–F0 resonance balance
independent variables	speaker (10) vowel height (close, mid-close, mid-open, open) register (clear, breathy) recitation order (first or second)

6.3.3 FUNDAMENTAL FREQUENCY

Vowels were read by most consultants with a falling pitch contour, so care needed to be exercised in selecting a measure of fundamental frequency which could be applied consistently to all the recorded data and reasonably be considered representative of the whole vowel. It was decided to measure the maximum fundamental frequency of the vowel, which was typically a few periods after the onset of the vowel.

Table 6-9: Results of ANOVA tests for effects on fundamental frequency

Effect	*d.f*	*F*	*p*	*sig*
main effects				
Register	1	34.43	< 0.0001	●
Speaker	10	306.32	< 0.0001	●
recitation order	1	43.94	< 0.0001	●
vowel height	3	29.78	< 0.0001	●
significant higher order interactions				
Register by speaker	10	5.51	< 0.0001	●
Register by vowel height	3	4.69	0.003	○
Speaker by vowel height	30	3.47	< 0.0001	●

Clear register is, on average, 7.86Hz higher than breathy register ($n = 198$ data pairs, $p = 0.0001$), though there is a good deal of speaker variation, explored in Figure 6-1. As suggested by the significant interaction of register with speaker in the ANOVA test (Table 6-9: 10 d.f., $F = 5.51$, $p < 0.0005$), the F0 difference between clear and breathy registers varies from speaker to speaker. This variation is evident in Figure 6-1, where there is a reasonably clear distinction between the six speakers with a large (>7Hz) and highly significant ($p < 0.003$) F0 difference conditioned by register (the six longest black bars in Figure 6-1) and the less marked, statistically insignificant pitch difference between the two registers for the other speakers. These data give the impression that slightly higher fundamental frequency in clear register is a tendency, rather than a certainty.

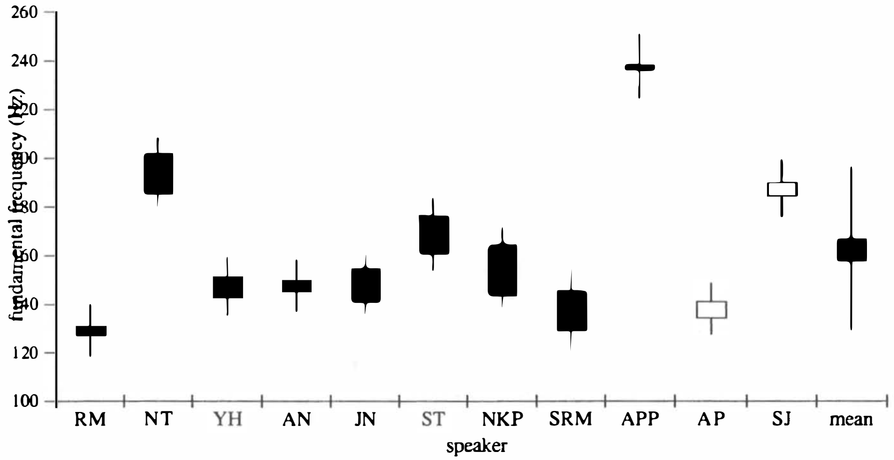


Figure 6-1: Graphic illustrating between-speaker variation in the effect of the register contrast on vowel fundamental frequency. Bars represent difference between clear and breathy registers: filled bars = clear greater; hollow bars = breathy greater. Lines represent mean +/– one s.d. Eighteen tokens per speaker.

Recitation order had a predictable effect on fundamental frequency for most speakers, such that the second repetition was, on average, 7.25Hz lower than the first ($n = 198$ data pairs, $p < 0.0001$, see Table 6-5). The difference has two possible causes. Either speakers read the two repetitions of the frame sentence in a single intonational phrase, in which case general downdrift is expected, or else they read the two repetitions as a two-item list consisting of two intonational phrases, the second of which has falling intonation. However, since the ANOVA test for effects on fundamental frequency did not indicate a significant interaction between the effects on fundamental frequency of recitation order and register, we can think of the listing effect as independent of any effect of register on fundamental frequency.

Another effect which must be considered here is the intrinsic pitch of vowels, or the correlation of vowel-height with fundamental frequency. This is another phonetic universal of the type discussed with reference to the duration of vowels in Section 5.1.3, and has been documented in a large number of languages (Peterson and Barney 1952:183; Whalen and Levitt 1995). Additionally, the vowel height / pitch correlation may play a role in speech perception, allowing listeners to adjust for cross- speaker variation in characteristic fundamental frequency and hence also formant frequencies (Maddieson 1997:623).

Though intrinsic pitch has been tested beyond all doubt, instrumental studies of the linguistic use of fundamental frequency often fail to take it into full consideration.[23] Intrinsic pitch does not detract from the measured effect of register on fundamental frequency, since it is prevented from skewing the data because of the pairwise arrangement of the data. The ANOVA test for effects on fundamental frequency (Table 6-9) indicates that there is a significant interaction between the influences on fundamental frequency of vowel height and register (3 d.f., F = 4.69, p = 0.003). This interaction is explored in Figure 6-2, where the mean fundamental frequency is plotted separately for each of the nine vowel qualities. We see in this plot that close vowels have higher F0 than open vowels. In fact, within this sample, the fundamental frequency is statistically inversely correlated (r = -0.68) with F1, our acoustic measure of vowel height. The other significant interaction between vowel height and speaker (30 d.f., F = 3.47, p < 0.0001) suggests that the extent of the intrinsic pitch effect varies between speakers.

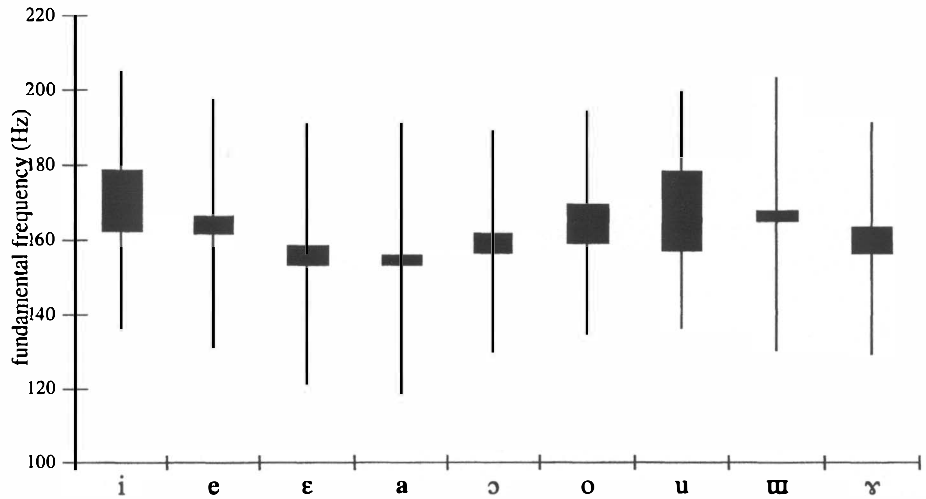


Figure 6-2: Graphic illustrating the interaction of vowel quality with the effect of the register contrast on fundamental frequency. Bars represent difference between clear and breathy registers: filled bars = clear greater (uniformly the case in this figure). Forty-four tokens per vowel.

It is also apparent from Figure 6-2 that register affects the fundamental frequency of close vowels /i u/ (though not /ɯ/) more than open vowels: the F0 difference between the two registers is greatest in these vowels, observable as longer black bars in Figure 6-2. There is little evidence that this is true in a more general sense, though the fundamental

[23] For instance, Svantesson's (1983b) study of Wa register finds evidence of intrinsic pitch, even though the study is of a small collection of data. He mentions it as an independent observation, but does not discuss its interaction with the register contrast.

frequency difference between registers is correlated ($r = 0.59$) with F1 for one of the consultants.

The fundamental frequency measurements confirm the following statement, translated from Wáng and Chén's edition of Luó Jìguāng's fieldnotes (Wáng and Chén 1981:53):

> 'Wa does not have tones ... but in careful pronunciation of single syllables, the tone of the tense [jǐn] and lax [sōng] registers is not the same.' In Àishuāi speech, 'the great majority of people say single syllables with a falling tone: if it is a tense register syllable, it is said with a high falling tone; lax syllables are thus said with a rather lower falling tone, some people may say tense register with a level tone and lax with low falling tone. In general, the tones of tense and lax register are variable but always distinguishable from each other. To say the tone incorrectly is not a grave error. If the tense-lax contrast is correct, the pronunciation will not be judged wrong.'

This description is borne out by the generally falling contour observed here, though no difference was noticed between the pitch contour of vowels in clear and breathy register syllables, nor was any attempt made to measure such a difference.

6.3.4 LOW-FREQUENCY ACOUSTIC MEASURES OF PHONATION TYPE

The acoustic measures of phonation type used here are the difference in amplitude between the first and second harmonics (H2–H1) and between the most prominent harmonic peak in the region of the first formant and the first harmonic (F1–F0).[24] These measures detect changes in spectral profile wrought by qualitative changes in the glottal source, as discussed in Section 3.3.1, but all other things being equal, these measures are expected to return greater values in creaky phonation and smaller or negative values in breathier phonation.

These two acoustic measures of phonation type were made at the mid-point of each vowel in the same set of syllables: 198 pairs of open syllables, one clear and one breathy register.

The ANOVA tests (Table 6-10 and Table 6-11) of effects on the H2–H1 and F1–F0 measures of phonation type reveal two significant sources of variation besides register in each case: vowel height (3 d.f., $F = 18.62$, $p < 0.0005$ for H2–H1; 3 d.f., $F = 53.88$, $p < 0.0005$ for F1–F0) and speaker (10 d.f., $F = 16.47$, $p < 0.0005$ for H2–H1; 10 d.f., $F = 12.67$, $p < 0.0005$ for F1–F0). Furthermore, vowel height and speaker interact significantly in both measures.

The effect of between-speaker variation on both measures is explored in Figure 6-3 and Figure 6-4 and discussed further below.

[24] H1 and F0 both refer to the first harmonic, of course.

Table 6-10: Results of ANOVA tests for effects on H2–H1 phonation measure

Effect	*d.f*	*F*	*p*	*sig*
Main effects				
Register	1	41.34	< 0.0001	•
Speaker	10	16.47	< 0.0001	•
Recitation order	1	0.85	0.358	
vowel height	3	18.62	< 0.0001	•
significant higher order interactions				
speaker by vowel height	30	3.81	< 0.0001	•
register by speaker by vowel height	30	2.2	< 0.0001	•

Table 6-11: Results of ANOVA tests for effects on F1–F0 phonation measure

Effect	*d.f*	*F*	*p*	*sig*
main effects				
Register	1	55.3	< 0.0001	•
Speaker	10	12.67	< 0.0001	•
recitation order	1	0.21	0.648	
vowel height	3	53.88	< 0.0001	•
significant higher order interactions				
register by speaker	30	3.81	< 0.0001	•
speaker by vowel height	30	2.2	< 0.0001	•

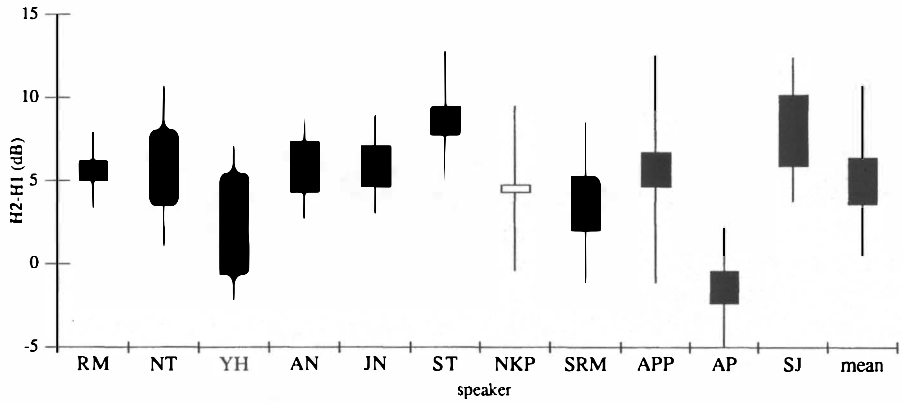


Figure 6-3: Graphic illustrating between-speaker variation in the effect of the register contrast on the H2–H1 phonation type measure. Bars represent difference between clear and breathy registers: filled bars = clear greater; hollow bars = breathy greater. Lines represent mean +/– one s.d. Eighteen tokens per speaker.

An inescapable problem in the use of low frequency measures of spectral profile is the interaction of low frequency Fl in close vowels with the amplitude of H1 and H2, which renders the H2–H1 and F1–F0 measures inapplicable across different vowel qualities (Ní Chasaide and Gobl 1997:443). The fundamental can come close to, or even coincide with, the low Fl (e.g. 300–350Hz) of close vowels, amplifying them. The relative frequencies of harmonics thus boosted by nearby formants are no longer representative of the source excitation function. A similar problem arises with high-pitched voices, where the location of formants may become increasingly difficult to discern in a spectrum with more widely-spaced harmonics (Kent and Read 1992:156).[25]

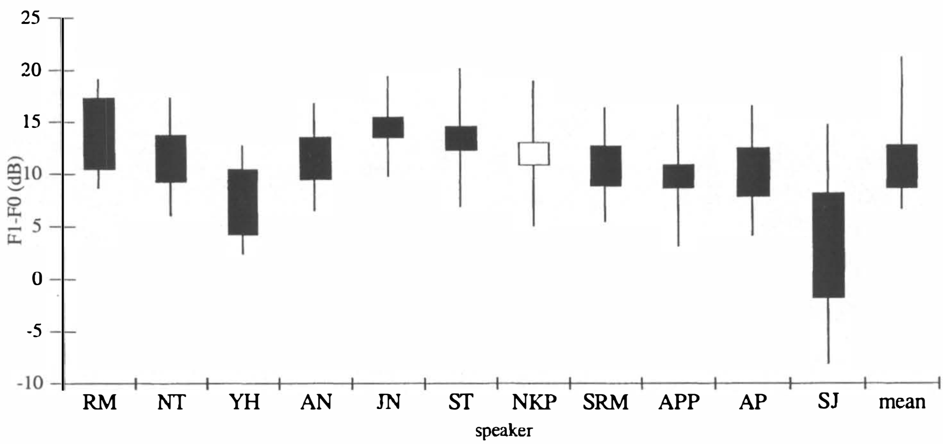


Figure 6-4: Graphic illustrating between-speaker variation in the effect of the register contrast on the F1–F0 phonation type measure. Bars represent difference between clear and breathy registers: filled bars = clear greater; hollow bars = breathy greater. Lines represent mean +/– one s.d. Eighteen tokens per speaker.

Figure 6-3 shows that both measures, and indeed the magnitude of the difference between the measures of like vowels in the two registers, seem to be inversely correlated with the frequency of F1, the acoustic manifestation of vowel height. The magnitude of the H2–H1 measure is greater in close vowels because in these vowels H2 is boosted by the proximity of a low F1. The difference between H2–H1 of like vowels in the two registers is likewise greater in close vowels, suggesting that the lower F1 of the clear register vowel in each pair, which is often closer in quality (see Section 6.3.7) boosts H2 more than H1. This suggests that the closer the proximity of Fl to a harmonic peak, the more it boosts both it and hence also the magnitude of the H2–H1 register difference.

[25] This interaction is frequently mentioned as a particular problem in analysing female voices. In fact, the voice of the single female speaker (APP) included in these calculations was lower in pitch than several of the male consultants.

The magnitude of the F1–F0 measure, however, is less in close vowels. This may be explained as the amplification of H1 by the proximity of low F1 in close vowels compared with the absence of this effect in open vowels where F1 is remote from H1. The relative proximity across registers of F1 to H1 is not a factor here; rather, it appears from Figure 6-6 that the difference between the F1–F0 measures of like vowels is greater in back vowels, an effect which may be attributed to the fusion into a single amplified peak of F1 and F2 in back vowels.

However, because all the data are suited to comparison of pairs of data, the interaction of F1 with these phonation measures does not detract from their consistent and significant (Table 6-4) differentiation of the clear and breathy registers.

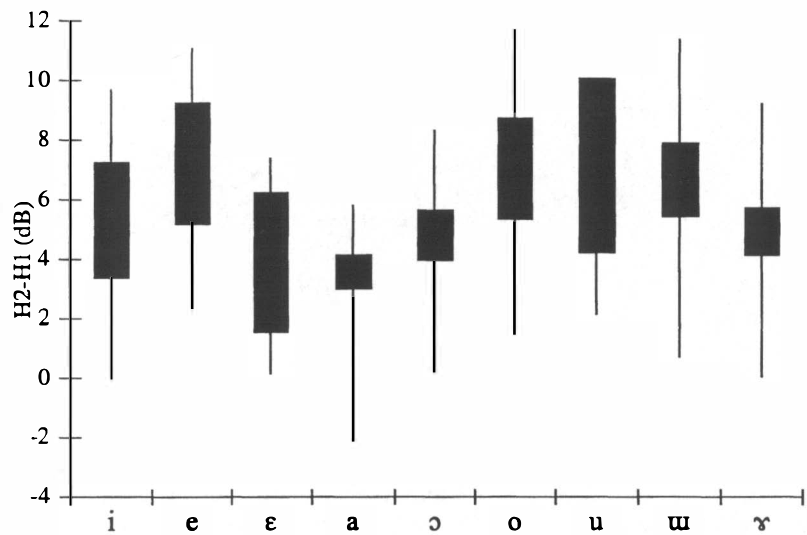


Figure 6-5: Graphic illustrating the interaction of vowel quality with the effect of the register contrast on the H2–H1 phonation type measure. Bars represent difference between clear and breathy registers: filled bars = clear greater (uniformly the case in this figure). Forty-four tokens per vowel.

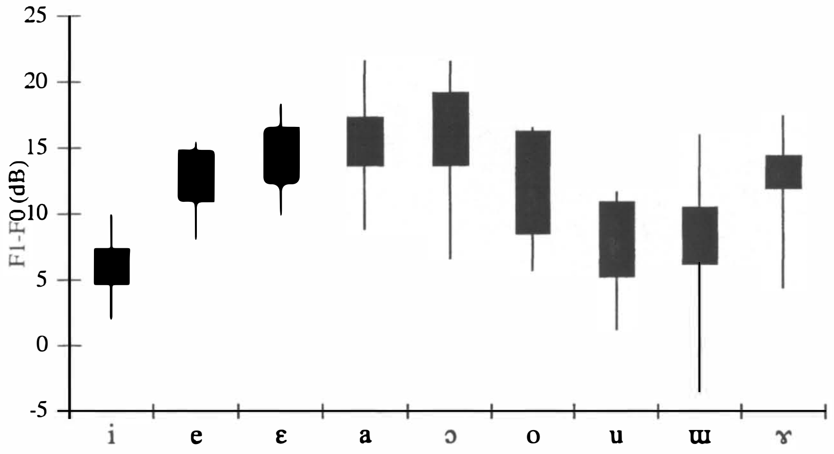


Figure 6-6: Graphic illustrating the interaction of vowel quality with the effect of the register contrast on the F1–F0 phonation type measure. Bars represent difference between clear and breathy registers: filled bars = clear greater (uniformly the case in this figure). Forty-four tokens per vowel.

Another problem which arises in studies of several subjects is between-speaker variation in phonation type. Female voices are generally more breathy (Kent and Read 1992:154), though this is not apparently the case for the single female subject, APP, in the present study. The amplitude of the fundamental is, on average, greater than that of the H2 and F1 peaks in both the clear and breathy registers of a single male speaker, AP. The ANOVA test (Table 6-11) detects a significant interaction between the effects of register and speaker on the F1–F0 measure, indicating that the effect of register on this measure is not uniform across speakers. However, clear register translates into greater H2–H1 and F1–F0 for all speakers (except one, NKP, identifiable as hollow bars in Figure 6-3 and Figure 6-4). The magnitude of the register difference varies between speakers, as do the values of the measures themselves, but the difference between the registers is significant for a majority of speakers.

As was expected, both measures return a lesser value in breathy register, reflecting the greater amplitude of the fundamental in breathy register. Increased amplitude of the very lowest harmonics of the source spectrum, which persist despite the filtering function of the vocal tract, covaries with increased open quotient, i.e. decreased closed quotient, according to Ní Chasaide and Gobl (1997:440).

Ladefoged et al. (1988:314) and Ladefoged and Maddieson (1996:316) compare the phonation type component of the Wa (referred to as Parauk by them) register contrast with the phonation types which contrast in other languages they have studied, such as the Otomanguean language Jalapa Mazatec and the Khoisan language !Xóõ. They find that the amplitude of the fundamental is typically greater than the second harmonic in the breathy phonation types observed in Jalapa Mazatec and !Xóõ. This is only exceptionally the case in Wa, according to the results of this study, in which the register contrast translates into a mean difference in H2–H1 and F1–F0 of 2.72dB and 3.86dB respectively ($n = 198$ pairs of vowels, $p < 0.00005$). They conclude that the difference in those languages may be considered extreme in comparison to Wa.

6.3.5 LARYNGOGRAPHICALLY DERIVED CLOSED QUOTIENT

The use of a laryngograph to measure phonation types has a number of practical advantages. In the present context it is worth mentioning the independence of the laryngograph trace from vowel quality, in contrast to the disruptive influence of vowel quality on the measurement of the acoustic correlates of phonation type in the previous section.

In contrast to the falling fundamental frequency observed in open syllable vowels, the computer-generated traces of closed quotient in open syllables appeared constant or gently decreasing through the vowel, with perturbations only in the first and last few periods of vocal fold vibration, at vowel onset and offset. Where closed quotient was stable through the vowel, it was measured at a point approximately half-way through the vowel; when some contour in the trace was evident, mean closed quotient was measured over a 100ms section in the middle of each vowel, using the computer's capacity to calculate this automatically.

Sample waveforms for comparison of clear and breathy register vowels from the consultants used in this study are shown in Figure 6-7–Figure 6-10. In impressionistic terms, closed quotient is a measure of the relative pointedness and/or breadth of the waveform peaks and troughs. The closed phase is longer, increasing CQ, when the peaks are broader relative to the troughs; the closed phase is shorter, reducing CQ, when the troughs are broader or fuller relative to the peaks. Figure 6-7–Figure 6-10 show that the waveform shapes are highly individual, especially with respect to the minimal contact phase. However, such differences have little bearing on the calculation of the closed quotient, except where there are fluctuations in impedance during the opening or closing phases of the waveform (for instance JN's *pi* in Figure 6-7 or APP's *tɛ̤* in Figure 6-9. Such fluctuations may distort the computer's interpretation of the division between open and closed phases.

