SOME ACOUSTIC PROPERTIES OF TONES IN BURMESE

U Thein Tun

1. PHONOLOGICAL TONES

On the basis of Trubetzkoy's definitions of phoneme, phonological unit, phonological contrast, and his rules 2 and 3 for the differentiation of phonemes and variants (Trubetzkoy 1968:7, 1969:48-49), the following phonological tones can be assigned to the phoneme inventory of Burmese phonology.

Four tones:

Tone I	/tɕá/	*'lotus', 'to take a long time'*
Tone II	/tɕâ/	*'to hear'*
Tone III	/tɕà/	*'to fall down'*
Tone IV	/tɕaˀ/	*'to be stringent', 'to be tight'*

The Burmese phonological tones, however, are classified differently by various writers. Taylor (1920) and Firth (1933) classify the Burmese tones into three. Firth (1936) and McDavid (1945) suggest that there are five tones in Burmese. Cornyn (1944), Burling (1967), Stewart (1955) and Becker (1964) agree in classifying the Burmese tones into four.

If the CVC phonological syllable pattern is recognised, as in present-day written Burmese and old epigraphic Burmese, it is true that /tɕaˀ/ (written tɕap), (Tone IV in the above example) could be treated as belonging to the CVC pattern, and thus there would be only three tones in Burmese. In present-day spoken Burmese, however, the final stops of the written CVC pattern are replaced by a final stop, which is a glottal stop in isolation. If the CVC pattern is regarded as one phonological syllable pattern, then this characteristic will be the sole representation of the final C of the CVC pattern. Therefore it is more acceptable to analyse the Burmese phonological syllable pattern as V and CV and to treat the final stop as a tonal feature.

Thein-Tun, U. "Some Acoustic Properties of Tones in Burmese". In Bradley, D. editor, *Papers in Southeast Asian Linguistics No. 8: Tonation*.
A-62:77-116. Pacific Linguistics, The Australian National University, 1982. DOI:*10.15144/PL-A62.77*

Firth (1936) and McDavid (1945) classify the Burmese tones into five because they treat the neutral vowel [ə] as a separate tone. The neutral vowel [ə] appears as a non-final **neutral** syllable in words consisting of two or more syllables, but never in monosyllabic words. Burmese is basically a monosyllabic language and any non-monosyllabic word in Burmese with a neutral vowel [ə] is either a borrowing or a lexical compound or the result of a derivational process. Therefore, in this analysis, the Burmese phonological tones are classified into four. [Note that Tones I, II and II in this analysis are generally described as even or level tone, heavy or breathy tone and creaky tone respectively in the literature. The cardinal order and symbols of the tones in this analysis are somewhat different from Okell (1969) but same as Cornyn (1944) and Cornyn and Roop (1968).]

2. EXPERIMENT 1

There are altogether fifty vocalic nuclei in Burmese apart from the neutral vowel [ə].

Basic symbol	non-nasalised				nasalised			
	Tone I	Tone II	Tone III	Tone IV	Tone I	Tone II	Tone III	Tone IV
i	1. í	2. î	3. ì	4. iʔ	5. ĩ́	6. ĩ̂	7. ĩ̀	X
e	8. é	9. ê	10. è	11. eiʔ	12. ẽ́i	13. ẽ̂i	14. ẽ̀i	X
ɛ	15. ɛ́	16. ɛ̂	17. ɛ̀	18. ɛʔ				X
ai				19. aiʔ	20. ã́i	21. ã̂i	22. ã̀i	X
a	23. á	24. â	25. à	26. aʔ	27. ã́	28. ã̂	29. ã̀	X
ɔ	30. ɔ́	31. ɔ̂	32. ɔ̀	33. auʔ	34. ã́u	35. ã̂u	36. ã̀u	X
o	37. ó	38. ô	39. ò	40. ouʔ	41. ṍu	42. õ̂u	43. õ̀u	X
u	44. ú	45. û	46. ù	47. uʔ	48. ṹ	49. ũ̂	50. ũ̀	X

([ei], [au] and [ou] can be regarded as the different realisations of /e/, /ɔ/, and /o/ in the environment of nasalisation or a final stop and [ãi] could be the allophone of /ai/ in the nasalised environment.)

All these fifty vocalic nuclei of two male native speakers and two female native speakers were recorded in [hVdá] (/hVdá/) frame for the monophthongal nuclei and in [hṽvndá] (/hṼdá/) and [hvvʔdá] (/hVʔdá/) frames for the diphthongal nuclei. The initial consonant [h] was chosen in the frames because it is the weakest consonant to bring forth any co-articulation effect on the following vowel; the medial

[d] was chosen to make the segmentation easy; and the final [á] was chosen to make the utterances natural for the Burmese speakers as this is a frequent vowel.

Some of the utterances in these frames are nonsense words whether the last syllable [dá] is eliminated or not. These nonsense words however have to be tolerated because the purpose of the experiment is to analyse the phonetic qualities of the vocalic nuclei of the utterances and they are not foreign for the Burmese speakers to pronounce. The established writing system enables the subjects to pronounce them easily and naturally whether they are meaningful or not.

Every speaker uttered every sound twice and both utterances were recorded. All the recorded sounds were processed with a Frokjaer-Jensen intensity and fundamental frequency meters, using the linear intensity output and the duplex oscillogram and fundamental frequency output. The outputs were displayed by a mingograph. The necessary precautions were observed both in recording and processing. When the fundamental frequency of every utterance was measured, a slight difference between the first and the second utterances of the same sound sometimes occurred. In such a case the average value of the two was taken.

Of the three outputs observed on the mingograph (i.e. intensity display trace, duplex oscillogram trace and the fundamental frequency trace), the intensity display trace of the tones does not show any consistency or any common factor by which the contrastive features of the tones can be distinguished. It is tempting to say that in the null context that these fifty utterances are in, the intensities of the tones do not behave regularly as they do in sentences. The duplex oscillogram trace also enables us only to distinguish the vowel segments from the adjacent consonants along the fundamental frequency trace. Therefore, of the three parameters, only the fundamental frequency trace of the tones is dealt with in this present analysis.

The fundamental frequency as shown in the mingograms of all the four subjects, rises gradually from Tone I to Tone IV. The fundamental frequency for Tone I starts at a relatively level range and tends to go down slightly; the fundamental frequency for Tone II starts at a relatively level range, goes up, and then falls down relatively low; the fundamental frequency for Tone III starts at a relatively high range, usually higher than or as high as the peak of Tone II, and falls down relatively low; the fundamental frequency for Tone IV starts at a high range, frequently higher or as high as the peak of Tone II and falls low, but not as low as Tone III because it stops very suddenly before it can drop lower. The general contrastive features of the four phonological tones offered by the analysis of their fundamental frequency can be described as:

I level, low
II high, rising, falling
III high, falling
IV high, falling, abrupt end.

For the detailed contrastive characteristics of the tones, in terms of their fundamental frequencies, there is no special point to be observed for Tones I and II because Tone I simply starts at a level range and falls slightly in the end and Tone II starts at a level range, goes up and falls down to the level range. However there are some detailed contrastive features to be observed for Tones III and IV in comparison with Tone II.

The fundamental frequency of all the utterances in Tone III by the two female speakers starts with a high range, higher than the peak of Tone II with one exception. For the one exception also, the starting range is the same as the peak of Tone II. The fundamental frequency of the utterances of the first male subject in Tone III starts with a relatively high range, usually as high as the peak of Tone II. Of the fourteen utterances of the first male subject in Tone III, the fundamental frequency for nine he starts with the high range equal to the peak of Tone II, the fundamental frequency for three starts with the high range higher than the peak of Tone II; and the fundamental frequency for the remaining two starts at a range slightly lower than the peak of Tone II. The fundamental frequency for all the utterances in Tone III by the second male subject starts at the high range, higher than the peak of Tone II.

For the two female subjects, the commencing high range of Tone IV is generally either higher than or as high as the peak of Tone III. However, in one case for one female subject and in three cases for the other, the commencing range of Tone IV is either equal to or slightly lower than the peak of Tone III. Of the eight utterances in Tone IV of one male subject, four are equal to and four are slightly lower than the peak of Tone III; of the eight utterances in Tone IV of the other male subject, three are equal to and five are slightly lower than the peak of Tone III.

The following table summarises the average fundamental frequencies of the four tones for the four subjects, out of their 200 utterances i.e. 50 each (14 in Tone I, II and III and eight in IV) among the four subjects i.e. out of 56 utterances in each of the first three tones and 32 utterances in Tone IV.

TABLE 1

Tone	Subject	Initial (High) HZ	Middle (Peak) HZ	Final (Low) HZ
I	1st female	226	-	174
	2nd female	230	-	176
	1st male	122	-	106
	2nd male	135	-	105
II	1st female	237	255	191
	2nd female	241	254	213
	1st male	144	165	142
	2nd male	146	152	137
III	1st female	302	-	190
	2nd female	300	-	160
	1st male	166	-	117
	2nd male	184	-	92
IV	1st female	297	-	204
	2nd female	294	-	175
	1st male	159	-	122
	2nd male	172	-	110

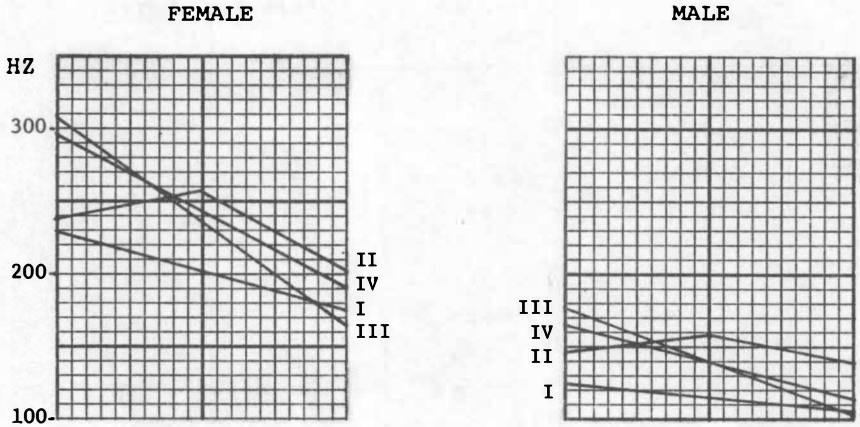
The following table summarises the average fundamental frequencies of the four tones for two females and two males.