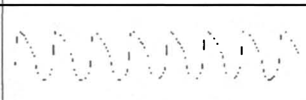
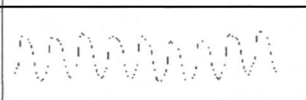
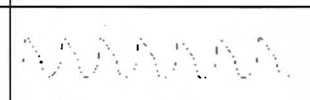
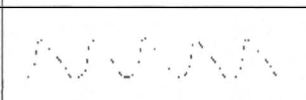
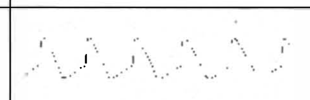
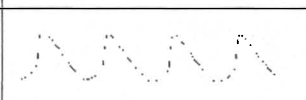
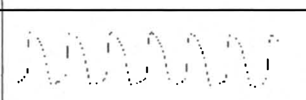
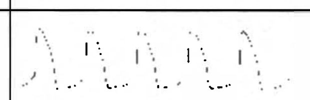
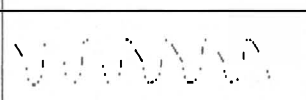
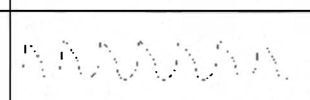
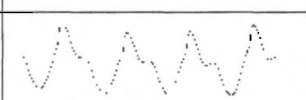
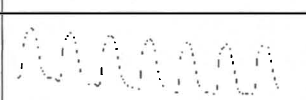
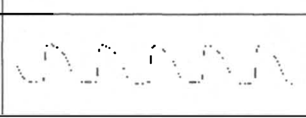
speaker	*clear register: pi 'flute'*	*closed quotient*		*breathy register: pi̤ 'forget'*
		clear	*breathy*	
NT		52.5	47.2	
RM		45.8	40.9	
ST		54.1	35.5	
SJ		52.5	47.6	
AP		53.9	39.2	
YH		46.6	41	
SRM		49	36.3	
NKP		48.9	38.4	
JN		43.5	48.1	
AN		47.4	41.6	
APP		52.1	42.3	

Figure 6-7: Laryngograph waveforms (each 25ms long) of clear register vowels /i/ and breathy register /i̤/ from the minimal pair *pi* 'flute' and *pi̤* 'forget'; closed quotient is given for each waveform.

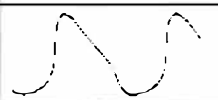
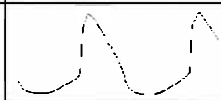
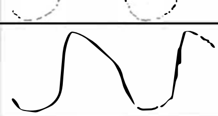
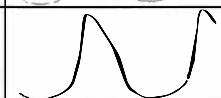
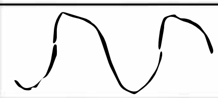
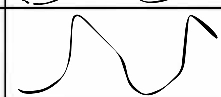
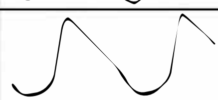
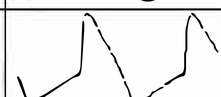
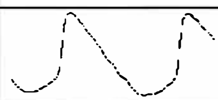
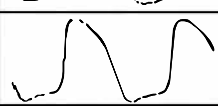
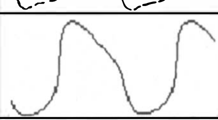
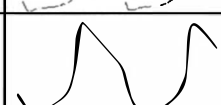
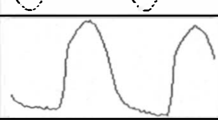
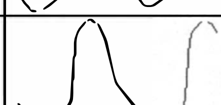
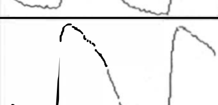
speaker	*clear register: pi 'flute'*	$CQ_{clear}-CQ_{breathy}$ *(per cent)*	*breathy register: p̤i̤ 'forget'*
NT		5.3	
RM		4.9	
ST		18.6	
SJ		4.9	
AP		14.7	
YH		5.6	
SRM		12.7	
NKP		10.5	
JN		4.6	
AN		5.8	
APP		9.8	

Figure 6-8: The laryngograph waveforms of /i/ and /i̤/ in Figure 6-7 re-scaled and cropped for comparison, such that the distance between adjacent peaks and the peak-to-trough distance is equal for each wave. The difference in closed quotient between each pair is shown in the central column.

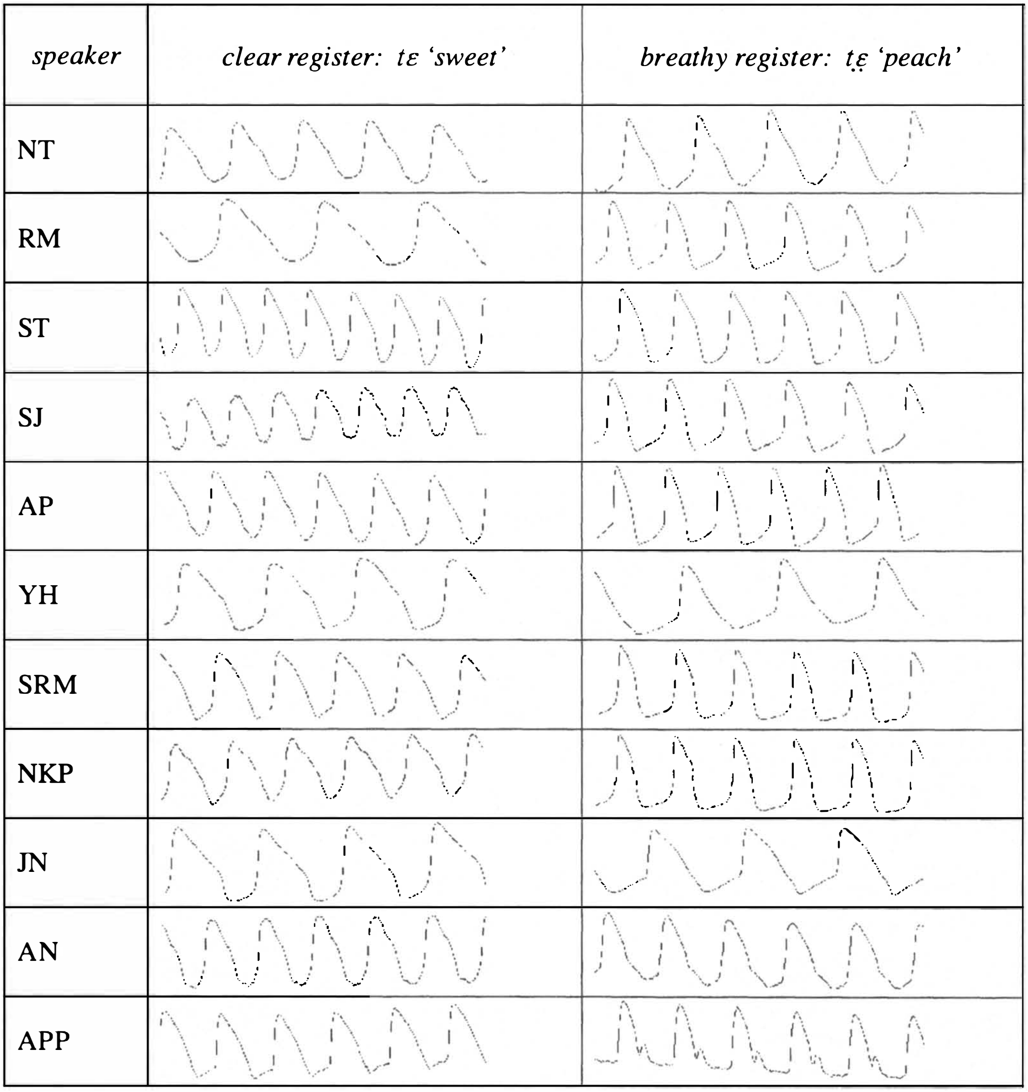


Figure 6-9: Laryngograph waveforms (each 25ms long) of clear register vowels /ɛ/ and breathy register /ɛ̤/ from the minimal pair *tɛ* 'sweet' and *tɛ̤* 'peach'; closed quotient is given for each waveform.

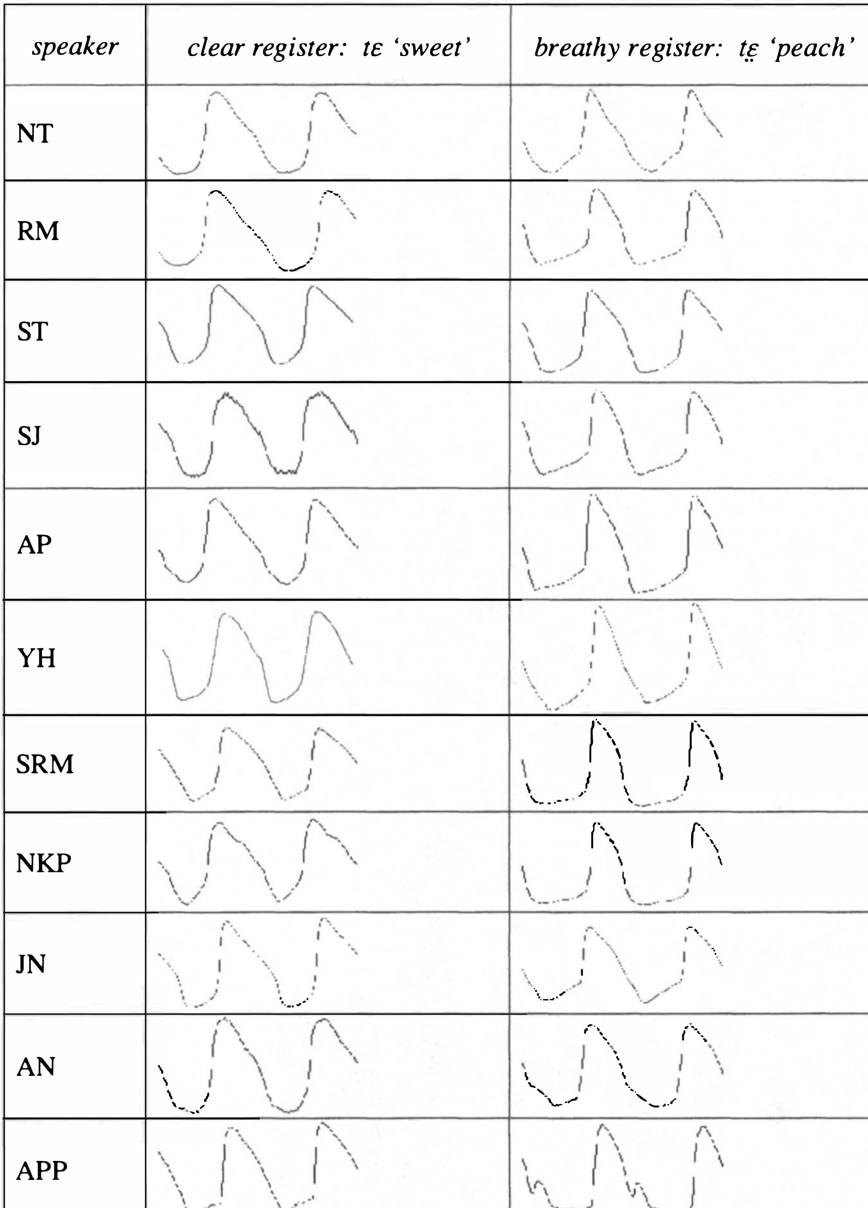


Figure 6-10: The laryngograph waveforms of /ɛ/ and /ɛ̤/ in Figure 6-9 re-scaled and cropped for comparison, such that the distance between adjacent peaks and the peak-to-trough distance is equal for each wave.

Table 6-12: Results of ANOVA tests for determinants of closed quotient

effect	*d.f.*	*F*	*p*	*sig*
main effects				
register	1	399.9	< 0.0001	•
speaker	10	25.2	< 0.0001	•
recitation order	1	1.83	0.177	
vowel height	3	14.07	< 0.0001	•
significant higher order interactions				
register by speaker	10	6.89	< 0.0001	•
speaker by vowel height	30	3.16	< 0.0001	•
register by speaker by vowel height	30	3.09	< 0.0001	•

Clear register has consistently greater closed quotient than breathy register in the recordings of all the consultants, as illustrated in Figure 6-11. The mean difference between closed quotient in clear and breathy registers, measured by pairing clear and breathy tokens, was 7.71 per cent (198 data pairs, $p < 0.00005$). The magnitude of the closed quotient difference between the two registers is remarkably consistent (s.d. 5.78 per cent in 198 data pairs) across the entire set of speakers. In contrast to the high degree of variation between speakers observed in the other correlates, closed quotient emerges as the most stable phonetic correlate of register.

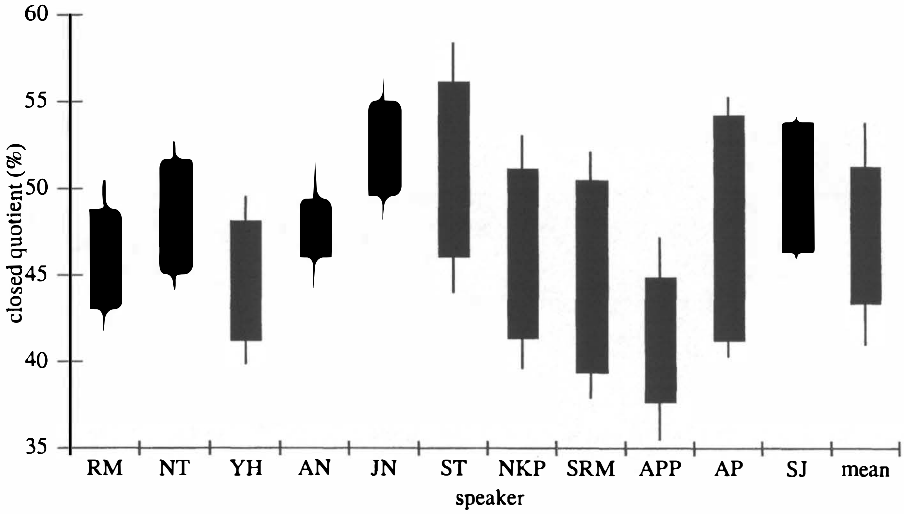


Figure 6-11: Graphic illustrating between-speaker variation in the effect of the register contrast on the laryngographically derived closed quotient. Bars represent difference between clear and breathy registers: filled bars = clear register greater than breathy (uniformly the case in this figure). Lines represent mean +/– one s.d. Eighteen tokens per speaker.

The range of closed quotients measured varies from speaker to speaker, even though the register contrast is clearly maintained for each. This accounts for the significant interaction (10 d.f., $F = 6.89$, $p < 0.0005$) of register with speaker detected by the ANOVA test (Table 6-12). For instance, it is evident from Figure 6-11 that JN's breathy register vowels have higher mean closed quotient than AN's clear register, but this overlap does not impede the ability of either speaker to maintain a difference between the two registers.

The effect of recitation order on closed quotient emerges as a significant effect on closed quotient in a paired t-test (Table 6-5: 198 data pairs, $p = 0.015$), though the difference recorded is slight: closed quotient of first repetition vowels is only 0.54 per cent less than that of second repetition. Additionally, the ANOVA test (Table 6-12) detects no significant interaction between the effects of recitation order and register on closed quotient.

Further effects on closed quotient detected by the ANOVA test are vowel quality and a two-way interaction of vowel quality with speaker. The vowel quality effect is explored in Figure 6-12. Though there is no clear pattern to suggest a correlation between vowel height and phonation type, a pattern for which there is limited but inconclusive evidence in Section 6.3.7 below, the possibility of such a correlation cannot be ruled out because the interaction of vowel quality with speaker suggests that this effect varies between speakers.

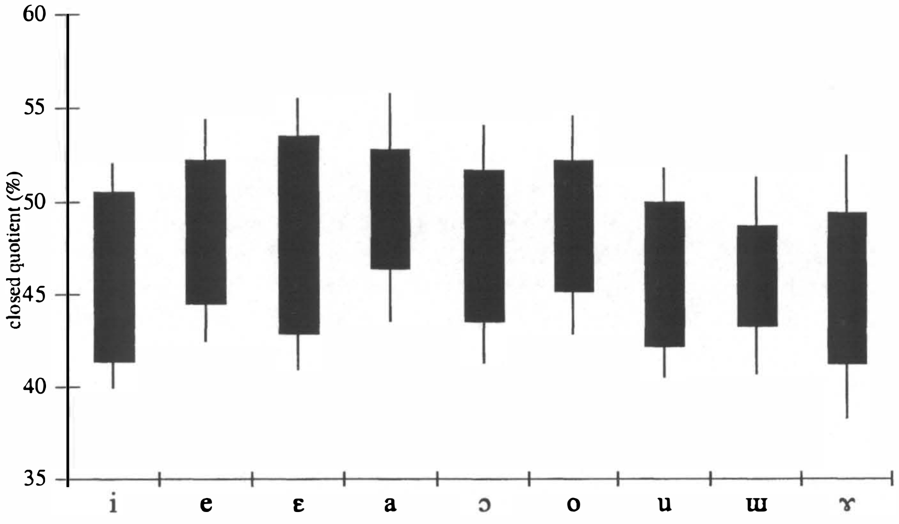


Figure 6-12: Graphic illustrating the interaction of vowel quality with the effect of the register contrast on laryngographically derived closed quotient. Bars represent difference between clear and breathy registers: filled bars = clear greater (uniformly the case in this figure). Forty-four tokens per vowel.

6.3.6 SPECTRAL TILT: THE RESONANCE BALANCE MEASURE

So far, the influence of register on spectral profile has concentrated on the low frequency range of the spectrum: it was shown above that the relative amplitudes of the fundamental and the second harmonic and of F1 with the fundamental are affected by the register contrast in a way consistent with a difference in phonation type.

Watkins (1997) set out to focus attention on the higher formants, examining the possibility of some correlation of phonation type with formant amplitudes beyond the frequency range of H1, H2 and F1. This effect is expected in the light of the known effects of phonation type on spectral tilt (discussed in Section 3.3.1). The spectral differences detected in that paper were neither extreme, nor necessarily consistently observable in all the data presented. Another spectral profile measure is included in the present study with the aim of ascertaining the extent to which the expected higher-frequency spectral characteristics of phonation types may be observed in the Wa register contrast.

A difference in the relative amplitude of the high- and low-frequency regions of the spectrum can indicate either an increase in the high-frequency range and/or a decrease in the low-frequency range. If recordings are not calibrated for intensity, it is meaningless to compare the absolute intensity of spectra between vowels. Instead, an indication of spectral tilt is inferred from the net difference between different regions of the spectrum. This measure complements the low-frequency spectral measures in the previous section, since the effects of increased low-frequency amplitude and of steeper spectral slope, expected of breathier phonation type, are mutually enhancing.

A number of studies, both in descriptive linguistics (Hayward et al. 1998) and in singing science (Howard 1992, El Ashiry 1996) have used a 'resonance balance' measure to captures the essential features of changes in spectral tilt. Resonance balance is calculated from a narrow-band spectrum as the difference in amplitude between the highest harmonic peaks in two regions of the spectrum, 0–1kHz and 3.5–4.5kHz, as illustrated in Figure 6-13. Comparing regions of the spectrum rather than individual formant or harmonic peaks carries with it clear advantages: the problems introduced by comparing vowels of different vowel qualities or data from different speakers are more likely to be avoided, since the measure is affected neither by the exact position of peaks in the frequency dimension nor by their identity as specific formant or harmonic peaks. The risk of oversimplifying the complexity of the spectrum in deriving the resonance balance is offset by the advantage that large quantities of data can be processed. In any case, the data were processed in pairs, with the result that the resonance balance measure of clear register is, at 28.83dB, on average 2.35dB less than breathy average at 30.18dB (198 data pairs, $p = 0.0003$).

In practice, for these data the highest harmonic in the 0 – 1kHz region was the tallest of H1, H2 and F1 (and F2 for back vowels); the 3.5 – 4.5kHz region maximum was the greater of F4 and F5, or whichever of those two fell within the 3.5 – 4.5kHz range.

The ANOVA test (Table 6-13) showed that register is an effect (1 d.f., $F = 5.65$, $p = 0.018$) and that speaker variation and vowel height are also significant. Looking at the resonance balance measure for each speaker, illustrated in Figure 56, it is clear that the measure does not detect a consistent effect on the high frequency region of the spectrum for all speakers. The expected effect was found to be significant for five speakers, and highly significant for SJ alone. Contrary to expectation, resonance balance was greater in clear register than in breathy register for two speakers, shown as black bars in Figure 6-14; moreover this unexpected result was statistically significant for one of them. The variation between speakers also suggests that the resonance balance is sensitive to other types of variation within a speaker's habitual voice quality.

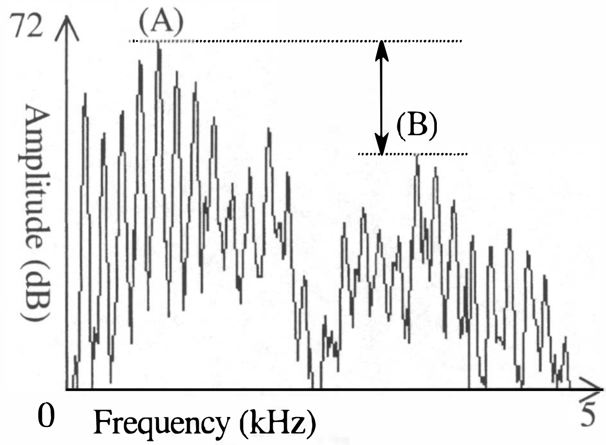


Figure 6-13: Calculation of resonance balance measure from a narrowband spectrum. (A) is the harmonic with greatest amplitude < 1 kHz, (B) is the harmonic with the greatest amplitude between 3.5 and 4.5 kHz. Resonance balance = (A) – (B).

Table 6-13: Results of ANOVA tests for effects on resonance balance measure

effect	*d.f.*	*F*	*p*	*sig*
main effects				
register	1	5.65	0.018	○
speaker	10	9.83	< 0.0001	●
recitation order	1	.22	0.637	
vowel height	3	5.71	0.001	○
no significant higher order interactions				

The evidence from this study, and from Watkins (1997), is that the register contrast in Wa does influence the amplitude of the high frequency region of the spectrum relative to the low amplitude region. It is likely, but remains to be proven, that the resonance balance measure may detect a difference in spectral slope between phonation types. This result complements the low frequency spectral measures in the previous section. However, the significant vowel quality effect indicates that this measure was not ultimately able to detect spectral tilt changes independent of formant structure.

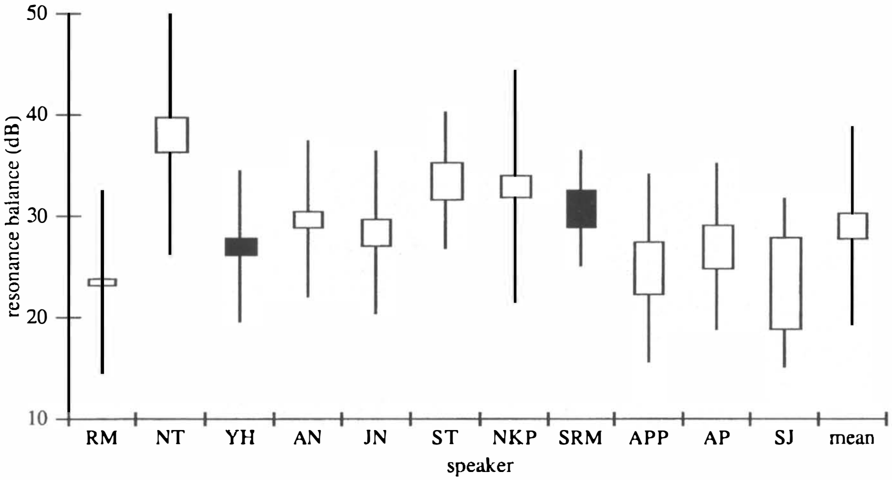


Figure 6-14: Graphic illustrating between-speaker variation of the effect of the register contrast on the resonance balance measure. Bars represent difference between clear and breathy registers: filled bars = clear greater; hollow bars = breathy greater. Lines represent mean +/– one s.d. Eighteen tokens per speaker.

6.3.7 VOWEL QUALITY

The changes which may be wrought by register on vowel quality in a historical perspective have been discussed in the context of registrally conditioned diphthongisation in Section 4.2.3. It was shown firstly that the influence of register on vowel quality is not uniform: different vowels are affected in different ways. Secondly, it was suggested that the influence of register on vowel quality in Wa displays patterns similar to those observed in Khmer, pointing to some general properties of register in Mon-Khmer.

The influence of Mon-Khmer register on vowel quality has been described by Gregerson (1976), who finds, for those languages in which register is responsible for vowel quality changes at all, that tense (i.e. clear) register produces closer vowels. Diffloth (1980:27) reports that for standard (Àishuāi) Wa: 'the [register] contrast is manifested by vowel quality, at least for the high vowels, which are slightly lowered and backed [in clear register]'. Svantesson's (1983b) sketch of Wa register finds that the 'lax vowels seem to be more central than the tense ones'. He has also reported diverse tonogenetic mechanisms in Northern Mon-Khmer. Luó Jìguāng's sketch of clear and breathy register vowels on the vowel quadrilateral, reproduced by Wáng and Chén (1981:50), suggests that clear register vowels are lower and more central than their breathy register counterparts.

These accounts make conflicting predictions about the effects of register on vowel quality. The Wa data here are approached without any expected pattern, other than that register is likely to affect vowel quality in some way. The goal here is simply to elicit a fitting description of the contrast in Wa from the evidence of these data, and to determine whether the contrast is consistent, variable within speakers or variable between speakers.

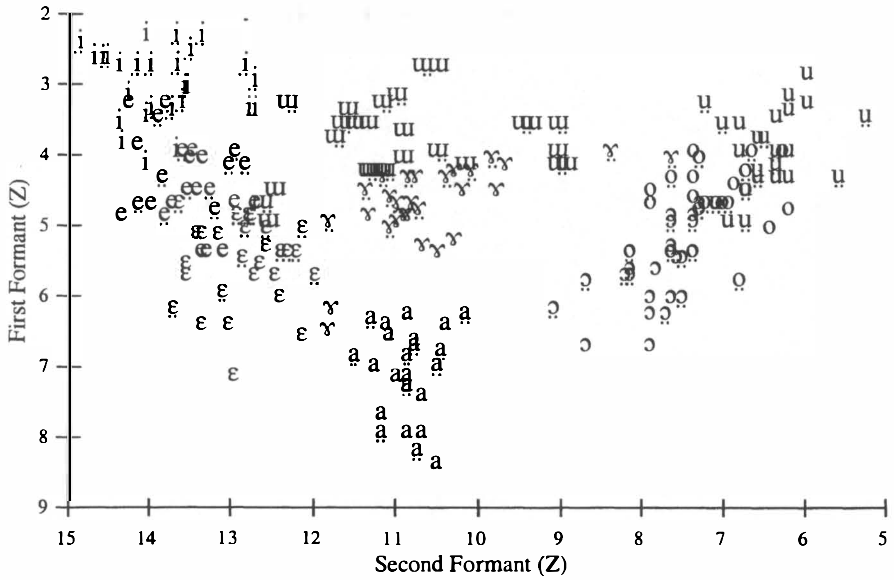


Figure 6-15: Effect of register on vowel quality: Plot of Fl and F2 in Bark (Z) for nine vowels in clear and breathy register. Total 396 tokens (9 vowels x 2 registers x 2 utterances x 11 speakers).

The measurements are made from the same recorded data which were used to illustrate vowel quality in Section 5.1.2, where the two registers were pooled. The phonologically contrastive vowel qualities having been established, the focus of study shifts now to perturbations of vowel brought about by register. The half-close vowels /e o/ are included only hesitantly, because they are produced by a number of speakers as diphthongs with an inherent vowel quality change.

The Fl and F2 measurements (in Bark) of vowels in clear and breathy registers are presented in Figure 6-15 and Figure 6-16. All the tokens measured are displayed in Figure 6-15. In Figure 6-16, each shape is the outline traced around the clusters of tokens representing phonemically identical vowel qualities in Figure 6-15. The mean Fl and F2 of all the tokens of each phonological vowel quality are plotted in Figure 6-17.

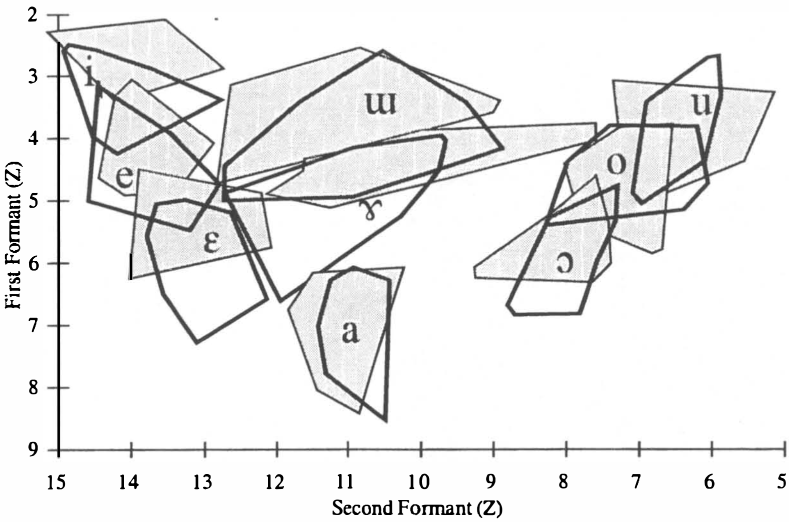


Figure 6-16: Effect of register on vowel quality: variation in F1 and F2 in Bark (Z) for nine vowels in clear (thick outlines) and breathy (shaded shapes) registers. Each marker represents twenty-two tokens (2 utterances x 11 speakers).

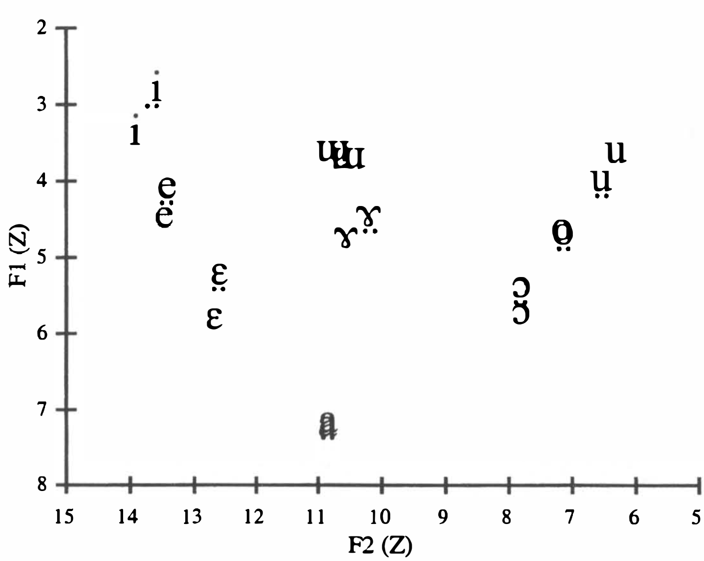


Figure 6-17: Effect of register on vowel quality: mean F1 and F2 in Bark (Z) for nine vowels in clear and breathy register. Each marker represents twenty-two tokens (2 utterances x 11 speakers).

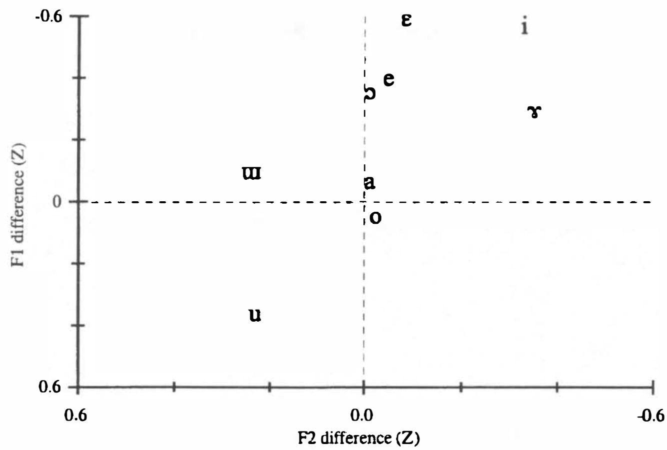


Figure 6-18: Mean vowel quality displacement by register. Each marker shows the mean displacement of breathy register vowel quality in the F1–F2 plane relative to clear register at the origin. Pooled data from eleven speakers.

No consistent registral vowel quality difference is immediately apparent from the clusters of markers in Figure 6-15, due to the high degree of overlap between vowel qualities which is evident in Figure 6-16. If anything can be interpreted from the positions of the pairs of markers in Figure 6-17, it is that the vowel quality effects of register are slight. One-tailed t-tests found that only the F1 differences in /i e ɛ ɤ/ ($p < 0.005$ for /i ɛ ɤ/; $p < 0.05$ for /e/) and none of the F2 differences have any statistical significance. This suggests that more importance might be attached to vowel quality differences in the close–open dimension rather than in the front–back dimension.

An alternative strategy is to consider the vowel quality difference in terms of the Euclidean distance in the F1-F2 plane between the clear and breathy register vowels, calculated using the formula

$$\sqrt{\left(F1_{clear} - F1_{breathy}\right)^2 + \left(F2_{clear} - F2_{breathy}\right)^2}$$

This measure of 'vowel displacement' is equivalent to the distance between clear–breathy pairs of tokens in Figure 6-17. Figure 6-18 illustrates this by plotting the net change in vowel quality: for each pair the breathy register vowel quality is plotted relative to the clear register at the origin in the centre of the Figure.

The pattern which emerges, albeit not particularly clearly, is that close front vowels are relatively closer and more back in breathy register. The close back vowels /u ɯ/ are rather fronted and /u/ is lowered. This is sufficient to conclude that the registral effect on vowel quality is not uniform across the vowel space.

The limited significance of the data suggests alternatively that there might be cross-speaker differences in the effects of register on vowel quality. Figure 6-19–Figure 6-29 illustrate the mean measurements of clear and breathy vowel qualities for all eleven speakers.

Figure 6-19–Figure 6-29 suggest that the vowel quality effect on register varies greatly from speaker to speaker. For some consultants (AN, ST, SRM), the effects are minimal, but some patterns emerge for other consultants. A number of other patterns are evident. For RM and NT, front vowels are more affected than back, and are closer in clear register; for JN and YH back vowels are lower in breathy register than in clear; for AP and APP back unrounded vowels are more affected. There is no compelling evidence to support any one pattern of behaviour.

6.3.8 VOWEL DURATION

Vowel duration has been discussed in this study in two other contexts, namely the length differences between vowels in open and closed syllables and emphatic lengthening. Vowel duration is investigated here to determine whether it is a correlate of the register contrast, although no existing studies have reported it being so.

Vowel duration may be observed as a fixed property of certain tones in a number of East Asian tone languages. For instance, the Burmese system of suprasegmental contrasts shows that vowel duration may complement contrasts based otherwise on phonation type, amongst other things: one of the distinctive features of the Burmese 'creaky' tone is its brevity (Bradley 1982; Wheatley 1987). Matisoff (1973) has also suggested that duration is one of the factors typically associated with contrastive phonetic complexes, such as Mon-Khmer register.

Vowel duration is not phonologically contrastive in Wa. Phonologically contrastive vowel length is a feature of Mon-Khmer which has disappeared from Waic (Diffloth 1980), apparently without disrupting the system of contrasts sufficiently to necessitate compensating for the loss of contrast elsewhere in the phonological system.[26]

Vowel duration was investigated by measuring the same set of syllables and the same techniques used in previous sections. Most of the syllables begin with voiceless unaspirated obstruents (plosives or /s/), after which vowel onset consistently takes place only a few milliseconds after the release. The beginning of the vowel was measured as the burst where there was an initial stop, or as the end of high-frequency friction in the case of /s/, or a sudden increase in spectral energy in the case of nasals. The two remaining syllables begin with alveolar approximant /r/, representing the greatest risk of mismeasurement. The beginning points of these vowels were pinpointed visually by taking into account the onset of higher formant structure on the spectrogram, an increased intensity in the speech pressure waveform. The absence of an acoustically abrupt boundary between /r/ and the vowel which follows it is evident in Figure 5-59. The end-point of the vowel was determined from the laryngograph trace in the same way for all syllables as the cessation of vocal fold vibration. The potential for error as a result of differences in measuring technique between unaspirated obstruents and other consonants is probably less than 10ms. Consequently, vowel duration was recorded to the nearest 10ms,

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[26] This is not the case in Mon-Khmer generally. For instance, the loss of contrastive vowel length was the conditioning factor for tonogenesis in other Northern Mon-Khmer languages (Svantesson 1989).

which is felt to be sufficient accuracy given the range of durations measured: mean 342ms, s.d. 97.35, n = 396 (Table 6-4).

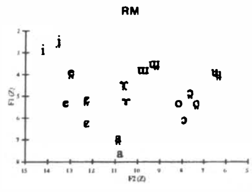

Figure 6-19

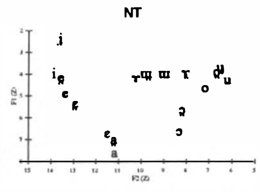

Figure 6-20

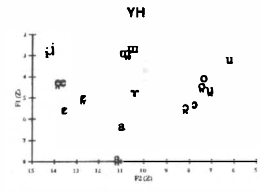

Figure 6-21

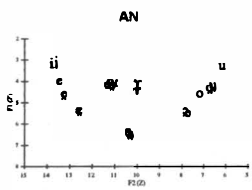

Figure 6-22

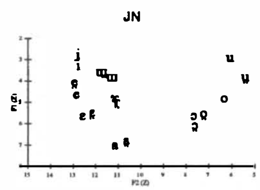

Figure 6-23

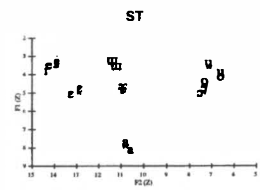

Figure 6-24

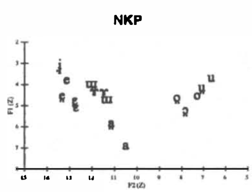

Figure 6-25

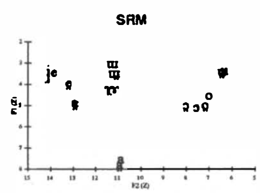

Figure 6-26

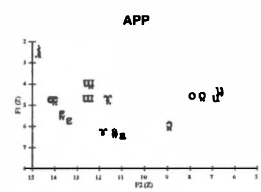

Figure 6-27

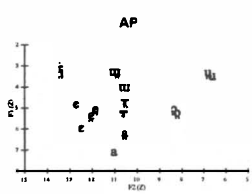

Figure 6-28

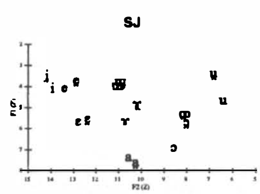

Figure 6-29

Figures 6.19–6.29: Mean vowel quality displacement by register. Each marker shows the mean displacement of breathy register vowel quality in the F1–F2 plane relative to clear register at the origin; individual data for eleven speakers.

Table 6-14: Results of ANOVA tests for effects on vowel duration

effect	*d.f.*	*F*	*P*	*sig*
main effects				
Register	1	0.57	0.453	
Speaker	10	104.89	< 0.0001	●
recitation order	1	20.42	< 0.0001	●
vowel height	3	15.35	< 0.0001	●
significant higher order interactions				
register by speaker	10	2.05	0.029	○
speaker by vowel height	30	2.58	< 0.0001	●

The ANOVA test for effects on vowel duration (Table 6-14) identified three significant factors: speaker, recitation order and vowel height, but not register, replicating the findings of Section 5.1.3, which included the syllables measured here. In this set of vowels, second repetition tokens were shorter by 23ms on average (Table 6-14: p < 0.0005, 198 data pairs). The between-speaker and intrinsic duration effects found earlier are also found here, illustrated in Figure 6-30 and Figure 6-31.

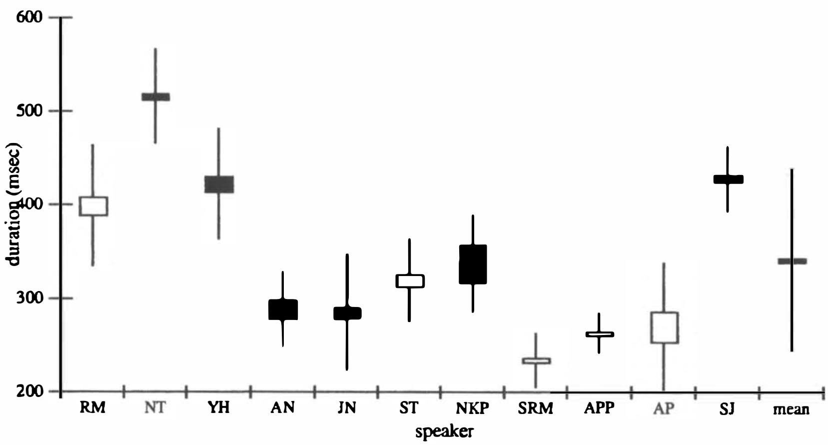

Figure 6-30: Graphic illustrating between-speaker variation in the effect of the register contrast on vowel duration. Bars represent difference between clear and breathy registers: filled bars = clear greater; hollow bars = breathy greater. Lines represent mean +/– one s.d. Eighteen tokens per speaker.

It is clear from Figure 6-30 that differences in vowel duration are mostly a matter of between-speaker variation. Mean duration ranges from 234ms (speaker SRM: s.d. 29ms, n = 36) to 517ms (speaker NT: s.d. 51ms, n = 36). However, the ANOVA test also detects a significant interaction between register and speaker, corroborating the apparently highly significant effect of register on the vowel duration of one speaker, NKP. In the data of this speaker, the effect is that predicted above: NKP's clear register vowels (357ms) are on average 39ms longer than his breathy register ones (318ms), a difference which is highly significant (p = 0.001, 18 data pairs).

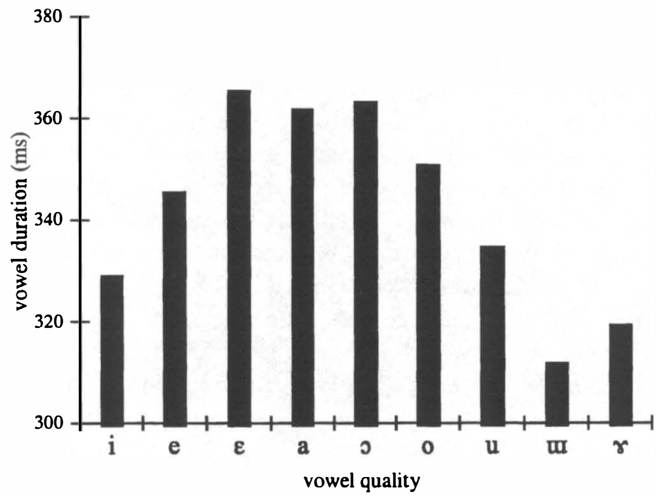

Figure 6-31: Vowel duration by vowel quality. Forty-four tokens per vowel.

The effect of vowel height on duration is consistent with the intrinsic duration effect examined earlier, as is evident from comparing Figure 6-31 with Figure 5-16. We can conclude only that register does not have a systematic effect on vowel duration.

6.4 COMPARING PHONETIC CORRELATES OF REGISTER

It has been established that fundamental frequency, vowel quality, phonation type and vowel duration are all contributory phonetic correlates of the register complex in Wa. None of the phonetic correlates of register is conditioned by register alone, independent of all other variables. It is important to bear in mind that the register complex in Wa, as in Mon-Khmer generally, is a complex of phonetic features which may all contribute to the whole. It is therefore unremarkable that no single correlate should be overwhelmingly evident, or be measurable with unshakable statistical significance. The between-speaker variation in this study suggests strongly that within the blended whole of any individual speaker's production of the register complex, the relative prominence of individual correlates may vary.

Many of the phonetic correlates of register are subject to variation due to factors other than register. Fundamental frequency is subject to the effects of intonation (as a function of recitation order) and emphasis (see Section 6.6); the nine vowel qualities are merged and pulled about in diphthongs and consonantally-conditioned glides; phonation type is as much a feature of the voicing contrasts in obstruents and of glottal consonants as it is of register; the duration of vowels, while not phonemically contrastive *per se*, is massively affected by the presence of final consonants.

Of course the goal of the experimental design was to reduce the extent of these non-register effects, but it is, of course, impossible to remove these effects entirely. On the other hand, gathering data in this way has the simultaneous disadvantage of generating speech which can hardly be considered 'natural'. The highly constrained phonetic environment of the carrier sentence may enhance the phonetic correlates of register to levels of contrast which would not normally be observed in natural speech. But solving this problem lies beyond the capacity of the present study.

The question of the relative importance of phonetic correlates of register has been raised often in discussing whether languages should properly be classified as 'tone' or 'register' languages, or at least whether fundamental frequency is more important than phonation type or vice versa in a language already so classified.

A difference of opinion with regard to the exact phonetic manifestation of the registers in Mon provoked a lively debate between Gérard Diffloth (1985) and Thomas Lee (1983), with constructive efforts at reconciliation from Thongkum (1988a). Lee maintained that pitch dominated the contrast, to which Diffloth (1985:55) countered: 'everyone agrees that [Mon] is a true register language, i.e. one where phonation type distinctions (in this case clear voice vs breathy voice) are contrastive.' The central point raised by Diffloth was that very little is known about the perception of register in the absence of experimental evidence, such that any statement on the salience of the acoustic correlates of the Mon register complex can only be considered speculative. Diffloth (1985:56) issued the general reminder that:

> An answer to [the problem of the relative importance of pitch vs phonation type] would have required the use of a speech synthesizer able to imitate a wide spectrum of phonation types, as well as pitches, and the computation of recognition and error responses from native speakers of Mon.

The task of ranking the phonetic correlates into some hierarchy is far more complex than this discussion, as Thongkum (1988a) helpfully advised in the above debate. In the fight-out between these two particular variables in Wa, the author's impression is overwhelmingly that fundamental frequency is superseded by intonation in normal speech, and so should be placed low in any proposed hierarchy.

Another fact which emerges from this study is the extent of between-speaker variation in the relative magnitudes of the register contrast in individual phonetic correlates, evident from the range of 'mean differences' in Table 7.6 and Table 7.7. From this arises the possibility that individual speakers articulate the register contrast using an individual amalgam of the available phonetic correlates. Naturally, this has to be set against the backdrop of between-speaker variation of a more general kind. For instance, little can be deduced about the phonetic implementation of the register contrast from the fact that the APP's clear and breathy registers are both measured above 230Hz, while SRM's are below 150Hz, since the difference is explained by the fact that APP is a woman with shorter vocal folds which are naturally predisposed to vibrate at higher frequencies. However, it is interesting to note that the fundamental frequency difference appears, from the statistics, to be highly significant to the register contrast for SRM but irrelevant for APP.