TABLE 2

Tone	Initial HZ		Middle HZ		Final HZ	
	F	M	F	M	F	M
I	228	123	-	-	175	105
II	239	145	254	158	202	144
III	301	175	-	-	165	104
IV	295	165	-	-	190	116

This table can be visualised more clearly on the graph.

TABLE 3



In these graphic descriptions of the tones, there is very little distinction between Tone III and Tone IV. This kind of distinction is to be made clear in the next experiment and analysis where the factor of duration of the tones is taken into account.

3. EXPERIMENT 2

The aim of this experiment is to find out the further acoustic qualities of the tones in terms of length. The author's original intention was to put the aforesaid fifty vocalic nuclei in one frame which can occur both in null context i.e. by itself as a meaningful syllable; and in phrase or sentence context. As the most suitable syllable pattern for this purpose, the writer originally chose [tv(v)] (/tV/) frame. The initial consonant [t] was chosen to make the segmentation easy. All the fifty vocalic nuclei can fit meaningfully into this frame. The author made up fifty sentences with these fifty vocalic nuclei in [tv(v)] frame. As a tentative effort, four male native speakers were asked to utter these fifty nuclei in [tv(v)] frame, both in null context and sentence context. Their utterances were recorded and processed with the Kay sound spectrograph. It was found that the correct analysis was almost impossible if these fifty vocalic nuclei are put in CV frame. The following major defects presented problems.

1. /V/ of /tV/ can be followed by any consonant which is the initial consonant of the next CV syllable and the following consonant can affect the F2 off-glide frequency value of the vocalic nucleus.

2. When /V/ of /tV/ is followed by a voiced stop which is the initial consonant of the next CV syllable in a close juncture, the

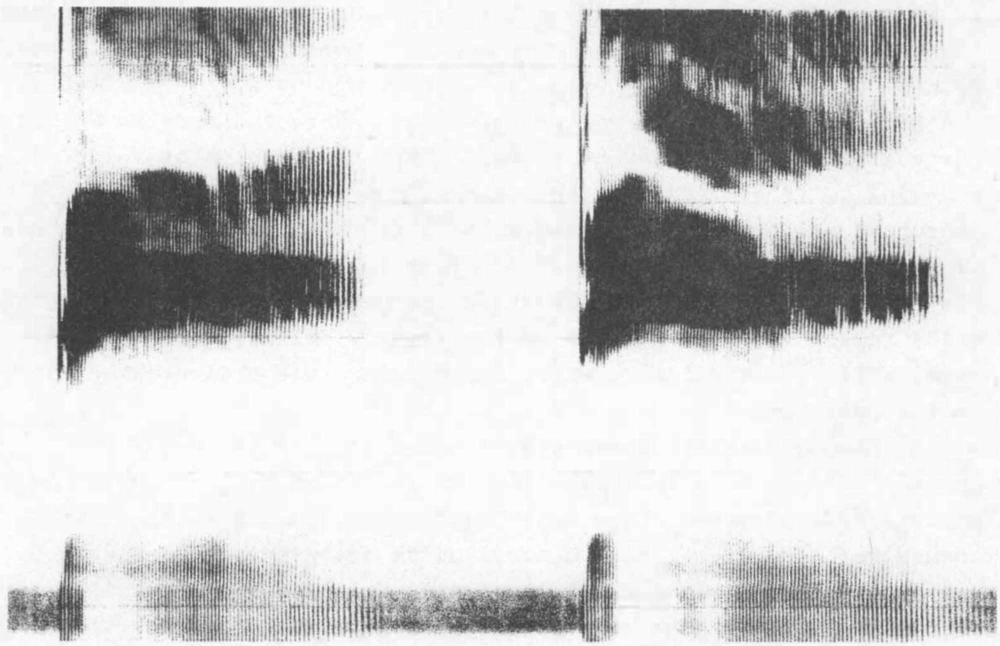
following voiced stop becomes continuant in the form of a fricative. For instance, /tí/ means *'earth-worm'* and /káu/ is a classifier for animals and insects. When /tí/ and /káu/ are combined in close juncture, /k/ becomes voiced according to the voicing rule and it becomes [tígáu]. However the process of the change from /k/ does not stop at [g]. That [g] which is the phonetic realisation of /k/ often becomes voiced and is shown on the sonogram as voiced velar fricative [ɣ]. In such a case it is very difficult to segment the preceding [V] from [ɣ] which shows the characteristics of a resonant and continuant like a vowel. Such a problem occurs especially when [a] is followed by a voiced bilabial and [i] is followed by a voiced velar consonant, and more so when the [tv(v)] frame is followed by a vowel. For the problem of voiced stops changing to fricatives and continuants, one might like to choose the consonant which does not become voiced, for the initial C of the next CV syllable which follows [tv(v)]. This is impossible because to get the right length of the /V/ of /tV/, the next syllable should immediately follow it, and when one CV immediately follows, two syllables are combined in close juncture where the voicing rule always takes place on the following C.