The 'individual amalgam' conception of the variable phonetic implementation of the register contrast was investigated by looking at the range of differences between the two registers for each phonetic correlate.[27] Clearly, since several phonetic phenomena are being considered, it would be meaningless to mix units of measurement, such as decibels with Hertz or milliseconds with closed quotient percentage points. Nor can any importance easily be attached to the spread of values for different speakers within any one correlate, since the variation is not necessarily conditioned exclusively by register. Instead, the speakers were simply ranked by the mean magnitude of the register contrast for each variable, scoring eleven for the largest and one for the smallest contrast in any one variable. All speakers were included for all six variables, so low scores in most cases represent observations which contradicted expectations, such as NT's spectral phonation measures, or observations which were statistically insignificant (see Table 7.6 and Table 7.7). The top seven ranking scores represent significant results for all the variables, with the sole exception of duration, in which only the top three scores represent significant results. The results of this ranking exercise are presented in Table 6-15.

Table 6-15: Eleven speakers ranked for magnitude of register difference in six phonetic correlates of register

speaker	*F0*	*CQ*	*duration*	*H2–H1*	*F1–F0*	*Ranking*	
						mean	*s.d*
RM	4	3	2	2	10	4.50	2.81
NT	10	4	6	10	7	7.50	2.14
YH	6	5	9	11	9	7.00	3.00
AN	5	1	10	7	6	5.33	2.87
JN	7	2	8	6	2	5.33	2.43
ST	8	9	3	3	3	4.50	2.93
NKP	11	8	11	1	1	6.00	4.24
SRM	9	10	4	8	5	7.50	2.22
APP	3	6	5	5	4	5.50	2.22
AP	1	11	1	4	8	6.00	4.24
SJ	2	7	7	9	11	6.83	2.85

The mean rankings in Table 6-15 range from 7.5 to 4.5; each consultant scores at least as high as eight, so the register contrast translates into a significant result in at least one variable for all the consultants.

With so many factors involved, drawing conclusions about the general nature of the register contrast is risky. The overriding impression of the various results reported here is that the phonetic correlates of the register complex are similar in their very variability. The register contrast was shown to be a significant effect on all the variables except duration if the data of all speakers were pooled. However, there is a high degree of between-speaker variation. Register was a highly significant effect on the data of at least one speaker (but usually more than half the group) for all correlates, but was of no statistical significance for at least three speakers for each correlate, except for closed quotient, which was the most reliable experimental correlate of the register contrast in the study.

[27] These have been visible in the various graphs illustrating between-speaker variation as the length of the thick bar.

A further point is that none of the phonetic correlates of register can be considered extreme. All are employed to greater effect in maintaining phonemic contrasts in some other area of the language phonemic inventory. The vowel quality differences which separate the monophthongs and diphthongs and the durational effects associated with closed syllable vowel shortening described in Section 5.1.3 involve differences of far greater magnitude than those observed for register. Phonation type changes in the context of aspiration and laryngeal consonants are more extreme than those of the register contrast. It is reasonable to suppose, though experimental evidence might prove otherwise, that none of the component correlates of register has robust perceptual salience individually. Yet combined they provide the basis for a phonemic contrast which is indisputably robust.

6.5 WHISPERING AND THE REGISTER CONTRAST

Earlier in this section, the laryngeal and supralaryngeal components of the Wa register contrast were considered as part of an articulatory complex, with distinctive changes of voiced phonation in a mutually complementary relationship with other registrally determined phonetic correlates. In order to produce the register contrast in whispered speech, we are forced to disassemble the register complex and consider to what extent it can be reconstructed in whisper phonation.

When asked whether they would be able to tell the difference between a pair of words which contrast minimally on the basis of the register contrast, Wa-speaking consultants confirmed that they would. This was tested informally using the minimal pair *tɛ* 'sweet' vs *t̤ɛ̤* 'peach'. Two Wa speakers clearly demonstrated that they could hear the difference when they said the words to each other while sitting back-to-back. The register contrast somehow remains perceptually intact in whispered Wa.

Giet (1956) saw off sceptical claims that it was impossible to communicate tonal contrasts effectively by whisper and that discrimination between whispered tonal minimal pairs was possible only from context. He showed that despite the absence of vocal fold vibration in whisper, there is no doubt that pitch can be conveyed effectively in whispered speech to produce intonational tunes in German, and argued that tonal contrasts could be communicated in the same way. This is assumed to be an uncontroversial claim, and was quickly confirmed by my own informal experiments of intonation in English and by consulting native speakers of Mandarin, Thai and Burmese.

In Fant's (1960) source–filter model of vowel production, a glottal voice source, the periodic vibration of the vocal folds, is shaped by the formant resonances of the vocal tract (Kent and Read 1992:20). Voiceless whisper phonation is produced in the same way, only the periodic voice source is replaced by a voiceless whisper noise source. The whisper noise is generated in the same way as the non-strident fricative noise source, by forcing air through a narrow constriction and causing turbulent flow. The vocal folds are held stiff and pressed together along most of their length, except for a triangular opening at the cartilaginous glottis formed by rotating the arytenoid cartilages. The vocal folds do not vibrate (Marasek 1997:22). The whisper noise spectrum may be shaped by the vocal tract in the same way as in voiced phonation to communicate differences in vowel quality. Since energy is distributed over a wide range of frequencies, the formant frequencies which characterise individual vowel qualities may be excited. It might be expected that the supralaryngeal correlates of register, the vowel quality contrast, might remain robust in whispered registers because of the possibility of maintaining formant structure in whisper phonation.

A problem arises with whisper in conveying pitch in the acoustic signal because the noise source is aperiodic and therefore lacks the harmonic peaks which are involved in pitch perception (Moore 1997:555–558). Giet concluded from experiments with Chinese tones that whisper phonation could reproduce tone by pursuing one or both of the strategies:

- *Changing phonation type* — by raising the larynx for 'high' tones and lowering it for 'low' tones;
- *Strengthening airflow*[28] — increased for 'high' tones and decreased for 'low' tones.

Richter and Mehnert (1990) investigated whisper in Burmese tones, in which fundamental frequency, intensity and length operate interdependently within segments. They wanted to establish to what extent the absence of fundamental frequency could be replaced by intensity or be otherwise represented in the formant structure of whisper.

It is not so obvious how the components of register which are controlled by the larynx, namely fundamental frequency and phonation type, might be represented in whisper. A true replica of the laryngeal component of the register contrast would presumably require that both be substituted. The noise source would somehow need to be varied qualitatively to replicate the phonation type component, while at the same time imitating fundamental frequency in the way described above.

One speaker, SJ, was asked to whisper six syllables, shown in Table 6-16, three times each, in the frame sentence used previously. The frequencies and amplitudes of the first three formants were measured from narrowband spectra.

Table 6-16: Syllables recorded for whispering experiment

clear register		*breathy register*	
tɛ	'sweet'	*tɛ̤*	'peach'
tɛʔ	'wager'	*tɛ̤ʔ*	'reduce'
tɛh	'land'	*tɛ̤h*	'turn over'

The formant measurements proved problematic. Average spectra of the whispered open syllable [ɛ] vowels, given in Figure 6-32, show why. The pronounced sharp peaks labelled with arrows in Figure 6-32 correspond to the expected values of neither F1 nor F2 for the vowel [ɛ] in either register, and are therefore assumed to be present in the whisper noise. The peaks labelled F1 and F2 are rather less prominent, and do not conform closely to the expected values. The values observed are plotted in the F1:F2 plane in Figure 6-33. With so few tokens to compare, it seems risky to infer anything general about vowel quality in whispered register.

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[28] 'Andersfärbung des vokalischen Charakters' and 'Luftstromverstärkung' (Giet 1956:377).

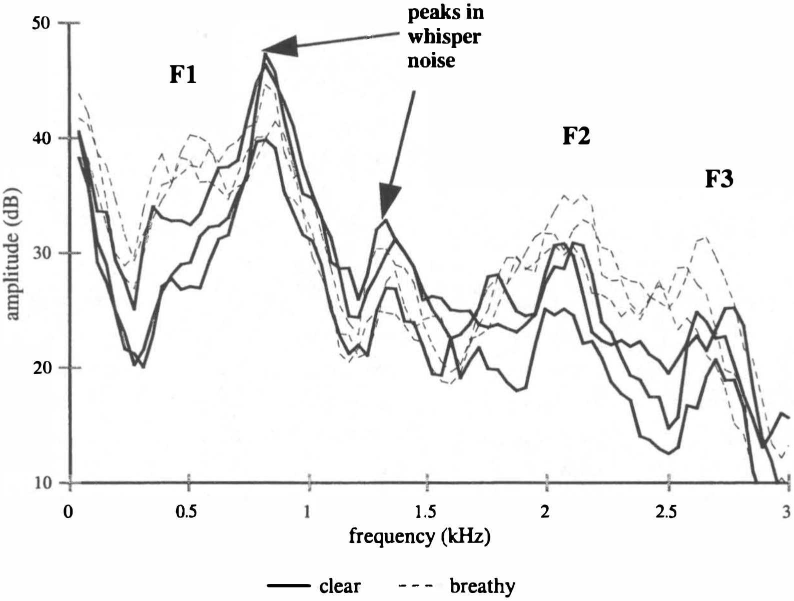

Figure 6-32: Whispering register. Low-frequency spectra (256-point, 40Hz bandwidth) of three clear and three breathy register vowels /ɛ/ and /ɛ̤/ spoken by SJ.

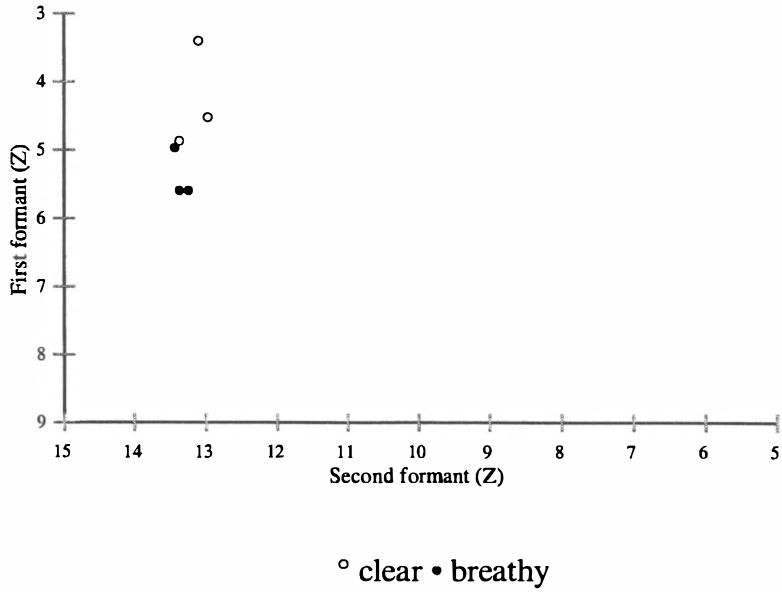

Figure 6-33: Unexpected F1:F2 measurements of whispered vowels.

However, there are consistent differences in spectral profile which are worthy of comment. The vowel formant peaks all have higher amplitude in breathy register whisper than in clear, while the two unexpected peaks both have higher amplitude in clear register than in breathy. In addition, there is more high frequency energy in breathy register whisper than in creaky, as is visible in the higher frequency spectra in Figure 6-34. The range of frequencies over which the increased energy is present can be of little auditory relevance, judging from the Bark scale plot (Figure 6-35) of the average spectra, where the upper third (4–6Hz) of the acoustic frequency plot is approximately equivalent to the top tenth (18–20Z) of the auditory frequency range. The higher frequency amplitude difference may presumably still contribute to the overall difference in spectral profile. Spectrograms of the clear and breathy register whispered vowels may be compared in Figure 6-36.

It was established earlier that differences in spectral balance are a consistent acoustic correlate of the Wa register complex in voiced speech, measurable as F1–F0 and H2–H1. In whispered speech there are no harmonics present, but a difference in spectral profile is still evident in the low-frequency range between the relative amplitudes of noise source peaks and vowel formant peaks. The spectral profile of the two registers in whispered speech is also differentiated by contrasting levels of spectral energy in the 4–6kHz frequency range. This corroborates the suggestion in Section 6.3.6 that register is responsible for spectral changes in that region of the spectrum, if it can be assumed that there may be at least a degree of similarity in the articulatory activity which produces the register contrast in both voiced and whispered speech.

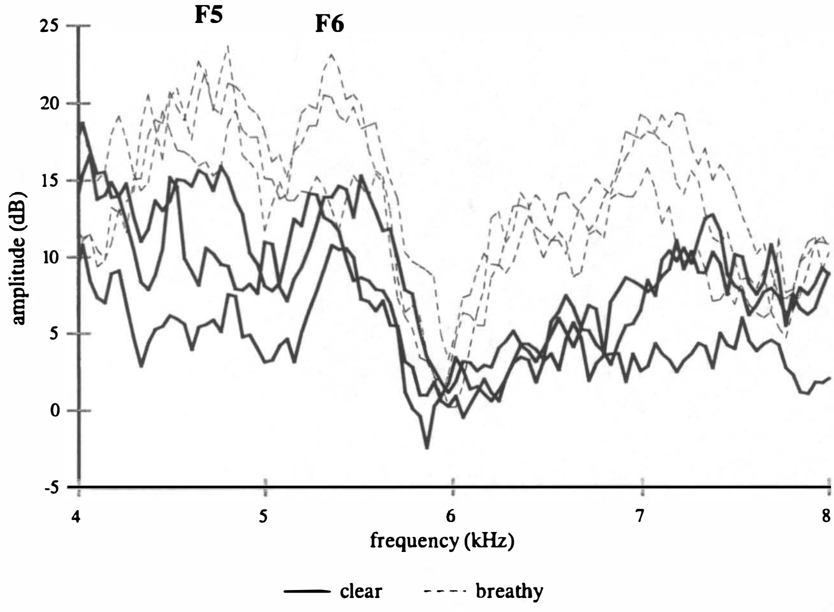

Figure 6-34: Whispering register. High-frequency spectra (256-point 40Hz bandwidth) of three clear and three breathy register vowels /ɛ/ and /ɛ̤/ spoken by SJ, plotted in Hertz.

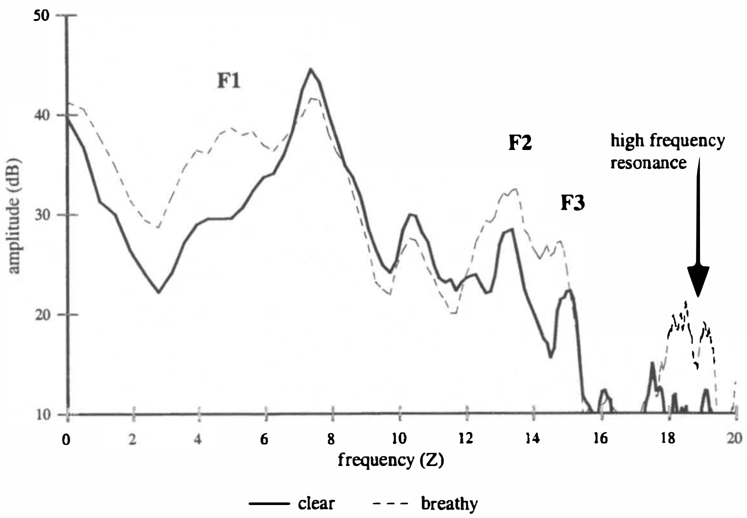

Figure 6-35: Mean spectra of whispered clear register /ɛ/and breathy register /ɛ̤/ vowels (Bark scale).

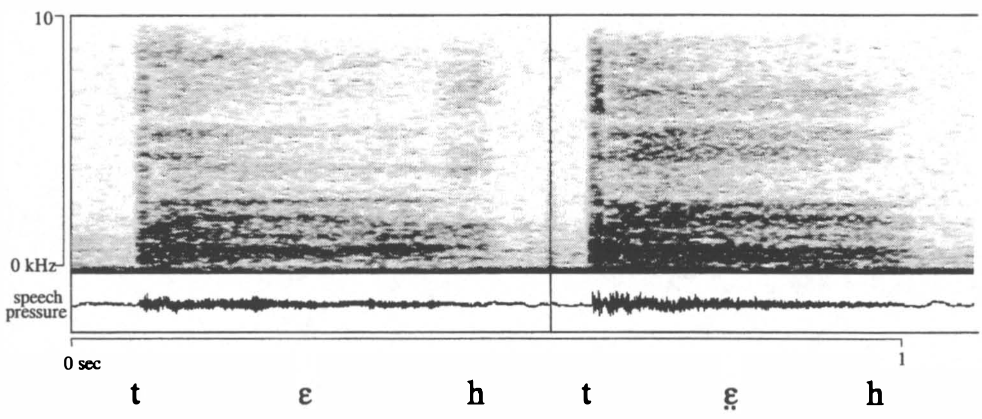

Figure 6-36: Spectrogram (40Hz bandwidth) and waveform of whispered syllables *tɛ* 'sweet' and *tɛ̤* 'peach' spoken by SJ.

6.6 Emphatic tone

Emphasis or intensification in Wa may be signalled by the use of a long, high tone comparable to the emphatic high tone of Thai, which has been described as 'high pitch ... and accompanied by lengthening of the syllable' (Abramson 1962:16), and 'is a prosodic unit that, when used, replaces whatever member of the five-tone set [in Thai] happens to be on the morpheme in question.' (Abramson, pers. comm.). The parallel in Wa is that emphasised syllables are likewise pronounced high and long, by some speakers high enough to bring about occasional falsetto phonation. It is to be expected that emphatic syllables of this kind fall outside the register system in Wa, as they do outside the tone system in Thai, although no experimental data are available to support this.

Emphatic tone is also employed freely in sentence particles such as *hɤi*, which are frequent in Wa, or in open syllables in utterance final position. It was mentioned earlier that the majority of speakers recorded for this study are Christian. Wa speakers accustomed to preaching or public speaking are prone to extend utterance-final open syllables to lengths occasionally in excess of one second. Super-long vowels such as these are also produced in exclamatory, declarative or demonstrative utterances, accompanied by distinctive intonation, which feature is apparently represented by the idiosyncratic use of the colon in Wa orthography (see Section 7.2.4). In a formal narrative speaking style, the last syllable in any utterance, or even any stressed word is likely to carry the emphatic high tone.

6.7 Coarticulation of phonation types

The account of register above does not attempt to classify the register of syllables with initial aspirated consonants, in which context there is no register contrast. Vowels following aspirated consonants have been described variously as either identical to clear register vowels (Zhōu and Yán 1984:7) or else as 'secondarily' creaky (Wáng and Chén 1981:49).

In this section, the phonation type of vowels following aspirated initials is compared to that of syllables with clear and breathy register vowels following unaspirated consonants, using closed quotient as an index of phonation type. Syllables with initial aspirated sonorants are examined first, followed by syllables with initial aspirated stops. The third part of this section is a brief account of the anticipatory coarticulation and interaction of aspiration, register and final laryngeal consonants.

6.7.1 Register and aspiration during and after sonorant consonants

Sonorant consonants are aerodynamically less complex than plosives in that the flow of air through the larynx and out through the oral and vocal tracts is not impeded. Rather, air is diverted into the nasal cavity and out through the nose by lowering the velum in the case of nasal consonants, or else channelled around the tongue in various positions in the case of liquid consonants. Because the airflow through the vocal tract is not impeded, the vocal folds may vibrate throughout sonorants, with no special activity required to maintain the transglottal pressure drop. The uninterrupted voicing of sonorants is exploited here to explore the articulation of aspiration at the laryngeal level in sonorants. The following experimental procedure focuses on phonation type during the transition from consonant to vowel.

The syllables used in this experiment include those used in Section 5.5.1 to measure the duration of initial nasals, with nine additional syllables, making up the matrix of twenty-one syllables in Table 6-17, which includes nasals at four places of articulation /m n ŋ ɲ/

and three varieties of approximant: alveolar /r/, alveolar lateral /l/ and palatal /y/.[29] Each consonant appears once unaspirated with clear register, once unaspirated with breathy register and once aspirated.

Two measurements were made:

(i) Fundamental frequency and closed quotient at the lowest point of the closed quotient trace during the consonant, usuaoplly shortly before the end of the consonant;

(ii) Fundamental frequency and closed quotient during the vowel, after the onset of vowel phonation. Fundamental frequency was slightly falling and closed quotient remained at a steady level through the vowel; the value recorded was the maximum.

Table 6-17: Syllables measured for investigation of register and aspiration in sonorants

		Nasal				approximant		
		bilabial	alveolar	Palatal	velar	alveolar	alveolar lateral	palatal
unaspirated	clear	*mai*	*na*	*ɲau*	*ŋai*	*ra*	*lai*	*yɯi*
	breathy	*ma̤i*	*na̤*	*ɲa̤u*	*ŋɔ̤*	*rɤ̤*	*la̤i*	*yɛ̤*
Aspirated		*mʰai*	*nʰa*	*ɲʰau*	*ŋʰa*	*rʰaŋ*	*lʰai*	*yʰa*

For the purposes of statistical analysis, clear and breathy register were considered to be two possibilities in a three-way categorisation, with aspiration treated as the third category. The effects on the measured variables were explored by means of a multivariate ANOVA test of four dependent variables, both of fundamental frequency and closed quotient during the consonant and during the vowel. The factors included in the design were speaker, recitation order and register.

The recitation order, i.e. the listing intonation effect, had a significant effect on F0 but not on CQ. Since the presentation of material and the recording procedure was the same as in previous experiments, it was assumed that the effects of listing were similar, and so were explored no further.

According to the ANOVA test, between-speaker variation is a significant effect on all four variables, in keeping with the findings of Section 6.3, where the value and range of both closed quotient and fundamental frequency were shown to vary between speakers in the context of the register contrast. We can expect, therefore, a similar degree of variation in these two measures here also. The effect on closed quotient and fundamental frequency of the three-way clear-breathy-aspirated register categorisation was significant in all cases. The effect is summarised in Figure 6-38 (fundamental frequency) and Figure 6-37 (closed quotient). Mean measurements are set out in Table 6-19.

[29] It was intended to include the labio-dental fricative /v/ in this experiment, but it had to be excluded owing to excessive numbers of missing or unmeasurable items.