3. Phonologically, a meaningful vowel or a syllable which is grammatically a free form can occur by itself in null context. People do say and understand these individual monosyllables which occur by themselves. However, these monosyllables are generally followed by a particle. If it is a noun it is usually followed by a classifier or a particle and if it is a verb it is usually followed by a particle, either stative, imperative or polite and so on. As people are so accustomed to adding particles to monosyllables, they unconsciously find it awkward to articulate one individual syllable by itself. Hence they either repeat it or put a strong stress on it when they have to articulate one individual syllable. That kind of stress is especially strong when they pronounce it consciously before the microphone in the studio. That is why the vocalic nuclei in null context of these subjects are extremely and unnaturally long, and hence the writer was not happy to use the sonagrams they produced, as reliable data. The following sonagram is an example of it.

FIGURE 1

Sonagram of /ti^{II}/ Repeated Twice.

/t/ followed by /i/ in Tone II.
The average length for /i/ in Tone II is only 21 Cs, whereas it is 30.8 Cs in this sonagram.



For these reasons, the writer had to eventually use the frames from Experiment 1. These frames /hVdá/, /hṼdá/ and /hVʔdá/ ([hvdá], [hṽṽndá], [hvvʔdá]) do not create either null context or sentence context. The last CV syllable [dá] in these frames has its grammatical function sometimes as a demonstrative particle (that or this) and sometimes as a nominaliser. For instance, in [hódá] ([hvdá] with [ó]), [hó] means there, [dá] means that, and hence [hó] and [dá] are two separate words forming a phrase. In [háundá] (/hṼdá/ with /áu/), [háun] (/háu/) means *'to bark'*, [dá] functions as a nominaliser, and hence [háundá] means *'barking'*, forming a separate word as a noun. In this way these three frames form either word or phrase context which lies between the two extremes - null context with one syllable where the nucleus length is extremely long, and sentence context where the nucleus length is extremely abrupt. Moreover, in these three frames, the nuclei are consistently followed by the same consonant i.e. [d] and hence there is no disturbance of different co-articulation effect on the F2 offglide value. Therefore in this experiment as well, the writer used, with satisfaction and assurance, the same three frames from Experiment 1.

The same procedure of utterance, recording and averaging between the first and second utterances, was also used in this experiment. However, in this experiment, to get the accurate average measurements of formant frequencies and lengths, ten more male native speakers were added to the original number of two (first and second male subjects, subjects 1 and 2) and thus the number of subjects was raised to twelve, and no female voice was used. This time all these recorded utterances (1,200 utterances altogether; 50 nuclei each uttered twice by every subject) of the twelve male subjects were processed with the Kay sound spectrograph. The analysis was made on 1,200 sonagrams produced from these 1,200 utterances.

4. TABLES SHOWING THE AVERAGE LENGTHS OF THE TONES

The following tables summarise the average component durations of the four phonological tones among the twelve male subjects. For monophthongal vowels, transitions toward and away from the steady state are given as onglide and offglide; for diphthongal vowels, first and second steady states, and transition between the two are shown, as well as onglide and offglide transitions if any.

TABLE 4

Basic Symbol	Tonal Symbol	Onglide Cs	Steady State (SS) Cs	Offglide Cs	Total Cs
/i/	I /í/	4.8	9.0	5.0	18.8
	II /î/	4.4	11.8	5.5	21.7
	III /ì/	3.9	8.9	3.2	16.0
	IV /iˀ/	2.0	4.3	2.8	9.1
/e/	I /é/	4.8	9.6	5.0	19.4
	II /ê/	5.7	12.0	5.2	22.9
	III /è/	3.6	9.1	4.1	16.8
	IV [eiˀ]/eˀ/	0	SS1 Trans SS2 3.8 6.0 3.8	0	13.6

TABLE 4 (cont.)

Basic Symbol	Tonal Symbol	Onglide Cs	Steady State (SS) Cs	Offglide Cs	Total Cs
/ɛ/	I /ɛ́/	4.5	11.5	4.5	20.5
	II /ɛ̂/	6.6	11.4	4.5	22.5
	III /ɛ̀/	4.1	8.5	4.8	17.4
	IV /ɛˀ/	1.7	7.6	1.6	10.9
			SS1 Trans SS2		
/ai/	IV /aiˀ/	0	4.6 6.7 3.7	0	15.0
/a/	I /á/	5.1	11.0	5.9	22.0
	II /â/	6.8	12.3	5.4	24.5
	III /à/	5.0	10.0	5.0	20.0
	IV /aˀ/	1.9	6.8	2.0	10.7
/ɔ/	I /ɔ́/	5.6	10.6	5.6	21.8
	II /ɔ̂/	5.6	12.4	5.2	23.4
	III /ɔ̀/	3.8	7.9	5.5	17.2
	IV [auˀ]/ɔˀ/	0.5	6.0 6.0 3.0	0	15.5
/o/	I /ó/	5.7	10.6	5.0	21.3
	II /ô/	6.6	11.6	5.9	24.1
	III /ò/	4.7	8.7	4.0	17.4
	IV [ouˀ]/oˀ/	0	4.2 6.7 3.3	.4	14.6
/u/	I /ú/	5.0	9.8	4.7	19.5
	II /û/	5.1	12.4	4.7	22.2
	III /ù/	3.9	7.4	3.6	14.9
	IV /uˀ/	2.2	4.8	2.7	9.7
/ɪ̃/	I [ɪ̃́]	3.4	8.1	2.8	14.3
	II [ɪ̃̂]	3.8	8.3	4.2	16.3
	III [ɪ̃̀]	2.1	6.3	2.4	10.8
/ã/	I [ã́]	3.6	6.4	3.4	13.4
	II [ã̂]	3.9	8.0	4.1	16.0
	III [ã̀]	2.73	6.53	2.73	12.0

TABLE 4 (cont.)

Basic Symbol	Tonal Symbol	Onglide Cs	Steady State (SS) Cs			Offglide Cs	Total
/ũ/	I [ṹ]	3.2	7.1			3.9	14.2
	II [ũ̂]	4.1	7.8			4.7	16.6
	III [ũ̀]	2.8	6.1			2.4	11.3
/ẽ/			SS1	Trans	SS2		
([e͠ɪ])	I [é͠ɪ]	0.3	5.3	7.8	4.5	0	17.9
	II [ê͠ɪ]	0.7	4.5	9.1	5.5	0.5	20.3
	III [è͠ɪ]	0	4.3	6.5	4.1	0	14.9
/a͠ɪ/	I [á͠ɪ]	0	5.4	10.1	5.0	0	20.5
	II [â͠ɪ]	0	6.0	10.6	5.7	0	22.3
	III [à͠ɪ]	0	4.7	7.2	4.4	0	16.3
/ɔ̃/ ([a͠u])	I [á͠u]	0.9	6.3	6.0	5.7	0	18.9
	II [â͠u]	0	7.1	7.2	5.6	0.6	20.5
	III [à͠u]	0.3	5.2	6.5	3.9	0	16.0
/õ/ ([o͠u])	I [ó͠u]	0	4.8	5.6	5.2	0.6	16.2
	II [ô͠u]	0	6.13	5.13	8.43	1.12	20.8
	III [ò͠u]	0.5	4.4	5.5	4.1	0.3	14.8

4.1. *TOTAL LENGTHS OF THE TONES*

The analysis of the overall lengths of the tones shows that the total length is a very consistent contrastive factor of the tones. For all the vocalic nuclei Tone I is of moderate length, Tone II is longer than Tone I, Tone III is shorter than Tone I, and Tone IV is so short and abrupt that it is even shorter than Tone III. Hence the conclusion that can be made for the general contrastive feature of the tones on the basis of their total length is:

Tone I	moderate
II	long
III	short
IV	abrupt

Of 600 (50 x 12) average (average of first and second utterances) measurements, there are only 34 exceptions that do not agree with the above-mentioned generalisation. The common feature of these exceptions is that either Tone II is slightly shorter or as short as Tone I, or Tone IV is slightly longer or as long as Tone III. There are some points that can explain the cause of these 34 deviations from the standard features.

1. All the subjects were instructed to utter every sound as they usually say it, but taking care to be accurate. When the subjects were told to articulate the sounds accurately, they were so cautious about glottis articulation and tongue and lip articulation (which shape the lower formant frequencies), that they tended to give less attention to the length factor; and this is more likely to happen especially at word and phrase level where the utterance frames are.

2. Of these 34 deviations more than half (18) are in [hṽvndá] /hṼdá/ frame, nasalised environment where the later part of nasalisation changes to the homorganic nasal of the following [d] i.e. [hṽvndá]. In such a case, in the sonagram, the nasal bar is sometimes present all along underneath both F1 and F2. Sometimes F1 and F2 overlap on the nasal bar underneath them and in such a case, it must be admitted that, the segmentation of [vv] from [n] is not clear cut. Therefore out of 34 deviations, 18 can be due to the inaccuracy of the segmentation.

3. It is a well known fact that the linguistic factors such as frequency, length etc. are significant only if they are compared with each other in sentence context. In an isolated context such as a word or phrase consisting of only two syllables, the linguistic factor may not be as significant as in sentence context.

Even if these three points fail to explain the cause of these deviations, the number of deviations (34) is tolerable compared to the overall number of 600; that is, the deviations from the standard represent only 5.5% of all the utterances. Therefore, the above-mentioned generalisation for the contrastive features of the four phonological tones, on the basis of their length, can be accepted as satisfactory.

As the table shows, these 34 exceptions do not carry any significant weight on the average. The average total length of all the four tones entirely agrees with the above-mentioned length contrastic features of the tones. The average length difference of the three tones from Tone I are summarised in the following table for basic vowel phonemes and allophones.

TABLE 5

Basic Symbol	Tone II Cs	Tone III Cs	Tone IV Cs
/i/	+2.9	-2.8	-9.2
/e/	+3.5	-2.6	-5.8
/ɛ/	+2.0	-3.1	-9.6
/a/	+2.5	-2.0	-11.3
/ɔ/	+1.6	-4.6	-6.3
/o/	+2.8	-3.9	-6.7
/u/	+2.7	-4.6	-9.8
[ĩ]	+2.0	-3.5	
[ã]	+2.6	-1.4	
[ũ]	+2.4	-2.9	
[ẽĩ]	+2.4	-3.0	
[ãĩ]	+1.8	-4.2	
[ãũ]	+1.6	-2.9	
[õũ]	+4.6	-1.4	
The average length difference of the three tones from Tone I, for all 14 basic vocalic nuclei	+2.53	-3.06	-8.40

The average length of Tone I for all the 14 vocalic nuclei is 18.5 Cs.