Table 6-18: Design and results of multivariate ANOVA for F0 and CQ during and after sonorants. Significant multiple effects only are shown.

dependent variables	*independent variables*
F0 during consonant CQ during consonant F0 during vowel CQ during vowel	speaker (10) register (clear, breathy, aspirated) recitation order (first or second)

N = 360		*d.f.*	*closed quotient*			*fundamental frequency*		
			F	*p*	*sig*	*F*	*p*	*sig*
During consonant (n = 180)	Speaker	9	7.72	< 0.0001	●	6.12	< 0.0001	●
	Register	2	0.051	0.48		12.72	< 0.0001	●
	recitation order	1	345.78	< 0.0001	●	39.69	< 0.0001	●
	speaker by register	18	7.72	< 0.0001	●	6.11	< 0.0001	●
During vowel (n = 180)	speaker	9	4.33	< 0.0001	●	1.95	0.012	○
	register	2	1.63	0.203		23.89	< 0.0001	●
	recitation order	1	137.16	< 0.0001	●	6.2	0.02	○
	speaker by register	18	4.33	< 0.0001	●	1.95	0.012	○

Table 6-19: Closed quotient and fundamental frequency during and after unaspirated sonorant consonants followed by clear and breathy register vowels, and during and after aspirated sonorants

		CQ (per cent)			*F0 (Hz)*		
		mean	*s.d.*	*n*	*mean*	*s.d.*	*n*
during sonorant	*clear*	45.44	6.18	144	144.4	30.34	144
	breathy	38.83	5.51	140	141.3	28.9	140
	aspirated	30.72	6.08	127	131.3	23.99	131
during vowel	*clear*	49.62	5.54	144	155.9	34.45	144
	breathy	41.73	5.9	139	155.3	32.68	139
	aspirated	48.38	5.72	128	158.1	32.9	128

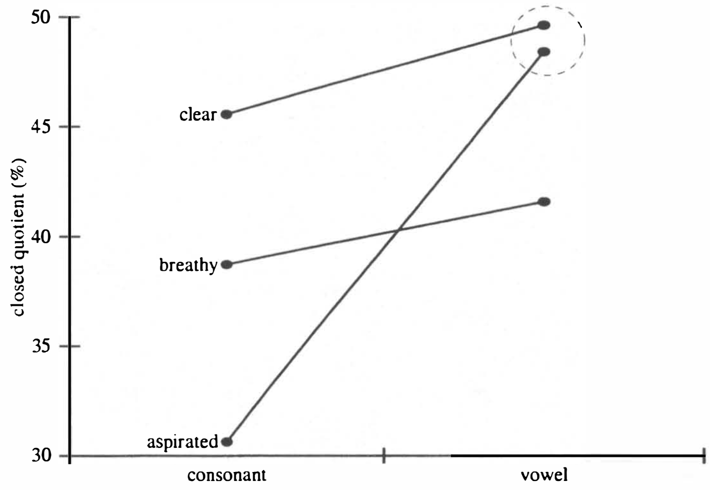

Figure 6-37: Closed quotient during and after unaspirated sonorant consonants followed by clear and breathy register vowels, and during and after aspirated sonorants. Each marker represents the mean of approximately 140 tokens from ten speakers. Dotted lines group means which Scheffé tests did not determine to be significantly different.

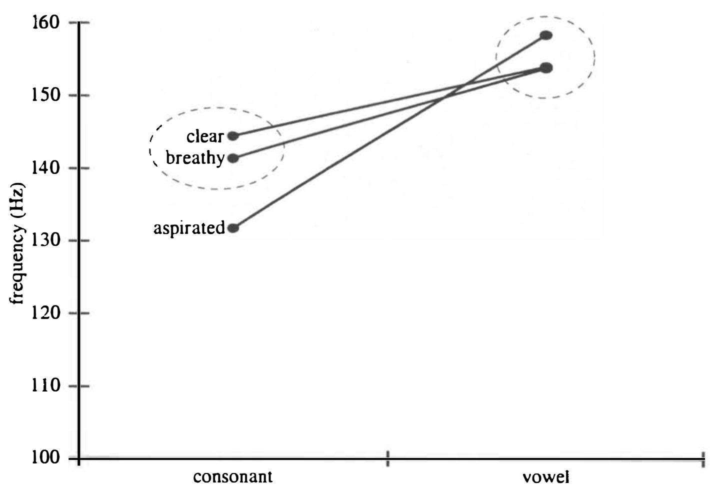

Figure 6-38: Fundamental frequency during and after unaspirated sonorant consonants followed by clear and breathy register vowels and during and after aspirated sonorants. Each marker represents the mean of approx. 140 tokens from ten speakers. Dotted lines group means which Scheffé tests did not determine to be significantly different.

The three 'register' categories (clear, breathy and aspirated) were compared using post-hoc Scheffé tests, to explore the effect of register on the four variables tested and illustrated above. A summary of the findings of the Scheffé tests is given in Table 6-20. Fundamental frequency is significantly lower in aspirated consonants (131.7Hz, s.d. 24.1, n = 126) than in than in unaspirated consonants. Among unaspirated consonants, the difference between clear register (144.4Hz, s.d. 30.5, n = 132) and breathy register (141.4Hz, s.d. 28.9, n = 132) is insignificant. During the vowel, however, mean fundamental frequency does not vary significantly between the three categories.

Table 6-20: Significantly different categories of closed quotient and fundamental frequency during sonorants and the following vowel

	Consonant				*vowel*			
	CQ		F0		CQ		F0	
	clear	breathy	clear	breathy	clear	breathy	clear	breathy
breathy	o				o			
post-aspirated	o	o	o	o		o		

There is a statistically significant difference between the mean closed quotient during the consonants of all three categories. As would be expected, clear register has the greatest CQ at 45.6 per cent (s.d. 6.3, n = 132), with breathy register somewhat less at 38.7 per cent (s.d. 5.5, n = 132). Closed quotient during an aspirated sonorant, however, is less still at 30.6 per cent (s.d. 6.0, n = 126). During the vowel, the three categories realign. The closed quotient of post-aspirated (49.6 per cent, s.d. 5.7, n = 132) and clear register (48.3 per cent, s.d. 6.8, n = 127) vowels are not significantly distinguishable, while breathy register is lower at 41.5 per cent (s.d. 5.9, n = 131). These groupings are indicated in Figure 6-38 and Figure 6-37 as dotted lines around markers.

The auditory impression of the author is that post-aspirated vowels are more similar to clear register than to breathy. This is presumably also the impression of the Chinese scholars (Zhōu and Yán 1984; Wáng and Chén 1981) who used the term *cìjǐn* 'secondarily tense' (rather than 'secondarily breathy') to describe the phonation type of vowels following aspirated consonants.

The measures of the registers here are consistent with those observed in Section 6.3. The difference in mean closed quotient between the two registers measured here (8.0 per cent) is of the same order as that measured earlier (7.7 per cent). Additionally, the fundamental frequency difference between clear and breathy registers is statistically insignificant in the measurements in this section, while a small but significant difference was measured in Section 0.

We can conclude that closed quotient during unaspirated sonorant consonants anticipates that of the following vowel, such that the register of a vowel could be predicted from the closed quotient during the consonant. Closed quotient rises slightly during the transition from consonant to vowel in both registers, though by much less than the difference between the registers, which is less than the more dramatic rise in closed quotient from consonant to vowel observed in aspirated sonorants.

6.7.2 REGISTER AND ASPIRATION IN STOPS

This experiment mirrors the investigation of aspiration and laryngeal activity in sonorant consonants in the previous section. Here, the search is for evidence of the anticipation of the register contrast during the voicing lead of stops. Additionally, the phonation type of the vowels following aspirated stops are considered. The results from the sonorants and the stops lend themselves to certain comparisons, though procedural differences prohibit the pooling of the two sets of results.

A single measurement was made of fundamental frequency and of closed quotient during the voice lead of the voiced syllables analysed in Section 5.2.2, using the computer's facility to calculate the mean fundamental frequency over the whole stretch of voicing.

Fundamental frequency and closed quotient during the vowel were measured following the same procedure used to assess the register contrast in Section 6.3. Fundamental frequency and closed quotient measures of vowels following aspirated stops were made at approximately the mid-point of each vowel. Since the mean vowel duration of the subset of forty syllables with aspirated initials was 403ms and the mean voice onset time 109ms, the mid-point was typically more than 90ms after the onset of vowel nucleus phonation, and therefore beyond the immediate effects of breathy aspiration.

The voice lead of all the stops was measured, regardless of whether the syllable ended with an open vowel or a final laryngeal consonant. Implicit in the decision to do so was the assumption that the effect, if any, of a final laryngeal consonant on the voicing of an initial stop would be negligible. Measurements of vowels followed by final laryngeal consonants were excluded because of the extreme effects of these consonants on both fundamental frequency and closed quotient. The coarticulation of register with laryngeal consonants is considered separately in Section 6.7.3 below, and so here only open syllable vowels are considered. The sample size of the vowels is therefore smaller than that of the consonants. The results are presented in the same way as for the sonorant consonants in the previous section. Aspiration was treated as a third 'register' category. A summary of the measurements is given in Table 6-21.

Table 6-21: Closed quotient and fundamental frequency during voice lead of, and during vowels following, unaspirated stops followed by clear and breathy register vowels, and during voice lead of, and during vowels following, aspirated stops

		CQ (per cent)			*F0 (Hz)*		
		mean	*s.d.*	*n*	*mean*	*s.d.*	*n*
during voice lead	*clear*	43	8.1	60	128	24	60
	breathy	38.39	6.11	57	124.7	22.44	58
	aspirated	39.36	4.56	53	122.7	25.65	56
during vowel	*clear*	53	5.5	40	151	40	40
	breathy	42.34	5.99	39	148.6	33.13	39
	aspirated	48.14	5.81	40	145.2	31.11	40

The design and results of a multivariate ANOVA for the four dependent variables (F0 and CQ during the voice lead and during the vowel), incorporating three factors in the design (speaker, register and recitation order), are set out in Table 6-22.

Table 6-22: Design and results of multivariate ANOVA for effects on F0 and CQ before and after voiced stops. Significant multiple effects only are shown

dependent variables	*independent variables*
F0 during voice lead	speaker (10)
CQ during voice lead	register (clear, breathy, aspirated)
F0 during vowel	recitation order (first or second)
CQ during vowel	

n = 300		*d.f.*	*closed quotient*			*fundamental frequency*		
			F	*p*	*sig*	*F*	*p*	*sig*
during consonant (n = 180)	speaker	9	12.02	< 0.0001	●	114	< 0.0001	●
	register	2	21.8	< 0.0001	●	8.2	< 0.0001	●
	recitation order	1	0.758	0.386		12.76	0.001	●
	speaker by register	18	6.92	< 0.0001	●	1.88	0.025	○
during vowel (n = 120)	speaker	9	8.02	< 0.0001	●	135	< 0.0001	●
	register	2	66.21	< 0.0001	●	3.18	0.049	○
	recitation order	1	0.041	0.84		11.14	0.001	●
	speaker by register	18	4.33	< 0.0001	●	1.94	0.03	○

The significance of the effects of recitation order and speaker match very closely the findings for sonorant consonants (see Table 6-18). Post-hoc Scheffé comparisons like those in Section 6.7.1 were made (Table 6-23) to explore the nature of the register effect on CQ and F0 during and following voiced stops. The mean measurements of the three categories are illustrated in Table 6-21, Figure 6 and Figure 6-39. The closed quotient and fundamental frequency measures of the clear and breathy register vowels were similar to earlier observations. However, the difference in mean closed quotient between clear and breathy registers emerges here as 10.63 per cent, greater than the 7.70 per cent difference detected in Section 6.3 above.

Table 6-23: Significantly different categories of closed quotient and fundamental frequency during voicing of stops and during the following vowel

	during voice lead				*vowel*			
	CQ		F0		CQ		F0	
	clear	breathy	clear	breathy	clear	breathy	clear	breathy
breathy	○				○			
aspirated	○	○	○	○	○			

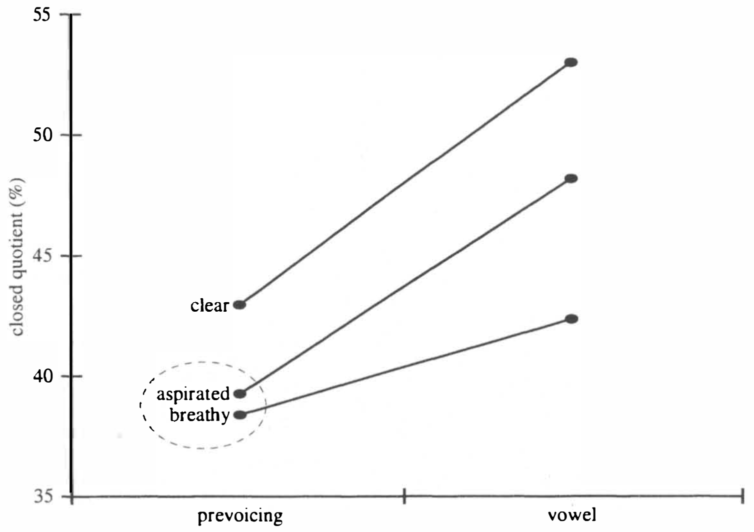

Figure 6.39: Closed quotient before and after unaspirated stops followed by clear and breathy vowels, and before and after aspirated stops. Each bar represents the mean of approx. sixty tokens (voice lead), approx. forty tokens (vowel), ten speakers. Dotted lines group means which Scheffé tests did not determine to be significantly different.

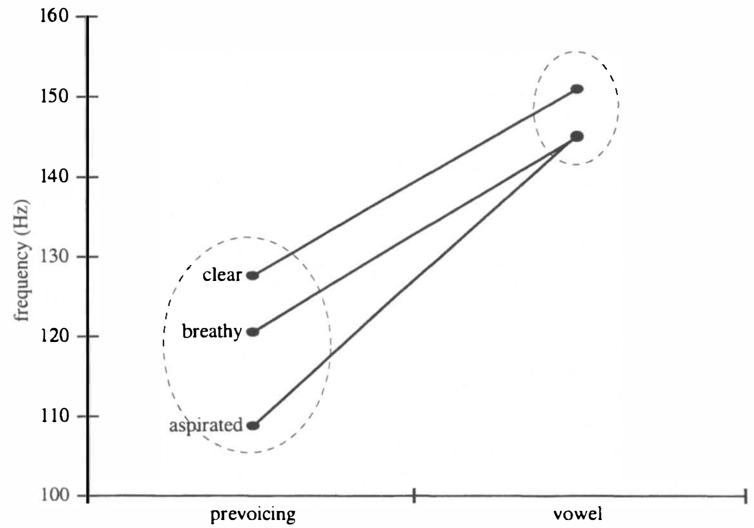

Figure 6-39: Fundamental frequency before and after unaspirated stops followed by clear and breathy vowels, and before and after aspirated stops. Each bar represents the mean of approx. sixty tokens (voice lead), approx. forty tokens (vowel), ten speakers. Dotted lines group means which Scheffé tests did not determine to be significantly different.

The Scheffé comparisons indicate that the mean fundamental frequency during stop voicing or vowel does not vary significantly between the three categories, although the measurements do vary in a predictable way, with breathy register slightly lower than clear, and post-aspirated vowels lower still. With regard to closed quotient during stop voicing, however, two statistically distinct categories emerge from the Scheffé tests: aspirated/breathy vs clear. During the vowel, all three categories are significantly different from each other. For this set of data, post-aspirated vowels are shown to be intermediate in register, in contrast to the previous section.

6.7.3 REGISTER, ASPIRATION AND FINAL LARYNGEAL CONSONANTS

Syllables in Wa may consist entirely of segments in which there is a distinctive phonation type component, as illustrated by the matrix of syllables in Table 5-20. Laryngeal consonants /ʔ/ and /h/ were shown in Section 5.3 to involve a shift in phonation type either to or away from the phonation type found in vowels, measurable using laryngographically derived closed quotient. When a vowel with a phonologically contrastive register specification is adjacent to a laryngeal consonant, then, the shift in phonation type associated with the laryngeal consonant is superimposed on the vowel, a phonetic environment in which phonation type is already distinctive. When examining final laryngeal consonants, the register specification of the preceding vowel determines the phonation type of the environment upon which the laryngeal consonant is superimposed. Since the phonation type of vowels has been shown to be influenced by aspiration in a preceding consonant, aspiration, too, is taken into consideration by adopting a three-way register classification of clear, breathy or aspirated, in the same way as in previous sections.

Laryngeal consonants were measured by sampling closed quotient and fundamental frequency of a subset of the syllables used to describe stops in Section 5.2, namely those syllables with final laryngeal consonants, reproduced below in Table 6-24. For the purposes of this section, voiced and voiceless stops were not differentiated, since the effect of voicing category on closed quotient and fundamental frequency appears to be negligible in comparison with the effects of aspiration, the register contrast and laryngeal consonants. The measurement schema was intended to chart the movement of these two variables through the syllable. The measurement schema is set out in Table 6-25.

Table 6-24: Set of syllables measured for investigation of coarticulation of register, aspiration and final laryngeal consonants

		initial consonant					
		clear register		*breathy register*		*aspirated*	
		voiceless /t/-	voiced /^{n}d/-	voiceless /t/-	voiced /^{n}d/-	voiceless /t^{h}/-	voiced /^{n}d^{h}/-
final consonant	glottal fricative /h/	*tɛh* 'lessen'	*^{n}dɛh* 'tie'	*tɛ̤h* 'turn over'	*^{n}d^{h}ɛ̤h* 'clap'	*t^{h}ah* 'cut wood'	*^{n}d^{h}ah* 'long'
	glottal stop /ʔ/	*tɛʔ* 'land'	*^{n}dɤʔ* 'stupid'	*tɛ̤ʔ* 'wager'	*^{n}de̤ʔ* 'nearby'	*t^{h}ɯʔ* 'shove'	*^{n}d^{h}uʔ* 'gobble food'

Table 6-25: Schema for measurement of laryngeal consonants

(i)	F0 and CQ in the 1st period of voicing onset
(ii)	F0 and CQ in the 4th period of voicing onset
(iii)	F0 and CQ of vowel phonation (see definition in Section 5.2.3)
(iv)	F0 and CQ in the 4th period from voice offset
(v)	F0 and CQ in the last period of voicing offset

Measurements (i)–(iii) are explained with reference to Figure 5-34 in Section 5.2.2. Measurements (iv) and (v) were made in the same way as (i) and (ii), but applied to the last four well-formed cycles of vocal fold vibration instead of the first four; they are labelled in Figure 5-34.

These measurements amount to a crude sampling of the constantly changing values of fundamental frequency and closed quotient observed as the larynx coordinates phonation type and the rate of vocal fold vibration to preserve the system of contrasts between aspiration, registers and laryngeal consonants. The quantity of data was reduced by excluding open syllables and ignoring the temporal coordination of these syllables.

The fundamental frequency and closed quotient measurements are presented in Figure 6-40 and Figure 6-41. In these figures, each of the six syllables under observation is plotted separately.

Two ANOVA tests were employed to ascertain which aspects of the data were statistically significant. The design of the tests is outlined in Table 6-26, the results in Table 6-27 and Table 6-28.

Predictably, register is found to have a significant effect on both fundamental frequency and closed quotient in the vowel, consistent with the findings reported in Section 6.3 above. The patterns displayed in Figure 6-40 and Figure 6-41 are representative of the majority of speakers, notwithstanding the significance of the speaker effect. Figure 6-40 suggests that the effects of register and final laryngeals on fundamental frequency are greatest in the mid-vowel measurements, but that the contour in the first and last four periods does not show much variation.

Fundamental frequency, the rate of vocal fold vibration, decreases both in /ʔ/, in which closed quotient is relatively high, and in /h/, in which closed quotient is relatively low. Even if vocal fold vibration does not stop completely in final /ʔ/ or /h/, the slowing of the rate of vocal fold vibration here suggests that cessation of vibration is the target of the laryngeal activity of glottal stops, although the target is not necessarily reached for a laryngeal consonant in utterance-mid position.

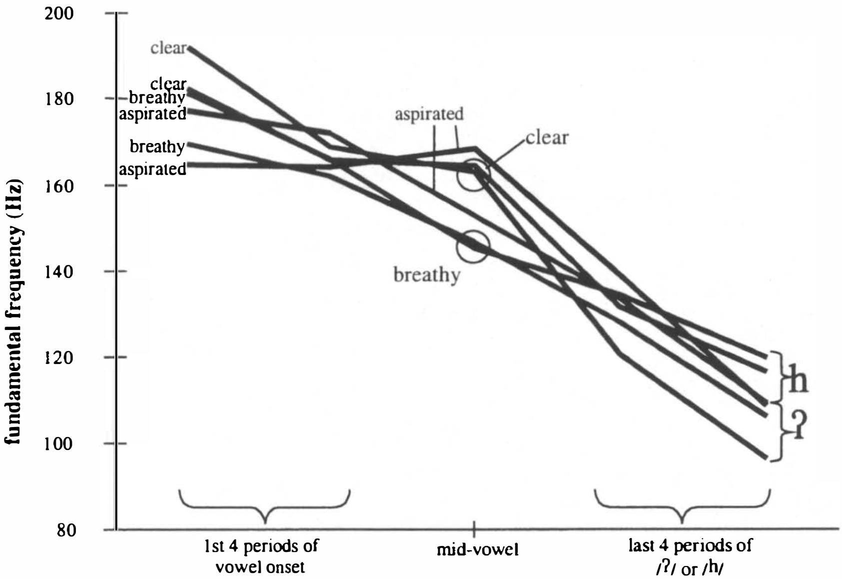

Figure 6-40: Illustration (time not to scale) of changing fundamental frequency through syllables with initial aspirated stops, or with unaspirated initials in clear and breathy register vowels, with final laryngeal consonants /ʔ/ and /h/.

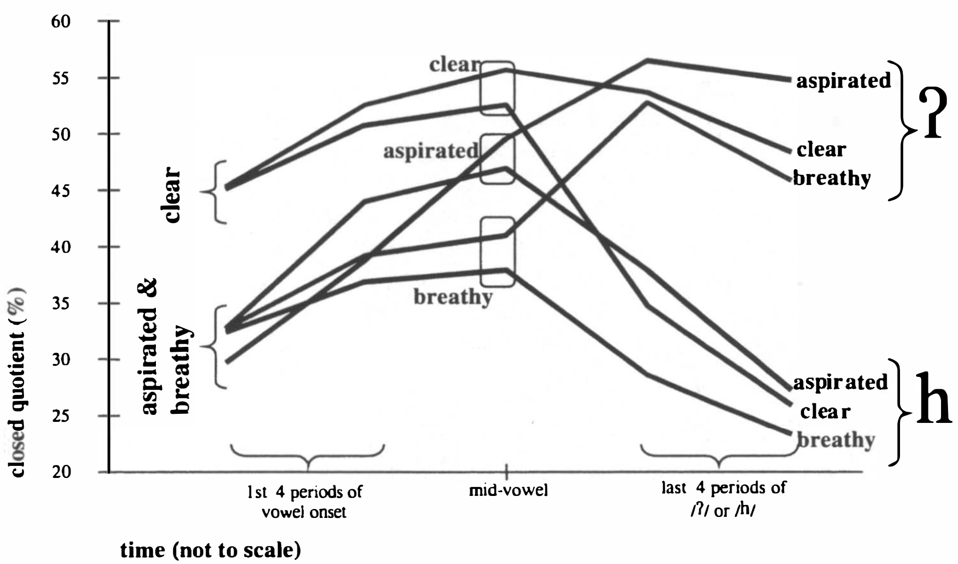

Figure 6-41: Illustration (time not to scale) of changing closed quotient through syllables with initial aspirated stops, or with unaspirated initials in clear and breathy register vowels, with final laryngeal consonants /ʔ/ and /h/.