In the previous analyses the average lengths of both monophthongs and diphthongs in stop-final environment (Tone IV) are compared with those of their oral counterparts in the other three tones. It should be of some interest to compare the average lengths of these stop-final nuclei with those of their nasalised counterparts in the other three tones. The following tables show that the alternative comparison of tones in terms of their lengths also follows the pattern of moderate (Tone I), long (Tone II), short (Tone III), and abrupt (Tone IV).

TABLE 6

Basic Symbol	Tonal Symbol	Total Length (Cs)
/i/	I [í]	14.3
	II [î]	16.3
	III [ì]	10.8
	IV [iʔ]	9.1
/a/	I [á]	13.4
	II [à]	16.0
	III [à]	12.0
	IV [aʔ]	10.7
/u/	I [ú]	14.2
	II [û]	16.6
	III [ù]	11.3
	IV [uʔ]	9.7
average for monophthongs	Tone I	13.97
	II	16.30
	III	11.37
	IV	9.83

TABLE 7

Basic Symbol	Tonal Symbol	Total Lengths (Cs)
[ei]	I [éi]	17.3
	II [êi]	20.3
	III [èi]	14.9
	IV [eiʔ]	13.6
[ai]	I [ái]	20.5
	II [âi]	22.3
	III [ài]	16.3
	IV [aiʔ]	15.0
[au]	I [áu]	18.9
	II [âu]	20.5
	III [àu]	16.0
	IV [auʔ]	15.5

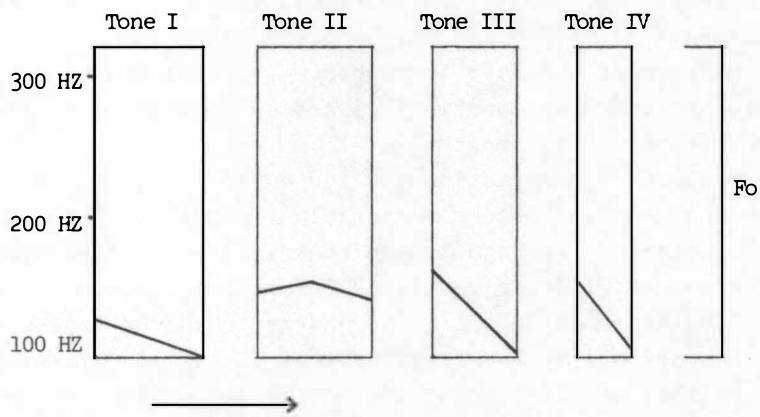
TABLE 7 (cont.)

Basic Symbol	Tonal Symbol	Total Lengths (Cs)
[ou]	I [óu]	16.6
	II [ôu]	20.8
	III [òu]	14.8
	IV [ou$^{?}$]	14.6
average for diphthongs	Tone I 18.48	
	II 20.98	
	III 15.56	
	IV 14.68	

If we add the contrastive features of the tonal fundamental frequency found in Experiment 1 to the length contrastive features of the tones found in this experiment, we will have the following complete contrastive features of the tones, fundamental frequency and duration.

Tone I level, low; moderate
II high rising, falling; long
III high falling; short
IV high falling; abrupt

The complete contrastive features of the tones can be visualised more clearly in terms of their average length and average fundamental frequency as shown in the following chart for the male speakers:



Time Scale: 1 cm = 1 Cs

5. COMPONENT DURATIONS OF THE MONOPHTHONGAL NUCLEI

As the table of average component durations of the twelve subjects shows, the average durations of onglides, steady states and offglides of the four tones in all the monophthongal nuclei for the twelve subjects, tend to behave in conformity with the contrastive feature of the total length of the four tones i.e. the pattern of 'I moderate, II long, III short and IV abrupt' as mentioned above. Out of the ten monophthongal vocalic nuclei (seven vowel phonemes which occur in all the tones and three nasalised variants which occur in the first three tones) the onglide of /í/ and /ɔ́/, the steady state of /ɛ̂/ and /ã̀/, and the offglide of /ɛ̂/, /â/ and /ɔ̂/, show exception in that they do not behave in conformity with the above-mentioned pattern.

For the onglide, Tone II of /i/ is 0.4 Cs shorter than Tone I of /i/ and Tone II of /ɔ/ is the same as Tone I of /ɔ/.

For the steady state, Tone II of /ɛ/ is 0.1 Cs shorter than Tone I of /ɛ/ and Tone III of /ã/ is 0.4 Cs longer than Tone I of /ã/.

For the offglide, Tone II of /ɛ/ is the same as Tone I of /ɛ/, Tone II of /a/ is 0.5 Cs shorter than Tone I of /a/, and Tone II of /ɔ/ is 0.4 Cs shorter than Tone I of /ɔ/.