Table 6-26: Design of ANOVA tests

independent variables: speaker (10)
register (clear, breathy, aspirated)
final consonant (/h/, /ʔ/)

	measure	*purpose*	*calculation* (see Table 6-25)
Test 1	F0 change in 1st four periods CQ change in 1st four periods	contour characterising vowel onset	(i)–(ii)
	vowel F0 vowel CQ	level characterising mid-vowel	(iii)
	F0 change in last four periods CQ change in last four periods	contour characterising final laryngeal consonant	(iv)–(v)
Test 2	F0 change from onset to vowel CQ change from onset to vowel	contour characterising change from initial consonant to vowel	(iii)–[(i)–(ii)]/2
	F0 change from vowel to final CQ change from vowel to final	contour characterising change from vowel to final laryngeal consonant	(iii)–[(iv)–(v)]/2

With respect to register and aspiration, the closed quotient measures support the findings in Section 6.7.2 above, where vowels following aspirated stops were found to be intermediate and distinct from both clear and breathy registers.

The relationship between final laryngeal consonants and closed quotient is still obscure. The most intrusive factor identified by the ANOVA tests was that of between-speaker variation, which had a more significant effect on closed quotient in more contexts than register or final consonant. The closed quotient data of the majority of speakers conformed to the pattern illustrated above in Figure 6-41, allowing the following general statements to be made about the laryngeal activity they illustrate:

- CQ falls in last four periods for both /ʔ/ and /h/;
- CQ is high falling for /ʔ/ and low falling for /h/;
- CQ generally rises before the high fall of /ʔ/ and falls before the low fall of /h/ (all speakers except RM).

A few notable exceptions are two consultants, NT and NKP, for whom closed quotient rises during a glottal stop, and consultant RM, whose glottal stop was associated with a low falling contour in the closed quotient trace.

Since the closed quotient traces for final glottal stops can be generally characterised as high fall in contrast to the low fall observed for /h/ it is still possible to describe glottal stops in terms of a tensing gesture, in which vocal fold tension is increased and then relaxed.

The way in which the larynx coordinates conflicting phonation types is of great interest. A single syllable may require the larynx to produce a range of phonation types in quick succession. For instance, breathy register vowel /ɛ̤/ and /ʔ/, realized as creaky phonation, adjoin one another in the syllable *tɛ̤ʔ* 'wager', while in the syllable *tɛh* 'reduce', clear register vowel /ɛ/ is followed by breathy consonant /h/.

The larynx preserves the necessary contrasts by subtle adjustment of phonation types through the syllable. In a syllable with an unaspirated initial consonant, the register and hence also the phonation type of the vowel is distinctive, since for all speakers closed quotient is greater in clear register both in the middle of the vowel and at the fourth period, immediately following the onset. In a syllable with an aspirated initial consonant, however, the phonation type of the vowel onset is fixed, since the breathy phonation at vowel onset is an immutable feature of aspiration, measured as low closed quotient after aspirated consonants. The phonation type of the central portion of a vowel following an aspirated initial is much more variable, and it seems likely that it would have little perceptual relevance.

Looking now at closed quotient during final laryngeal consonants, we see that the distinction between /ʔ/ and /h/ depends on high and low closed quotient, respectively. For a final glottal stop /ʔ/, the syllable must end with a high closed quotient phonation type. Where the preceding vowel is clear register, this means no more than maintaining the clear register phonation type with its relatively high closed quotient. If the preceding vowel is breathy register, a brisk change is necessary to rapidly switch from the low-CQ breathy register phonation type to the high-CQ glottal stop. The switch is necessarily abrupt because the breathy register phonation type, with its relatively low closed quotient, must be preserved into the vowel if the vowel is to be identifiably breathy register. This abrupt change is evident in the closed quotient patterns in Figure 6-41.

If the syllable has an aspirated initial consonant and final /ʔ/, the vowel onset is necessarily accompanied by a rising closed quotient contour, as vowel phonation is restored after the initial glottal abduction-adduction gesture and continues to rise as the glottal stop approaches. A transition from breathy, low–CQ phonation at vowel onset to high closed quotient in preparation for the glottal stop is still necessary, only because the phonation type of the vowel is flexible, the closed quotient transition can be more direct: the initial rising closed quotient contour is continued until a level suitable for the final /ʔ/ is reached.

The phonation type changes preceding final /h/, for which closed quotient must be low, are similarly variable. If /h/ is preceded by a breathy register vowel, closed quotient starts low and stays low. If the vowel before /h/ is clear register, closed quotient begins high and must remain high into the vowel, forcing a sharp drop to achieve the low level of closed quotient necessary for the /h/ in time.

In syllables with an aspirated initial consonant and a final /h/ (a with dotted line), a distinctive pattern is observed. The necessary components are rising low closed quotient initially and low falling closed quotient finally. This forges an overall rising-falling closed quotient contour over the entire syllable. The closed quotient trace of the syllable *ⁿdʰuʔ* 'gobble food' spoken by NT is shown in Figure 5-34.

The corpus of recordings did not yield sufficient data to enable a description of the phonation type of vowels following initial laryngeal consonants. The instrumental evidence of /h/ presented above shows that the articulations of both initial and final /h/ have much in common with the glottal abduction-adduction gesture which underlies aspiration in Wa. This similarity is reiterated by the fact that the register contrast is neutralised after initial /h/, just as it is after aspirated consonants. It seems likely, given the similar closed quotient patterns of aspiration and /h/, that both would have a similar effect on the vowel. From an inspection of the limited data which are available for vowels following glottal stops, after which the register contrast is also neutralised, it seems that closed quotient falls from a high level (associated with initial /ʔ/) to a level similar to that of clear register, or at least not markedly different from it.

Table 6-27: Main effects on fundamental frequency and closed quotient in syllables with laryngeal consonants (first ANOVA test)

Main effects:

		change in 1st four periods			*value during vowel*			*change in last four periods*		
	d.f.	*F*	*P*	*sig*	*F*	*p*	*sig*	*F*	*p*	*sig*
fundamental frequency										
speaker	9,171	6.869	<0.0001	●	147.248	<0.0001	●	3.544	<0.0001	●
register	2,171	4.854	0.009	○	5.475	0.005	○	1.653	0.194	
final	1,171	2.560	0.111		7.319	0.008	○	1.164	0.282	
closed quotient										
speaker	9,171	0.599	0.796		5.397	<0.0001	●	4.163	<0.0001	●
register	2,171	1.620	0.201		86.461	<0.0001	●	1.367	0.258	
final	1,171	0.442	0.507		3.005	0.085		2.105	0.149	

Higher order interactions:

		CQ during vowel			*F0 during vowel*		
	d.f.	*F*	*p*	*sig*	*F*	*p*	*sig*
Speaker/register	18,171	3.920	< 0.0001	●	1.948	0.015	○
speaker/final	9,171	2.299	0.018	○	0.485	0.883	
register/final	2,171	0.521	0.595		1.749	0.177	
speaker/register/final	36,171	2.555	0.001	●	0.788	0.712	

Table 6-28: Main effects on fundamental frequency and closed quotient in syllables with laryngeal consonants (second ANOVA test)

		onset to vowel			*vowel to final*		
	d.f.	*F*	*p*	*sig*	*F*	*p*	*sig*
closed quotient							
speaker	9,171	1.152	0.329		12.659	< 0.0001	●
register	2,171	17.246	< 0.0001	●	3.769	0.025	○
final	1,171	2.598	0.109		2.688	0.103	
fundamental frequency							
speaker	9,171	1.575	0.126		23.068	< 0.0001	●
register	2,171	7.431	0.001	●	7.280	0.001	●
final	1,171	3.140	0.078		0.536	0.465	
No significant higher-order interactions							

6.8 PATTERNING OF PHONATION TYPES IN WA

> The tense-lax contrast penetrates the whole syllable. "One cannot think of the tense-lax contrast as being a property solely of the vowel", "but the register phenomenon manifests itself most prominently in the vowel". (translated from Wáng and Chén 1981:53)

This observation states succinctly what the three experiments in this section have shown collectively. Laryngeal articulations are partially interdependent phonetically, although their function is to maintain independent phonological contrasts.

This study has made use of laryngographically derived closed quotient to describe various types of laryngeal activity in Wa. This sections sets out some tentative conclusions drawn from the patterns of phonation type change which are observed in Wa speech sounds. It is possible to draw a distinction between the near-modal phonation types used in the register contrast and the more extreme phonation types observed in glottal consonants and aspiration gestures.

Despite the great variety of possible compound phonation types in Laver's or other descriptive systems (see also Catford 1964), for descriptive purposes in a South East Asian linguistic context it is generally only necessary to define a three-way classification of phonation: creaky, modal and breathy (Thongkum 1988b:321). This simplification takes advantage of the fact that several phonation types share a relatively small repertoire of more general characteristics, both in terms of the laryngeal activity required to produce them and of their acoustic correlates. For instance, increased tension of the vocal folds of one type or another is specified for both tense and creaky voice, while breathy and lax phonation types have in common a lack of tension. Maddieson and Ladefoged (1985) have also pointed out that when applied to specific languages, the terms creaky, tense, modal, lax and breathy may simply be used to describe relative contrasts rather than specific laryngeal settings.

Unfortunately, even a three-way categorisation of phonation type is unsuitable for the facts of Wa. As stated earlier, the assessment of the phonation types of the Wa register contrast in Ladefoged and Maddieson (1996:316—a summary of previous work) describes clear and breathy register as 'slightly breathy and slightly stiff' phonation. They measure the difference in terms of airflow, finding that there is higher mean airflow in breathy register vowels, and concluding that the glottis must be less constricted in breathy register. Ladefoged points out that in Wa the difference between the phonation types is not as extreme as in other languages whose contrastive use of phonation type has been investigated experimentally, such as Jalapa Mazatec and !Xóõ (Ladefoged et al. 1988:314). A similar conclusion, namely that the phonation type differences involved in the register contrast are slight, was drawn in the present study (see Section 6.7).

Clear register phonation may be described as modal tending towards slightly tense, and breathy register as modal tending towards slightly breathy and/or lax. The difference between the two is often slight. On the other hand, laryngeal consonants /ʔ ɦ/ and aspiration involve a transition between either of the near-modal register phonation types and more extreme phonation types: creaky voice or creak in the case of /ʔ/ and extremely breathy phonation in the case of /h/ or aspiration. These facts are better explained in terms of a continuum of phonation types, such as that described by Ladefoged and Maddieson (1996:49), with creaky phonation at one end, breathy phonation at the other, and modal phonation in the middle. Lax and tense voice are incorporated slightly to either side of modal voice. This hypothetical continuum may be invoked to describe the relative breathiness or creakiness of the phonation types in any two instances of phonation without any need to quantify them precisely. In this view, the phonation types of vowels in clear and breathy register are rather close to one another on the continuum, with clear register on the tense/creaky side of modal, and breathy register tending towards the lax/breathy side, but with some overlap between the two. The phonation types observed in the articulation of laryngeal consonants or of aspiration involve travel towards the extremes of the continuum. This conceptualisation of a phonation type continuum may be represented as in Figure 6-42.

Ladefoged and Maddieson (1996:49) extend the continuum to states of voicelessness at either end. At the creaky end, voicelessness comes about as adductive and longitudinal tension and medial compression are increased until the glottis is sealed and vocal fold vibration is no longer possible; at the breathy end, voiceless results because the glottis is too wide for vocal fold vibration to occur. The acoustic correlates of the continuum may be thought of as cyclic: silent voicelessness may be approached via either of two routes. In articulatory terms, however, there is a discontinuity in the middle. The breathy route from modal phonation to voicelessness involves progressive widening of the glottis, referred to by Ladefoged and Maddieson (1996:49) as a 'continuum of glottal opening', in addition to general reduction of tension. But the transition from modal phonation to voicelessness via the creaky half of the continuum involves no such change in glottal width, since the vocal folds remain adducted throughout the creaky half of the continuum. Rather, it is degrees of tension and compression which increase towards the creaky extremes of phonation.

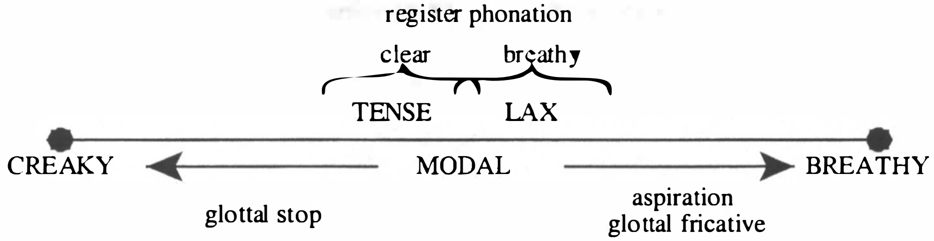

Figure 6-42: Laryngeal articulations in Wa positioned on a hypothetical phonation type continuum.

The involvement of a glottal abduction-adduction gesture activity of the larynx in stop-consonant voicing distinctions has been established in a number of languages: e.g. English: (Munhall and Löfqvist 1992), Swedish (Löfqvist and Yoshioka 1980), Hindi (Benguerel and Bhatia 1980; Dixit 1989), using one or more of the techniques of electromyography, photoelectric glottography and fibreoptic laryngoscopy.

The accounts of register and aspiration in Wa in this study suggest that a distinction can be drawn between two types of laryngeal activity. The production of registral phonation types involves minor adjustments of laryngeal setting which appear to be inherently static. On the other hand, laryngeal gestures, such as the glottal abduction-adduction gesture which is present in stop consonant aspiration and laryngeal consonants, are dynamic. Furthermore, the static laryngeal settings and dynamic gestural activity operate on markedly different time scales. As a phonetic correlate of the register contrast, phonatory adjustment operates at the syllable level, as evidenced by the coarticulatory effects of register observed across sonorant and even stop consonants. Gestural activity seems to be more specifically associated with single segments.

7 *Wa orthographies*

7.1 Scripts in use in the Wa-speaking area

The linguistic area in which Wa is spoken makes use of diverse writing systems, which fall into three categories: Chinese characters, Indic-derived South East Asian scripts and the Latin alphabet. The phonology of Chinese and the principles governing Latin and Indic-derived scripts have all had some influence, be it direct or indirect, on the ways in which Wa has been written down. Only Latin letters have been used to write Wa, but two orthographies compete: Bible orthography and PRC orthography.

Chinese characters are in use throughout the Wa-speaking areas of Yúnnán, where it is the official language. Chinese operates as one of the *lingue franche* (others are Dai, Lahu and Shan) in the Wa-inhabited areas on both sides of the China-Burma border, and growing Chinese economic activity in the Shan State means that Chinese characters are frequently encountered there also. Wa in Yúnnán who have attended Chinese schools will have learnt Chinese characters, but no attempt has been made to write Wa using them. Chinese phonology, however, can be said to have had an indirect influence on Wa writing, since some of the design features of the Chinese *hànyŭ pīnyīn* system of romanisation were applied to PRC orthography.

The Brāhmī script is the antecedent of all the Indic scripts now in use. The southern variety of Brāhmī was the source of the Dravidian scripts of south India and ultimately also of all the Indic scripts used in mainland South East Asia, arriving there with the spread of Buddhism. Khmer was the first South East Asian language to be written using an adaptation of an Indic script, with the earliest inscription in Khmer dating back to the 7th century (Huffman 1970:4). The Khmer script was adapted to write Mon, and the Mon script was used, with small changes, to write Burmese a few centuries later. The Burmese script was subsequently adapted to write the Tai languages Shan and Tai Khün, spoken in the Shan States. Independently, another script was developed from the Khmer script in the 13th century to write Thai, a feat attributed to King Ramkhamhaeng of Sukhothai. Adaptations of this script are used to write other Tai languages spoken in the Wa-speaking area, such as Tai Lü and varieties of Dai.

Wa in Burma may be familiar with Burmese script if they have attended school in Burmese. Otherwise, they may have some incidental familiarity with Burmese script or one of the other writing systems closely related to it, such as the Tai Khün script (Peltier 1996) which is not an unfamiliar sight in Keng Tung, or Shan script (Egerod 1957), which may be seen in all parts of the Shan State. Wa in Thailand will come into contact with the Thai script, especially if their children attend Thai school. Thai script has not been used to write Wa in Thailand, though a Thai alphabet orthography has been devised for Lavüa' (Lawa), another Waic language spoken in Thailand (Schlatter 1977, Lawa Readers 1985). The influence of Brāhmī scripts on Wa writing is limited to the fact that recent attempts to correct ambiguities and inconsistencies in the Bible orthography have drawn on the principles of Thai and Burmese orthography, both of Indic origin.

The Latin-based scripts of the region may be grouped crudely into two categories: missionary and official. This categorisation may similarly be applied to the Wa orthography situation. Wa was not written down until the 20th century, but since the 1930s two independent systems have been devised: Bible orthography by missionaries and PRC orthography by government-appointed linguists in the People's Republic of China.[30] The coexistence of these two systems has brought about confusion: as efforts are made to correct problems in the Bible orthography, the two systems have cross-pollinated to both fruitful and detrimental effect.

Whether missionary or official in origin, the degree to which a new script may come to be accepted or widely used is determined by a number of complex factors, both linguistic and social. William Smalley, an expert in the field of minority language orthographies in Thailand, has proposed five criteria which will help writing systems to succeed (Smalley 1977:27–38). He attaches greatest practical importance to the need for a new script to be desirable for those who will use it, and to be accepted officially and socially. The next most important criterion, according to Smalley, is the optimum representation of the language concerned. It is helpful to bear these criteria in mind when considering the relative merits of Bible orthography and PRC orthography.

7.2 Development of Wa orthographies

7.2.1 EARLY ILLUSTRATIVE TRANSCRIPTION

The earliest descriptions of Wa, such as Drage (1907), Davies (1909) and Antisdel (1912) all transcribed Wa using Latin letters. These three used romanisations which drew on the English-based systems which were used to transcribe Burmese and Shan, formalised in rules set out by the British colonial government (Drage 1907:7). However, Wa makes use of sounds which are not provided for in these systems, so some innovation was necessary. Antisdel favours simplicity of reproduction, avoiding diacritics. He mentions that Wa pupils at the school in Keng Tung, who were presumably already able to read and write English, 'read correctly and with perfect understanding.' Drage is more imaginative in combining and modifying symbols, but the end result is erratic and sketchy, even though his material is abundant. There is no indication that any of these authors envisaged that the transcription systems they devised would come into popular use, and so they cannot properly be given the status of writing systems. They are mentioned here because they illustrate the types of romanisation which were prevalent at the time when the first Wa writing system intended for wider popular use was devised.

7.2.2 BIBLE ORTHOGRAPHY

Developing a writing system is one aspect of the work of many Christian missionaries. Smalley (1994:291) suggests that 'Christian missionaries have prepared writing systems for far more languages in the world than has any other category of people.'

During the 1910s, the Baptist missionary Vincent M. Young devised an orthography for Wa. With the help of native speakers, he translated the New Testament into Wa. His

[30] Bible orthography is known in Chinese as *lǎo Wǎwén* 老佤文 'old Wa script', or *S˧˥~ wén* 撒拉文 'Missionary writing' < Wa *sa̤la̤ʔ* 'priest, missionary' < Burmese *sʰəja:* ဆရာ 'teacher'. PRC Wa script is known in Chinese simply as *Wǎwén* 佤文 'Wa script' or *xīn Wǎwén* 新佤文 'new Wa script'.

translation was published in the 1930s in Rangoon by the American Baptist Mission Press and reprinted by the PRC State Christian authority, the Christian 'Three-Self' Patriotic Movement, in Shanghai in 1985. Young was active during in the Wa-speaking areas which are now Cāngyuán and Láncāng Counties in Yúnnán, and built his first church in Láncāng County. The translation of the Bible was based on the speech of Wa speakers from Àishuāi and Ānkāng, as far as can be deduced from textual analysis (Yán 1981:77).

Young's writing system, like the great majority of other missionary orthographies, was written using Latin script, which presented problems when it came to representing tone, phonation type or breathy–aspirated consonants. Since the task of designing orthographies was undertaken by people who were highly motivated, but not necessarily methodical, linguists, missionary orthographies tend to represent phonological systems with varying degrees of accuracy.

In James Outram Fraser's orthography for Lisu, for instance, tones are clearly indicated by assigning a consonant letter to each tone and writing it at the end of each syllable bearing that tone (Fraser 1922). In Lahu and Akha, tones are generally written using specially devised diacritics written after each syllable (Bradley 1991). This system is used in the Lahu bible, published in 1949. Other languages, such as Wa and Jinghpo, did not fare so well. The Swedish-American Baptist missionary Ola Hansson's orthography for Jinghpo, developed in the late 19th century and still in widespread and officially sanctioned use in both China and Burma after more than a century, does not represent the lexical tones. Young's orthography for Wa ignored the register contrast, aspiration of sonorants and fricatives, and final laryngeal consonants /h/ and /ʔ/, although he clearly had an impressive command of the spoken language.[31] Young's Bible orthography was well-received at the time of its development. In the absence of any alternative writing system, the motivation to read the Bible and to accept the orthography Young used to translate it could be assumed within the communities of converts to Christianity for whom it was intended.

The failure of the Bible orthography to represent certain phonological contrasts generates widespread homography, examples of which are given in Table 7-1.

Another problem in Bible orthography is inconsistency. One aim in designing an alphabetic writing system is to try to represent the phonological contrasts of a language's sound system consistently, ideally by means of a single symbol or combination of symbols. But a number of Wa sounds, predominantly diphthongs, are represented in more than one way in Young's orthography. His use of hyphens and of the letters 'y' and 'w' are particularly misleading, as shown in Table 7-2.

These inconsistencies introduce either a degree of arbitrariness to the spelling of words, or else necessitate spurious distinctions in spelling between words or parts of words containing the same sound, resulting in anomalies such as in Table 7-3 below.

In some cases, illustrated in Table 7-4, the spelling variations reflect allophonic variation of Wa vowels or the reanalysis of diphthongs as glide+vowel, in which case there is a tendency not to use a hyphen. Often, however, they are arbitrary.

[31] A Wa speaker played the author a tape recording of Young reading from his translation of the Bible and commented that he 'sounded just like a Wa person'.

Table 7-1: Homography in Bible orthography

Bible orthography	*phonemic transcription*	*gloss*
teh	*tε*	'sweet'
	tεh	'less'
	tεʔ	'land'
	tɛ̤	'peach'
	tɛ̤	'turn'
	tɛ̤ʔ	'wager'
bang	*^{m}baŋ*	'awning'
	^{m}b^{h}aŋ	'open'
da	*^{n}da*	'dry out'
	^{n}d^{h}a	'before'
Lai	*lai*	'squirrel'
	la̤i	'writing'
	l^{h}ai	'aslant'

Table 7-2: Inconsistencies in Bible orthography: representation of Wa vowels

Bible orthography	*phonemic transcription*	*gloss*
i-ya / i-a / ya	*ʔia*	'chicken'
ku-at / kuwat / kwat	*kṳad*	'old'
moi / maweh	*mɔi*	'cow'

Table 7-3: Spelling anomalies in Bible orthography

Vowel	*Bible orthography*	*phonemic transcription*	*Gloss*
/ɔi/	kwe	*koi*	'have'
	mo-e	*moi*	'axe'
/ua/ /ṳa/	bwan	*^{m}buan*	'luck'
	kwat	*kṳat*	'old'
	mu-wat	*mṳat*	'carbuncle'
	luan	*lṳan*	'exceed'
	plu-at	*pluat*	'stop'

Table 7-4: Bible orthography vowel spellings of diphthongs

Diphthong	*Bible orthography spelling*
/ia/	i-ya / i-a / ya / ia / i-eh / eha
/iau/	i-ao / eh-ao
/ua/	u-a / ua / u-wa / wa
/ɔi/	oi / aw-eh / aw-e
/oi/	o-e / we
/ui/	u-i / wi
/ɯi/	ui-i / ui-e

This arbitrariness seems undesirable, though, admittedly, when an illogical or unusual spelling becomes fixed for a particularly common word, there is no problem. When the time comes to reform the system, however, there may be a reluctance to change from the established, irrational, spelling to a new, more phonologically principled one.

These inadequacies aside, Young's orthography was largely systematic in its treatment of consonants and monophthongs, as can be seen in the comparative Table 7-12. His choice of digraphs was based on conventions of English spelling: 'aw' and 'eh' for /ɔ/ and /ɛ/ respectively. Since final /h/ sounds are not represented, this use of 'h' was unambiguous, though it caused a problem for those reforming Bible orthography later. He indicates voiced/voiceless pairs by switching symbols: p/b; t/d; c/j; k/g, and marks aspiration (of voiceless stops only) by adding a symbol 'h'.

7.2.3 WA ORTHOGRAPHY IN CHINA

Official scripts for a number of China's minority languages were researched and developed in the 1950s by the Chinese Academy of Social Sciences' Department of Anthropology as part of the minority nationalities policy of the newly established People's Republic of China (see Svantesson 1991b).

According to official Chinese sources (Wáng 1994), Bible orthography was never accepted by the Wa for 'political reasons', and was indeed 'rejected' by the Wa after the Wa-speaking areas came under Communist control in 1951 shortly after the establishment of the PRC in 1949.

Working groups were established under the aegis of the Chinese Academy of Social Sciences for sixteen minority languages, including Wa. Eight scholars, known officially as the 'Chinese Academy of Social Sciences Third Work Party (Wa Group) for Research on Minority Nationality Languages' were given the task of documenting the Wa language and developing a new writing system for it. Their work was finished in 1956 and culminated in the publication in early 1957 of a Provisional Kawa Script Programme (Chinese Academy of Social Sciences 1957), referred to here as 'provisional PRC orthography'.

PROVISIONAL PRC ORTHOGRAPHY

Provisional PRC orthography is Latin alphabet based, and assigns one symbol to each segmental phoneme. The register contrast is represented not by a diacritic, as is more common for suprasegmental features, but rather by the insertion of the symbol 'ъ'[32] after vowels with clear register. The sign is not written in phonological contexts where the register contrast does not apply, that is, in syllables beginning with an aspirated consonant, /h/ or /ʔ/.

The Latin letters in the provisional PRC orthography are ascribed values consistent with their use in European languages for the majority of consonants, which receive largely the same treatment as in Bible orthography. There is additional provision for voiced aspirates, also indicated by inserting 'h'. The voiced palatal approximant /y/ is represented as 'z', reflecting the fact that close approximation may tend towards friction, in this case /ʑ/. The vowel system seems to have been independently conceived, using 'y' for /ɤ/ and 'w' for /ɯ/. IPA symbols are used for the velar nasal 'ŋ' and the half-open front vowel 'ɛ'. The symbol 'ɵ' is used for /ɔ/. The connection with Cyrillic having already been established, 'ɵ' is presumably borrowed from the extended Cyrillic alphabet used to write Mongolian and other languages, in which it represents a half-close front rounded vowel [ø]. Final glottal consonants /h/ and /ʔ/ are written 'h' and 'q' respectively.

PRC ORTHOGRAPHY

At roughly the same time, in February 1956, *pŭtōnghuà* was decided upon as the national and official language of the newly-established People's Republic of China, and in 1958 *hànyŭ pīnyīn* was adopted as the official system for transcribing it. *Pīnyīn* has at various times been intended as a future replacement for Chinese characters, or at least an alternative to them, as part of the Chinese programme of script reform and simplification (Norman 1988:263). Significantly, the adoption of *pīnyīn* put an end to the debate over whether Cyrillic or Latin letters should be used for transcribing Chinese.

Consequently, central Chinese government policy dictated in 1957 that minority scripts also should conform to the principles of *pīnyīn* transcription, and so it was that *pīnyīn* came to be used as the yardstick against which new and reformed Latin-alphabet minority scripts were to be measured. From then on, the use of non-Latin letters in minority scripts was abandoned.

An understanding of the principles underlying the *pīnyīn* system explains one aspect of the design of PRC orthography which would otherwise seem counter-intuitive, namely the representation of consonant voicing and aspiration. In *pīnyīn,* aspiration is represented by switching symbols, as in Table 7-5, a convention which was adopted for Wa stops also.

Table 7-5: *Pŭtōnghuà* Chinese stop consonant aspiration in *pīnyīn* romanisation

IPA	p	p^h	t	t^h	tɕ	$tɕ^h$	tʂ	$tʂ^h$	k	k^h
pīnyīn transcription	b	p	d	t	j	q	zh	ch	g	k

[32] This symbol is the Cyrillic 'hard' *yer* sign, put to a variety of uses in Slavonic languages. It is used in Russian to undo the effects of assimilatory palatisation in consonants. Consonants thus depalatised are typically accompanied by velarisation. Its use to mark the clear register in Wa registers stems perhaps from an analogous comparison of the Russian velarised–palatalised contrast with the registral contrast.

Consequently, PRC orthography was forced to find an alternative means of representing the Wa voiced/voiceless contrasts, unnecessary in the *pǔtōnghuà* transcription system for Chinese. The script developers singled out the prenasalisation feature as representative of voiced stops, and indicated this by adding 'n' before the consonant. This had two knock-on effects. Firstly, prenasalised voiced velar stops /ᵑg/ had to be written 'mg' to preserve the integrity of the digraph 'ng' which had replaced 'ŋ' to represent the velar nasal. Secondly, there was now an apparent contradiction between the innovative *pīnyīn* symbol-switching method of representing aspiration in stops and the more conventional added-'h' method, which was now used only to indicate aspiration of sonorants and fricatives.

Clearly, adherence to the principles of *pīnyīn* entailed the removal from the provisional Wa orthography of Cyrillic letters and other non-Latin symbols. The system in Table 7-6 was devised to be capable of representing all the monophthongs, with the advantage that all polyphthongs could be written as sequences of monophthongs using the same convention. The sole exception was /ɤi/ which was written 'eui' to avoid confusion with /e/, written 'ei'.

Table 7-6: Monophthongs in PRC orthography

	phonemic transcription			*PRC orthography*		
	front	back		front	back	
	unrounded		rounded	unrounded		rounded
close	i	ɯ	u	i	ee	u
mid-close	e	ɤ	o	ei	e	ou
mid-open	ɛ		ɔ	ie		o
open		a			a	

The way of marking the register contrast was also revised. It was decided to mark breathy register instead of clear. The *macron* symbol ¯ used in *pīnyīn* to denote the *pǔtōnghuà* high tone which was chosen for the purpose.

7.2.4 WA ORTHOGRAPHICAL REFORM SINCE THE 1980S

More recently, since the loosening in the 1980s of the strict isolationist policies both of China during the Cultural Revolution and of Burma under the Burma Socialist Programme Party, it has been easier in some respects for Wa to cross the border which divides the area they inhabit between Yúnnán and the Shan State.

The sound design of PRC orthography has clearly caught the attention of the wider Wa community. The Christian Wa community, found all over the Wa-speaking areas, in the Shan States, Yúnnán and Thailand, is motivated to learn and teach written Wa for use in church. There is also evidence that written Wa is used in village schools in Wa-speaking parts of the Shan States where Burmese is not known, irrespective of the Christian motive, and sometimes in conjunction with it. In both cases, it is the Bible orthography which is used. According to Nyī Ka[33] (1989): 'Wa people in [Shan State Wa country] are accustomed to the [Bible] Wa orthography, but are not prepared to convert to [PRC] Wa orthography or to put up with the shortcomings of [Bible] Wa orthography.' Clearly, the mutual unintelligibility of the Bible and PRC Wa scripts has been a barrier to reform of the more widely used Bible orthography, while the advantages of PRC orthography over Bible orthography are known. Nyī Ka proposes 'making improvements by using [Bible] Wa orthography as a base and drawing on the good points of the [PRC] Wa orthography.' Nyī Ka (1989) recommends that certain aspects of PRC orthography should be borrowed to improve Bible orthography. Nyī Ka's suggestions are incorporated into Table 7-12. Nyī Ka's recommendations were made following contact with Wa scholars in Maing Maw, Shan State.

In 1992, the Wa Welfare Society (WWS) in Chiangmai, catering for the Wa community outside China to whom PRC orthography had not been available, reproduced a series of literacy booklets, which the editor claimed had been compiled in the Wa sub-state of the Shan State, possibly from the same source as Nyī Ka's suggestions above. The booklets were based heavily on the PRC primary school readers, containing many of the same texts written out in a revised form of the Bible orthography. The general design of the Bible orthography is preserved, ensuring that those accustomed to it are not alienated, while the changes address the major shortcomings of the Bible orthography. Breathy aspiration of stop consonants and continuants is marked consistently with an 'h' following the consonant, rather than preceding it, which is the unusual and phonetically incongruous convention in PRC orthography. Other imports from the PRC orthography include the representation of final glottal consonants /h/ /ʔ/ with 'h' and 'x' respectively, as a result of which the spelling 'eh' for the half-open front vowel /ɛ/ is replaced by the digraph 'ie', to avoid rendering ambiguous the letter 'h'. The use of hyphenated combinations of symbols to represent back vowels and diphthongs is also abandoned. The back vowels /ɯ/ and /ɤ/ are spelt 'ee' and 'eu' respectively. While the intended spelling of diphthongs is not explained systematically, a look at the texts shows that they are written as predictable combinations of monophthongs.

The Wa Welfare Society language primer *Lai Vax: Phuk Lai Gau* (Ai Pao 1994) introduces the writing system used in the other booklets in the series, and describes four possible syllable types for each vowel, set out in as in Table 7-7.

Table 7-7: Vowel categories in revised Bible orthography

syllable type description in Wa	*Gloss*	*revised Bible orthography*
loʔ laŋ	'long sound'	a
loʔ ⁿdɔt	'short sound'	ah
loʔ ⁿdut	'cut-off sound'	ax
loʔ lʰauŋ	'high sound'	a:

[33] Nyī Ka (1989) also writes that "[his] suggestions for the script had been approved by scholars in Burma, Thailand and China and preparations were being made for their widespread introduction, but they were shelved as a result of subsequent events [in June 1989]."

The 'short sound' and 'cut-off sound' seem to be a straightforward incorporation of the PRC Wa spelling for syllable-final laryngeal consonants ('h' and 'x' for /h/ and /ʔ/) into Bible orthography, and these two symbols are used consistently correctly in the booklets. Moreover, the labels 'long', 'short' and 'cut-off' are fair descriptions of the difference in duration between open and closed syllables observed as a result of closed syllable vowel shortening (Section 5.1.3). However, the layout of these categories, the failure to mention final stop consonants and the inclusion of the so-called 'high sound' are strongly suggestive of the four Burmese tones in the following order: low, creaky, killed, high[34] (see Wheatley 1987). It appears that these improvements became muddled by attempting to describe Wa phonology using a framework intended to describe the tones of Burmese.

The 'high sound' mark ':' is used occasionally but erratically throughout the booklets. This symbol ':' was used in Bible orthography principally to distinguish the pair of words in Table 7-8. Young's choice of symbol was perhaps inspired by the similar symbol, derived from the *visarga* of parent Indic scripts, which is used to indicate the Burmese high tone in Burmese script. The Burmese high tone occurs only in open syllables and is associated with high pitch and breathy voice quality (Bradley 1982, Wheatley 1987).

Table 7-8: Meaningful use of the symbol ':' in Bible orthography

phonemes	*Bible orthography*	*gloss*
mai	mai:	*'and'*
maiʔ	mai	*'you'*

This previously established (but now redundant, if 'x' and 'h' are used) usage of ':' in Bible orthography is extended in the WWS booklets to include other randomly selected vowel and nasal finals, especially with names, as shown in Table 7-9.

Table 7-9: Random use of ':' in Bible orthography

phonemes	*Bible orthography*	*gloss*
ka	Ka:	(personal name)
kɔi	koi:	'millet'
kiaŋ	kian:	'brave'
paŋ	pang:	'clump'
dɔi	toi:	'silver pheasant'

[34] The four tones in Burmese script: အာ အ အတ် အား; in IPA /a: a̱ aʔ á:/.

Secondly, this mark is also used to distinguish the register contrast in the minimal pairs in Table 7-10, but which register ':' is intended to indicate is not made clear. One assumes clear register from the evidence in Table 7-10. These data indicate an awareness of the register contrast, but indicate that there is some confusion surrounding it.

Table 7-10: Use of ':' to mark the register contrast in revised Bible orthography

	revised Bible orthography	*gloss*
kaɲ / ka̤ɲ	kaing: / kaing	'head' / 'work'
lɔŋ / lɔ̤ŋ	lawng: / lawng	'coffin' / 'plough'

Another attempt to write down the register contrast in orthography was described to the author.[35] This time, the choice of symbol used to write final stop consonants was used as an indication of the register of the vowel, as in Table 7-11. This approach was perhaps inspired by the representation of tones by different consonant letters in Thai (see e.g. Hudak 1987), or by the use of letters written after vowels to indicate tone in scripts such as Lisu (see e.g. Bradley 1991). Since final obstruent consonants are voiceless in Wa, this is a viable orthographic convention to distinguish a minimal pair such as in Table 45. But such a convention is otherwise useless for Wa since it enables the register contrast to be represented only in words with final stop consonants. Words with vowel, glottal stop, glottal fricative or nasal finals cannot be accommodated in such a system.

Table 7-11: Representing Wa register contrast by symbol switching

phonemes	*revised Bible orthography*	*gloss*
pak	pak	place
pa̤k	pag	rip

The influence of the Young family in the fate of Wa orthography continues to this day. Marcus Young, a descendant of the missionary Vincent M. Young, is currently coordinating a project based in Chiangmai to translate the Old Testament of the Bible into Wa. Using the WWS revision of Bible orthography as a base, he enlisted the help of the Summer Institute of Linguistics and other parties to identify the areas of Wa orthography which were in need of reform and to recommend appropriate modifications to the orthography before committing the translation to print.

One proposed modification would be the representation of the register contrast by the use of a simple diacritic over breathy vowels, as is the practice in the PRC orthography. The advantages of representing all a language's phonological contrasts in a writing system were mentioned above in the context of William Smalley's five 'bases for popular writing systems' (Smalley 1977). Another criterion in this set is 'maximum ease of reproduction'.

[35] Also by the editor of this series of booklets, Ai Pao Pleek Sgu.

Smalley admits that 'this is the least important principle with which we have to deal' and says that after the other, theoretical considerations have been taken into account, the 'choice of symbols which is easiest to type and print is the best.' It is not yet certain whether the use of a diacritic will be possible in Young's translation project, which is constrained by the use of computers.

7.3 Comparison of Wa orthographies

The differences between the two principal Wa orthographies in current use, and derived hybrids and varieties, are set out in Table 7-12. The comparison of the various systems is based on the phonological analysis of Wa given earlier in chapter 1.

The differences in look and feel between the systems is apparent from the comparison in Table 7-13 of the sentence 'Have you read my letter yet?' in Wa. Glossed texts in Wa are presented in chapter 9.

7.4 Wa orthographies in use

The use of Wa orthography in various schoolbooks and the Wa translation of the Bible have been discussed above. The school primers produced in Cāngyuán during the 1980s (Cāngyuán 1985) use PRC orthography throughout. Other than state school attendance statistics, no figures are available to indicate how many Wa in Yúnnán are competent in the use of PRC orthography, much less to suggest how many people actually do use it or are motivated to do so, but the numbers are likely to be small in a part of the world where written communication is overwhelmingly in Chinese.

Propaganda leaflets in Wa were produced by the Nationalities Publishing House in Kūnmíng in 1959--60. More recently, a small number of books have been published in Wa-Chinese parallel text edition (e.g. Chén and Wáng 1993; see Section 9.3.3 or Lǐ 1994 for a fuller list in Chinese), echoing the PRC policy of bilingual education for minority nationalities, under which Wa is used to complement and support Wa speakers' knowledge of Chinese.

Examples of Wa orthography in public view are few and far between. In Cāngyuán, the seat of the local government of the Cāngyuán Wa Autonomous County, signs outside public buildings which appear at first sight to be in Chinese characters and also in Wa turn out in fact to be Yunnanese Chinese written in PRC orthography, as in Table 7-14.

Table 7-12: Comparison of Wa orthographies

	phonemic transcription	*Bible orthography and revisions*	*prototype PRC orthography*	*PRC orthography*
stop consonants				
voiceless unaspirated	p t c k	p t c k	p t c k	b d j g
voiced prenasalised[36]	^{m}b ^{n}d $^{\text{ɲ}}$j $^{\text{ŋ}}$g	b d j g	b d j k	nb nd nj mg*
voiceless aspirated	p^{h} t^{h} c^{h} k^{h}	hp ht hc hk (ph th ch hk)**	ph th ch kh	p t q k
voiced prenasalised aspirated[37]	^{m}b^{h} ^{n}d^{h} $^{\text{ɲ}}$j^{h} $^{\text{ŋ}}$g^{h}	b d j g (bh dh jh gh)** (hb hd hj hg)‡	bh dh jh gh	np nt nq nk
other consonants				
nasals	m n ɲ ŋ	m n ny ng	m n ɲ ŋ	m n ny ng
breathy-voiced nasals	mh nh ɲh ŋh	m n ny ng (mh nh nyh ngh)**	mh nh ɲh ŋh	hm hn hny hng
continuants	r y l v s	r y l v s	r z l v s	r y l v s
breathy-voiced approximants	rh jh lh vh	r y l v (rh yh lh vh)** (hr hy hl hv)‡	rh zh lh vh	hr hl hy hv
final consonants				
oral stops	p t c k	p t t/k† k	p t k† k	b d g† g
nasals	m n ɲ ŋ	m n ng† ng	m n ng† ng	m n ng† ng
glottal consonants	h ʔ	(not marked) (h x)**‡	h q	h x
/s./ presyllable				
	s.	Si	si'	si-

[36] Diffloth's etymological lexicon (Diffloth 1980) describes these stops as prenasalised voiceless / /^{m}p ^{n}t $^{\text{ɲ}}$c $^{\text{ŋ}}$k/.

[37] Diffloth's etymological lexicon contains none of the voiced aspirated stops in Àishuāi Wa ('Kawa' in his lexicon), though they are clearly attested.

Table 7-12 : *Continued*

	phonemic transcription	*Bible orthography and revisions*	*prototype PRC orthography*	*PRC orthography*
monophthongs				
	i e ɛ a	i e eh a (i ei ie a)**‡	i e ɜ a	i ei ie a
	u o ɔ	u o aw	u o ɵ	u ou o
	ɤ ɯ	eu ui	w y	ee e
polyphthongs				
	ui oi ɔi	u-i o-e oi***	ui oi ɵi	ui oui oi
	ɯi ɤi aɯ	ui-i eu-e au	wi yi aw	eei eui ae(e)
	ia	i-a	ia	ia
	iao uai ua	i-ao u-ai u-a (iao uai ua)**‡	iau uai ua	iao uai ua
register contrast				
clear / breathy	a / a̤	a /a (a / ā)‡	a / aъ	a / ā

* This apparently anomalous use of 'm' is explained below.

** Revisions included in Wa Welfare Society (WWS) booklets (Ai Pao 1992, 1994).

*** Bible Wa spellings of diphthongs were subject to arbitrary variation, discussed below.

‡ Revisions proposed by Nyī Ka (1989).

† None of the scripts distinguishes palatal final consonants. The phonological contrast is maintained instead by the preceding palatal glide, characteristic of Mon-Khmer palatal finals, and reclassifying the palatal as either velar or alveolar.

Table 7-13: Examples of Wa writing systems

phonemes	*l̤ai*	*pɔ̤t*	*ʔɤʔ*	*kɯm*	*hɔc*	*ᶮjʰak*	*maiʔ*	*nɔh*	
Bible	Lai	pawt	au,	kuim	hoit	jak	mai	naw?	
revised Bible		Lai	pawt	aux,	keem	hoit	jak	maix nawh?	
prototype PRC		Lai	pɵt	wq,	kwъm	hɵik	jhak	maiъq	nɵъh?
PRC	Lāi	bōd	ex,	geem	hoig	nqag	maix	noh?	
gloss	letter	write	I-1SG	then	yet	read	you	it-3SG	
	'Have you read my letter yet?'								

Table 7-14: Yunnanese Chinese in PRC orthography

Chinese characters	沧源	佤族	自治县
hànyŭ pīnyīn	Cāngyuán	Wăzú	zìzhìxiàn
Bĕijīng Chinese	˥tsʰaŋ ˧˥jɥɛn	˨˩˦wa ˧˥tsu	˥˩tsz̩ʏ ˥˩ʈʂʐ̩ʏ ˥˩ɕjɛn
PRC orthography	Qangying	Vāxqux	zizising
phonemes	*cʰaŋ yiŋ*	*va̤ʔ tɕuʔ*	*tsi tsi siŋ**
gloss	Cāngyuán	Wa nationality	autonomous county

* the alveolar affricate /ts/ is used exclusively in Chinese loanwords containing the affricates /ts/ or /ʈʂ/, and is spelt 'z' in PRC orthography.

In Burma, signs in Wa using Bible orthography were seen outside the Wa boarding school in Lashio and outside a Wa meeting centre in Taunggyi. In China, Wa restaurants in Láncāng and Xīmĕng, and a practitioner of traditional Wa remedies in Cāngyuán all advertised their identity with signs in (PRC orthography) Wa. Calendars and posters with Wa orthography are prominently displayed in many Wa homes. These examples suggest that Wa orthography functions to some degree as a symbol of Wa identity, even though its use as a general-purpose medium for written language is limited.

The future of Wa orthography seems to lie with the reformed Bible orthography, which enjoys the widest usage and is set to become more attractive and easy to use as its idiosyncrasies and anomalies are ironed out. It also benefits from the support of the United Wa State Party (known in Chinese as *Wă Bāng* 佤邦), a *de facto* Wa government based in Pang Hsang, centre of Wa political affairs and the probable source of future revisions to the Bible orthography.

While this manuscript was being prepared for publication (2001), the author learnt of such a revision, promoted by the UWSP literacy authorities in Pang Hsang, which had been adopted by Young's translation project. In this revision, the register contrast is marked in some contexts but not in others, according to the schema in Table 7-15. This system combines features from the spelling systems examined above.