Although there are only two exceptions for onglide, two for steady state and three for offglide, the writer would not be inclined to conclude that the average onglide, steady state and offglide lengths of the tones on all the monophthongal nuclei among the twelve subjects generally follow that moderate-long-short-abrupt pattern of the tonal length. There are two points that make the writer reluctant to draw that conclusion:

1. The pattern of moderate-long-short-abrupt length on onglide, steady state and offglide durations is not as consistent at the individual level as the total length.

2. The pattern of contrastiveness for onglide, steady state and offglide on the average, is not remarkably significant. In other words, that pattern of average length contrastiveness for onglide, steady state and offglide is very weak. For instance, on the average, though the Tone III onglide of /a/ is shorter than the Tone I onglide of /a/, it is only 0.1 Cs shorter; the Tone II onglide of /u/ is only 0.1 Cs longer than the Tone I onglide of /u/ and so on. There are quite a number of similar instances for the average tonal lengths of steady state and offglide as well.

Therefore the writer has to be content with a broad generalisation that the average durations of onglide, steady state and offglide of the four tones on all the monophthongal nuclei for the twelve subjects tend to behave in conformity with the total length contrastive pattern of 'moderate-long-short-abrupt'.

6. COMPONENT DURATIONS OF THE DIPHTHONGAL NUCLEI

The four two-target nuclei [ẽĩ], [ãĩ], [ãũ] and [õũ] occur only in first three tones. On the individual level they either have very short onglides and offglides or no onglide and offglide at all. Their overall length is usually the total of SS1, transition and SS2. That is why they show very limited duration of onglide and offglide or neither of the two. It is clear that the following consonant [d] has limited co-articulation effect on the diphthongal nuclei as Burmese has no VC or CVC phonological syllable pattern. As in onglides, steady states, and offglides of one-target nuclei, SS1, transition and SS2 lengths of diphthongal nuclei merely tend to follow the contrastive pattern of the total length with some exceptions and little significance.

7. CONCLUSION FROM THE TWO EXPERIMENTS

In the above discussions, some consistent acoustic features of the tones namely, fundamental frequency, total length, and component durations were explained. Of these three properties, the consistency of component duration is only of small significance. Only fundamental frequency and total length can be regarded as consistent factors. It may also be of interest to examine whether fundamental frequency or total length is the more consistent parameter of the tones. So far as these two experiments with the utterances of word and phrase level are concerned, it is difficult to determine which of the two factors is more consistent. However, a close look at the mingograms and sonagrams of the sentences shows that total length is more consistent than fundamental frequency. In the mingograms of the sentences, the fundamental frequency of Tone II does not rise under certain circumstances.

Though deciding the phonetic cues without any hearing experiment may be open to criticism, it is tempting to say that total length is the more important phonetic cue by which the herearers can distinguish the phonological tones.

8. EXPERIMENT 3

8.1. *SPECTRAL QUALITIES OF THE TONES ON VOCALIC NUCLEI*

In the previous experiments, fundamental frequency, total length and component durations were examined as acoustic properties of the phonological tones. In this analysis, an attempt will be made to examine the different spectral qualities of the vowels with different tones. The 1,200 sonagrams obtained from experiment 2 were used again for this analysis.

8.2. *MONOPHTHONGAL NUCLEI*

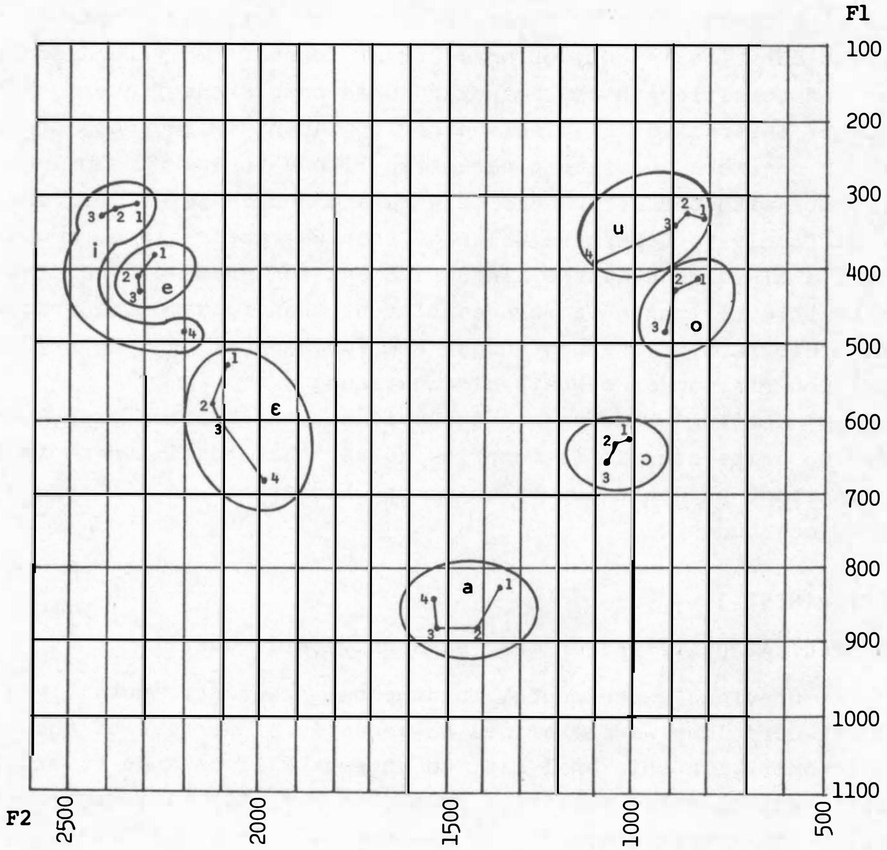
For all the monophthongal nuclei ([i, ĩ, e, ɛ, a, ã, ɔ, o, u, ũ]) three lower formants of all the sonagrams in all the different tones were measured at their steady state positions. All monophthongal nuclei can be explained under two categories, that is, non-nasalised monophthongal nuclei and nasalised monophthongal nuclei.