Table 7-15: Marking register in UWSP revised orthography of 2001

syllable type	*example minimal pair clear / breathy*	*UWSP revised spelling (2001)*	*comment*
CV syllables; final nasal	*tɛ* 'sweet' / *tɛ̤* 'peach'	'tie:' / 'tie'	clear register marked with colon ":"
	kaɲ 'head' / *ka̤ɲ* 'work'	'kaing:' / 'kaing'	
final stop	*nap* 'two (on calendar)' / *na̤p* 'respect'	'nap' / 'nab'	symbol switching: breathy register marked with voiced consonant symbol
	mak 'chop' / *ma̤k* 'handle'	'mak' / 'mag'	
final glottal consonant	*tɛʔ* 'earth' / *tɛ̤ʔ* 'wager'	both 'tiex'	register contrast not marked
	rauh 'red' / *ra̤uh* 'bark (v.)'	both 'raoh'	

The continued motivation to use the original Bible orthography amongst the core body of Christian Bible-readers and hymn-singers in China, Burma and Thailand is assured. This competence could be easily transferred to reformed Wa orthography by wide circulation of a newly translated Old Testament in reformed Bible orthography, or of a reformed Bible orthography edition of New Testament, of which there has been talk.

In Burma, there is the additional prospect that the use of reformed Bible orthography will spread with education in the remoter Wa-speaking areas in the Shan States, as was suggested by teachers at the Wa Orphanage in Lashio. In China, the future of PRC orthography seems assured, although any currency this orthography acquires from its official status and use in state primary education is tempered by the emphasis on Chinese in the later years of education. In Thailand, the motivation is overwhelmingly to be literate in Thai, especially for children, for whom opportunity lies in passing through the Thai education system. Other than Christian worship, there would seem to be little motivation for Wa to acquire literacy in their own language.

7.5 LITERACY IN WA

CHINA

According to the 1982 census, illiteracy among China's minority nationalities was 43 per cent, considerably higher than the adult average of 32 per cent (Svantesson 1991b). The PRC government began to address the issues of development and education for minority nationalities soon after it came to power in 1949. The PRC government policy on ethnic minority affairs of February 1951 prompted the Academy of Social Sciences to recruit anthropologists to undertake research on minority nationality societies and languages. This was the birth of what was to become the Central Institute for Nationalities (中央民族学院 *Zhōngyāng mínzú xuéyuàn*), now the Central Nationalities University (中央民族大学 *Zhōngyāng mínzú dàxué*). The initial purpose of this Institute was to train ethnic Chinese linguist-anthropologists to research minority languages. From 1957 onwards it provided higher education and teacher training for students from the minority nationalities, including Wa. This role was later devolved to local Institutes, the one responsible for Wa being the Yúnnán Institute for Nationalities (云南民族学院 *Yúnnán mínzú xuéyuàn*) in Kūnmíng.

Svantesson (1991b) mentions a series of government-produced educational materials, including Wa readers and basic mathematics texts in Wa, published in 1964. These can have been used only briefly before the Cultural Revolution disrupted the education system generally during the late 1960s and 1970s.

During the late 1980s, the Nationalities Publishing House in Kūnmíng published a series of five school primers produced by the Culture and Education Office (文教局 *wénjiàojú*) of the Cāngyuán Wa Autonomous County Government for use in Chinese Government primary schools (Cāngyuán 1985) using the PRC orthography. These were apparently reissues of the 1964 series. The content of the readers is shown in Table 7-16.

Table 7-16: Wa and Chinese language content of Wa Primary Education Texts

Year	Textbook content
1	Wa spelling; sentences and short texts in Wa
2	Longer texts in Wa; introduction of *hànyŭ pīnyīn* system of transcribing Chinese characters; recognition of 282 characters
3	Material presented in *pīnyīn* and characters with Wa translation; writing characters; 109 more characters
4	Material presented variously in characters with *pīnyīn* and/or Wa translation; c.300 more characters introduced
5	Longer texts in Wa (translation of 3rd year primary Chinese schoolbook)

The structure of the course content of these readers (and the pictures in them of children wearing traditional Wa dress together with the red neck-scarves of the Communist Youth League) is consistent with the PRC policy on bilingual education for minority nationalities in China, which advocates teaching in minority languages at the primary level to supplement subsequent learning of, and education in, Chinese. The stated purpose of the fifth year text book, in which Wa and Chinese are kept completely separate, is to 'advance the study of Chinese texts and to revise and consolidate their knowledge of Wa orthography' (Cāngyuán 1989).

Beyond primary level, no government provision is made for general education in Wa. At tertiary level, a small number of Wa are admitted annually to the Yúnnán Nationalities University (*Yúnnán mínzú dàxué*) at Kūnmíng, which provides higher education for students from all Yúnnán's minority nationalities. The University offers classes in the languages and cultures of six minority groups, including a Wa class which typically attracts between five and ten students each year.

Outside the government sector, grass-roots organised education in Wa is found in Christian Wa villages, where Bible orthography is taught to enable Wa speakers to read the Bible and participate in Christian worship.

BURMA

There is a dearth of recent data on the sociolinguistic situation of minority languages in Burma. According to Anna Allott (1985), national policy dictates that education in all government schools be in Burmese, and efforts have been made to train teachers from ethnic minorities to this end. The want of education throughout Burma, exacerbated by the complex political climate since the early 1990s, is such that no significant developments in national education can have been possible.

However, information gathered from the consultants interviewed for this study indicate that education in Wa of some kind is available to more than a few. Basic reading and writing skills in Wa were part of the religious instruction provided by church schools in Christian Wa villages. The Baptist Mission Wa Orphanage in Lashio provides education in Wa for about fifty children. Associated with this institution are Christian teachers in village schools throughout the Wa state, who aim to provide basic schooling in Wa.

Several interviewees also mentioned that government schools in some Wa villages did in fact use Wa as the medium of instruction, particularly in more remote areas.

Thailand

No provision is made for education in Wa at an official level. In Thailand, few people are motivated to acquire an education in languages other than Thai. Non-Thai education is officially discouraged.

8 *Wa language materials*

8.1 Recording wordlist

The 136 items are shown in phonemic transcription, PRC orthography and Bible orthography, sorted according to PRC orthography spelling (see Table 7-12 for conversion table).

NB Sequences of back vowels + /i/ are transcribed here as vocalic diphthongs, rather than as monophthong + glide /y/ sequences, the notation found in Diffloth (1980).

	Gloss	*PRC orthography*	*Bible orthography (revised)*
paɯ	faded	bae	pau
pa̤ɯ	protect	bāe	pau
pauh	open	baoh	paoh
pauʔ	uncle	baox	paox
pa̤uʔ	friend	bāox	paox
pe̤h	spit	bēih	peh
pi	flute	bi	pi
pi̤	forget	bī	pi
pɔ	side of body	bo	paw
pɔ̤	don't	bō	paw
po	mortar	bou	po
poi	blow	boui	poe
po̤i	interrupt	bōui	poe
pu	fly (v.)	bu	pu
pṳ	thick	bū	pu
pṳi	person	būi	pwi
tɯi	pineapple	deei	teei
tɯ̤i	take	dēei	teei
te̤	arrow	dēi	te
tiam	write	diam	tiam
ti̤am	low	dīam	tiam
tɛ	sweet	die	tie
tɛ̤	peach	dīe	tie

	Gloss	*PRC orthography*	*Bible orthography (revised)*
tɛh	reduce	dieh	tieh
tɛ̤h	turn over	dīeh	tieh
tɛʔ	land	diex	tiex
tɛ̤ʔ	wager	dīex	tiex
tuih	conversation	duih	twih
ka	afterwards	ga	ka
ka̤	gnaw	gā	ka
kah	untie	gah	kah
kaɲ	head	gaing	kaing
ka̤ɲ	work (n.)	gāing	kaing
kau	ten	gao	kao
ka̤u	set up	gāo	kao
ka̤uh	peck	gāoh	kaoh
kaʔ	fish	gax	kax
ke	gourd	gei	ke
kɔi	sticky rice	goi	koi
kɔ̤i	slowly	gōi	kaweh
kraɯŋ	drum	graeng	kraung
kra̤ɯŋ	clothing	grāeng	kraung
kṳaʔ	stir	gūax	kwax
hɤi	(emphatic)	heui	heue
lʰai	skew	hlai	lhai
mʰai	mark (v.)	hmai	mhai
nʰa	stale	hna	nha
ŋʰa	gelding	hnga	ngha
ɲʰɯ	hay	hnyee	nyhee
hɔc	already	hoig	hoit
hoc	come	houig	hwet
rʰa	snow	hra	rha
rʰaŋ	tooth	hrang	rhang
vʰau	burn	hvao	vhao
yʰa	give birth (animals)	hya	yha
cah	wear a hat	jah	cah
cau	master	jao	cao
ca̤u	early	jāo	cao
ca̤uʔ	angry	jāox	caox
caʔ	drive animals	jax	cax

	Gloss	*PRC orthography*	*Bible orthography (revised)*
cɛ̤h	pierce	jīeh	cieh
k^{h}au	mix	kao	khao
k^{h}auʔ	tree	kaox	khaox
lai	squirrel	lai	lai
la̤i	writing	lāi	lai
la̤i	hunt	lāui	leue
loi	three	loui	loe
lo̤i	swim	lōui	loe
mai	and	mai	mai
ma̤i	widow	māi	mai
^{ŋ}ga̤ɯ	learn	mgāe	gau
^{ŋ}gaih	reversed	mgaih	gaih
^{ŋ}gau	hold in collar	mgao	gao
^{ŋ}geʔ	sour taste	mgiex	giex
^{ŋ}gɛ̤ʔ	empty-handed	mgīex	giex
^{ŋ}gṳah	hatch	mgūah	gwah
mo̤	crawl	mōu	mo
na	lie spread out	na	na
na̤	perhaps	nā	na
^{m}ba	thigh	nba	ba
^{m}bauh	nearby	nbaoh	baoh
^{m}ba̤uh	cheek	nbāoh	baoh
^{m}ba̤uʔ	again	nbāox	baox
^{m}baʔ	invite	nbax	bax
^{m}bɯ	earring	nbee	bee
^{m}bɯ̤	oil	nbēe	bee
^{m}bɯi	mole	nbeei	beei
^{m}bo̤	evening	nbōu	bo
^{n}dai	skirt	ndai	dai
^{n}dɯ̤i	careless	ndēei	deei
^{n}de̤ʔ	nearby	ndēix	dex
^{n}dɤʔ	stupid	ndex	deux
^{n}dɛ̤	finish	ndīe	die
^{n}deh	lessen	ndieh	tie
^{n}dɛ̤h	clap	ndīeh	ndieh
ŋai	eye	ngai	ngai
ŋɔ̤	worm	ngō	ngaw

	Gloss	PRC orthography	Bible orthography (revised)
^{ɲ}jauh	drop (n.)	njaeh	jauh
^{ɲ}ja̤uh	begin	njāeh	jauh
^{ɲ}ja̤uʔ	wet (v.)	njāex	jaux
^{ɲ}jau	jump	njao	jao
^{ɲ}ja̤u	reason (n.)	njāo	jao
^{ŋ}g^{h}a	work (v.)	nka	gha
^{ŋ}g^{h}ah	loosen	nkah	ghah
^{ŋ}g^{h}aiʔ	turn	nkaix	ghaix
^{m}b^{h}aʔ	tobacco	npax	bhax
^{m}b^{h}ɔ	loose	npo	bhaw
^{m}b^{h}ɔh	cheap	npoh	bhawh
^{ɲ}j^{h}ah	frayed	nqah	jhah
^{ɲ}j^{h}ai	clairvoyant	nqai	jhai
^{ɲ}j^{h}aʔ	swear	nqax	jhax
^{ɲ}j^{h}e	tiptoe	nqei	jhe
^{n}d^{h}a	beforehand	nta	dha
^{n}d^{h}ah	long	ntah	dhah
^{n}d^{h}uʔ	gobble	ntux	dhux
ɲau	rub clean	nyao	nyao
ɲa̤u	very	nyāo	nyao
p^{h}au	now	pao	phao
p^{h}eʔ	eat fruit	piex	phiex
p^{h}ɔh	hop	poh	phawh
c^{h}aʔ	tea	qax	chax
c^{h}ɤ	try	qe	cheu
c^{h}ɯ	sack	qee	chee
c^{h}ɤh	limp	qeh	cheuh
ra	two	ra	ra
rɤ	pull	re	reu
rɤ̤	boat	rē	reu
sɯ	pour	see	see
sɯ̤	straight	sēe	see
t^{h}a	wait	ta	tha
t^{h}ah	cut wood	tah	thah
t^{h}ɯʔ	shove	teex	theex
vɔ̤	festival	vō	vaw
vo	(excl.)	vou	vo

	Gloss	*PRC orthography*	*Bible orthogr phy (revised)*
yɯi	fly (n.)	yeei	yeei
yɛ̤	easy	yīe	yie

8.2 TEXTS IN WA

Abbreviations used in glosses

ADV	adverbial marker
CL	Classifier
CM	comparative marker
COMP	Complementiser
CONJ	Conjunction
COP	Copula
DU	Dual
INCL	Inclusive
NEG	Negative
PERF	Perfective
PL	Plural
PREP	Preposition
REFL	Reflexive
REL	relative clause marker
SG	Singular
SP	sentence particle

8.2.1 THE NORTH WIND AND THE SUN

(1) Wa text in phonemic transcription with gloss

^{m}b^{h}auɯŋ	s.kwat	kɛʔ	s.ŋa̤iʔ	t^{h}uŋ	t^{h}iaŋ	pa̤uʔ	iʔ ‖
wind	cold	and.DU	sun	rgue		iend	EFL

'The North Wind and the sun argued with one another.'

ti̤ʔ	kauɯʔ	m^{h}aɲ	ti̤ʔ	kauɯʔ	ti̤ɲ	r̤iaŋ	k^{h}aɲ	pa̤uʔ	tiʔ ‖
one	CL	call	one	CL	big	strength	CM	friend	REFL

'Each said he was stronger than the other.'

kɛʔ	ja̤uʔ	pṳi	ʔih	s.^{m}be̤ʔ	ta̤i	hoc	ti̤ʔ	kauɯʔ ‖
they-3DU	see	person	wear	garment	cotton	come	one	CL

'They saw a man wearing an overcoat approaching.'

kɛʔ	tɔm	ʔah	nin	kah	pa̤uʔ	tiʔ ‖
they-3DU	CONJ	say	this.way	PREP	friend	REFL

'They said to one another:'

^{ŋ}ga̤c jа̤u? mɔ? pa po̤n ti? pɯc s.^{m}be̤? ta̤i kɔ̤ ?an ‖
watch see who REL can COMP take.off garment cotton CL that
'whoever can remove the overcoat,'

sɔn ?an mɔ̤h pa ti̤ɲ ri̤aŋ ‖
conclude that.one COP REL big strength
'will be considered the stronger'

^{m}b^{h}awɯŋ tɔm saɯ ri̤aŋ ti? p^{h}ru
wind CONJ use strength ADV blow
'The Wind blew strongly,'

lɔk pa po̤n nɔh ti? p^{h}ru ‖
manner REL can he ADV blow
'as hard as he could.'

^{m}b^{h}awɯŋ ni̤at ti? p^{h}ru ‖
wind urgent ADV blow
'The wind blew with urgency,'

pṳi ?an lɔk ni̤at ti? ndʑ^{h}ɔp s.^{m}be̤? ta̤i
person that CONJ strongly ADV grasp garment cotton
'but the man held his overcoat tightly;'

ti? tɔm kaɯ? tɔm se̤t ‖
COMP ADV steady ADV tight
'so that it was quite secure.'

^{m}b^{h}awɯŋ ?aŋ po̤n ti? pɯc s.^{m}be̤? ta̤i pa ?ih pṳi ?an ‖
wind NEG can COMP take-off garment cotton REL wear person that
'The Wind was unable to remove the man's overcoat.'

?aŋ nɔh lai tɔ̤ŋ kah saŋ jṳh ti? ‖
NEG he again know PREP want do REFL
'He did not know what to do next.'

nɔh tɕɯ̤n laɯ? ti? k^{h}aɲ ‖
he-3SG simply rest REFL SP
'So then he just rested.'

k^{h}ai? ?an s.ŋa̤i? lɔk saɯ tɕɛ̤ ti? ‖
after that sun CONJ use will REFL
'Then the Sun pondered'

nɔh saɯ ṛịaŋ tiʔ tɔŋ ||
he.3SG use strength ADV shine
'and shone strongly.'

kɛh koc haʔ ||
since sunlight burn
'As his rays were hot,'

pụi ʔan tɔm pɯc s.^{m}bẹʔ tại tiʔ p^{h}au ||
person that CONJ take-off garment cotton REFL now
'So the man removed his overcoat.'

^{m}b^{h}aɯŋ s.kwat kɛʔ s.ŋạiʔ tɔm tɕu s.ŋạiʔ mọh pa tịɲ ṛịaŋ ||
wind cold and.DU sun CONJ agree sun COP REL big strength
'The North Wind therefore agreed that the Sun was the stronger.'

2) PRC orthography

Npaeng Si guad giex Si ngāix tung tiang bāox dix. Dīx gaex hmaing dīx gaex dīng rīang kaing bāox dīx. Giex yāox būi ih si nbēix dāi houig dīx gaex. Gīex dom ah nin gah bāox dix, mgāig yāox mox ba bōun dix beeig si nbēix dāi gō an son an mōh ba dīng rīāng.

Npaeng dom sae rīang dix pru log ba bōun noh dix pru. Npaeng nīad dix pru, būi an lag nīad dix nqob si nbēix dāi dix dom gaex dom sīed. Npaeng ang bōun dix beeig si nbēix dāi ba ih būi an. Ang noh lai dōng gah sang yūh dix. Noh jēen laex dix kaing.

Kaix an, Si ngāix log sae jīe dix. Noh sae rīang dix dong. Gieh gouig hax, būi an dom beeig si nbēix dāi dix pao. Npaeng Si guad giex Si ngāix dom jū Si ngāīx mōh ba dīng rīang.

8.2.2 THE PARABLE OF THE SOWER

The following parallel text is given in broad phonetic transcription, Bible orthography and PRC orthography. The passage is Young's translation into Wa of the parable of the sower, from the New Testament of the Bible (Matthew 13.iii–ix).

ŋ^{h}iat hɤi ^{ɲ}j^{h}ak hɤi ||
listen SP look SP
'Listen! Look!'

pụi r^{h}uat s.mɛ̤ hu tiʔ r^{h}uat s.mɛ̤ hɤi ||
person sow seed go COMP sow seed SP
'A sower went to sow seed.'

mai yạm r^{h}uat nɔh s.mɛ̤ | s.mɛ̤ tịʔ ^{m}blah cọt kah ^{n}dẹʔ kraʔ |
CONJ time sow he seed seed one few fall PREP near path
'And as he sowed, some seeds fell near the path.'

mai sim k^{h}an kiʔ hoc sut tiʔ ʔih s.mɛ̤ khan kiʔ hɤi ||
CONJ bird that they.3PL come pick.up COMP eat seed that they.3PL SP
'so the birds came and ate them up.'

mai s.mɛ̤ ti̤ʔ ^{m}blah co̤t kah pi̤aŋ tɛʔ ^{n}dṳɪ koi s.mauʔ |
CONJ seed one few fall PREP on earth place have stone
'And some seeds fell on rocky ground'

^{n}dṳɪ ʔaŋ tɛʔ koi tɔm nɛ̤ ||
place NEG earth have COMP much
'where they did not have much soil'

mai s.mɛ̤ ʔan kṳah ^{n}dum mɔʔ ^{n}dum ʔan |
CONJ seed that sprout time which time that |
'and they sprouted immediately'

mɔ̤h k^{h}ɯ ʔaŋ tɛʔ rawʔ tan ||
COP reason NEG earth deep that.much
'because the soil was not all that deep.'

mai ya̤m hɔc li̤h s.ŋa̤iʔ kɛ̤t haʔ koc ||
CONJ time PERF leave sun very burn sunlight
'But when the sun rose they were scorched'

mai k^{h}ɯ ʔaŋ kiʔ koi ri̤ah kiʔ kroh hu hɤi ||
CONJ reason NEG they.3PL have root they dry go SP
'and since they had no root, they withered.'

mai s.mɛ̤ ti̤ʔ ^{m}blah co̤t kah s.naʔ paŋ kat ||
CONJ seed one few fall PREP middle clump thorn
'Other seeds fell among thorns,'

mai paŋ kat ʔan ti̤ŋ tɔm k^{h}ɯm ^{ŋ}gut kiʔ ||
CONJ clump thorn that large COMP bury overcome them
'and the thorns grew up so that they choked them'

mai kiʔ ʔaŋ ci̤ʔ pliʔ pliʔ hɤi ||
CONJ they.3PL NEG can bear fruit SP
'and they could not bear fruit.'

mai s.mɛ̤ ti̤ʔ ^{m}blaʔ co̤t kah ndṳɪ m^{h}ɔm tɛ̤ʔ |
CONJ seed one few fall PREP place good earth
'Other seeds fell on good soil'

mai pliʔ pliʔ hɤi || mai kiʔ t̪ḭŋ mai pian
CONJ bear fruit SP CONJ they.3PL large CONJ develop
'and brought forth grain. And they grew and flourished,'

tɔm po̤n t̪ḭʔ ŋoi so̤n mai t̪ḭʔ ᵑgl̪ḭah so̤n
COMP yield one thirty fold CONJ one sixty fold
'and some yielded thirtyfold, some sixtyfold'

mai t̪ḭʔ s.ye̤h so̤n hɤi ||
CONJ one hundred fold SP
'and a hundredfold.'

Bible orthography
(*Sān-Zì wěiyuánhuì* 1985).

Ngeht heu-e, jak heu-e, pwi ru-at simeh hu ti ru-at simeh heu-e. Mai: yam ru-at naw simeh, simeh tibla cot ka de kra, mai sim hkanki hwet sut ti i simeh hkanki heu-e. Mai: simeh tibla cot ka pehang teh dui kwe simao, dui ang teh kwe tom neh, mai: simeh an ku-wa dom maw dom an, moh hkeu ang teh rau tan. Mai yam hoit li singai, keht ha ko-ek, mai: hkeu ang ki kwe ri-a, ki kro hu heu-e. Mai simeh ti bla,cot ga sina pang kat, mai: pang kat an ting tom hkuim gut ki, mai: ki ang chi pli pli heu-e. Mai: simeh tibla cot ka dui mawm teh, mai pli pli heu-e. Mai: ki ting mai: pi-ehn tom pon tingo-e son, mai: tigli-a son, mai ti siyeh son heu-e.

2) PRC Orthography. Transcription of the above Bible orthography text from Chén (1981:134--5)

Hgniad heui, nqag heui, būi hruad si mīe hu dix hruad si mīe heui. Mai yām hruad noh si mīe, si mīe dīx nblah jōud gah ndēix grax, mai sim kan gix houig sud dix ih si mīe kan gix heui. Mai si mīe dīx nblah jōud gah bīang diex ndēe goui si māox, ndēe ang diex goui dom nīe, mai si mīe an gūah ndum mox ndum an, mōh kee ang diex raex dan. Mai yām hoig līh si ngāix, gīed hax gouig, mai kee ang gix goui rīah, gix grouh hu heui. Mai si mīe dīx nblah,jōud gah si nax bang gad, mai bang gad an dīng, dom keem mgud gix, mai gix ang jīx blix blix heui. Mai si mīe dīx nblah jōud gah ndēe hmom dīex, mai blix blix heui. Mai gix dīng maibian dom bōun dīx ngoui sōun, mai dīx mglīah sōun, mai dīx si yīeh sōun heui.

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