8.3. *NON-NASALISED MONOPHTHONGAL NUCLEI*

The F3 steady state frequency values of all monophthongal nuclei do not show any significant or consistent rise or fall in the four different tones. The F1 and F2 steady state frequency values of all monophthongal nuclei, however, show a fairly consistent rise on the average from Tones I to II and II to III. Graph 1 shows the average positions of the seven monophthongal nuclei in different tones for twelve subjects.

GRAPH 1

Movements of the Seven Basic Vowels in Different Tones Traced on their Average F1 and F2 Steady Values Calculated among the Twelve Subjects.



/i/ moves gradually forward and downward from Tones I to II and II to III. In other words, for /i/ both F1 and F2 frequency values rise gradually from Tones I to II and II to III. /i/ in Tone IV, however, as against the general tendency, is less peripheral than in the first three tones; so much so that it is even lower than /e/ in the first three tones.

/e/ in Tone II moves slightly forward and very noticeably downward from Tones I to II, that is, both F1 and F2 frequency values rise. /e/ in Tone III moves downward very slightly from /e/ in Tone II, that is, F1 frequency keeps rising and F2 frequency is more or less the same.

/ɛ/ moves downward and slightly forward from Tone I to Tone II, that is, both F1 and F2 frequency values rise. /ɛ/ in Tone III moves slightly downward from /ɛ/ in Tone II, that is, F1 frequency slightly increases. /ɛ/ in Tone IV, however, as against the general tendency, is less peripheral (much further back and lower and thus far more central) than /ɛ/ in the first three tones, that is, F1 frequency significantly increases and F2 frequency significantly decreases.

/a/ in Tone II moves downward and forward from /a/ in Tone I, that is, both F1 and F2 values increase. /a/ in Tone III moves horizontally forward from /a/ in Tone II, that is, F2 frequency significantly increases and F1 frequency is more or less the same. /a/ in Tone IV, however, as against the general tendency, moves upward and very slightly forward from /a/ in Tone III, that is, F1 frequency decreases.

/ɔ/ and /o/ become more fronted and lower gradually from Tones I to II and II to III, that is, both F1 and F2 frequency values increase gradually.

/u/ like /ɔ/ and /o/ has a gradual more frontal and lower movement from Tones I to II and II to III except for the fact that /u/ in Tone II tends to move slightly upward from /u/ in Tone I, that is, F1 frequency tends to decrease slightly.

From the points observed so far, it can be concluded that the non-nasalised monophthongal nuclei have a fairly strong tendency to move forward and downward from tones I to II, II to III, and III to IV, that is, both F1 and F2 values increase gradually from Tones I to II, II to III, and III to IV. There are three cases, however, which significantly differ from that general tendency, viz. /i/, /ɛ/ and /a/ in Tone IV.

This kind of deviation from the general tendency may be due to the influence of the final stop.

The following table summarises the average steady state frequency of the lower three formants among the twelve subjects, for all non-nasalised monophthongal nuclei.

TABLE 8

TABLE OF AVERAGE STEADY STATE FORMANT FREQUENCY

Basic Symbol		Tone I	Tone II	Tone III	Tone IV
/i/	F1	302	328	328	470
	F2	2334	2393	2419	2200
	F3	3095	3106	3078	2847
/e/	F1	372	410	424	
	F2	2278	2324	2315	
	F3	2880	2894	2880	
/ɛ/	F1	545	573	599	675
	F2	2093	2135	2111	1994
	F3	2721	2794	2761	2705
/a/	F1	833	876	876	847
	F2	1361	1411	1523	1529
	F3	2515	2570	2475	2492
/ɔ/	F1	632	639	665	
	F2	1014	1052	1074	
	F3	2527	2561	2541	
/o/	F1	412	435	481	
	F2	836	893	919	
	F3	2633	2660	2640	
/u/	F1	339	325	352	497
	F2	812	870	896	1107
	F3	2541	2574	2544	2502

8.4. *NASALISED MONOPHTHONGAL NUCLEI*

The three nasalised monophthongal nuclei (/ĩ, ã, ũ/) occur only in the first three tones. Each of their steady state positions, in any of the three tones, has its own wide area of random scattering when plotted on the graph for the twelve subjects. In spite of these large variations, they still keep their own distinctive area in all the three tones in which they occur. This is possible, mainly because there are only three nasalised monophthongal nuclei and thus there is a great amount of potential range for variation.

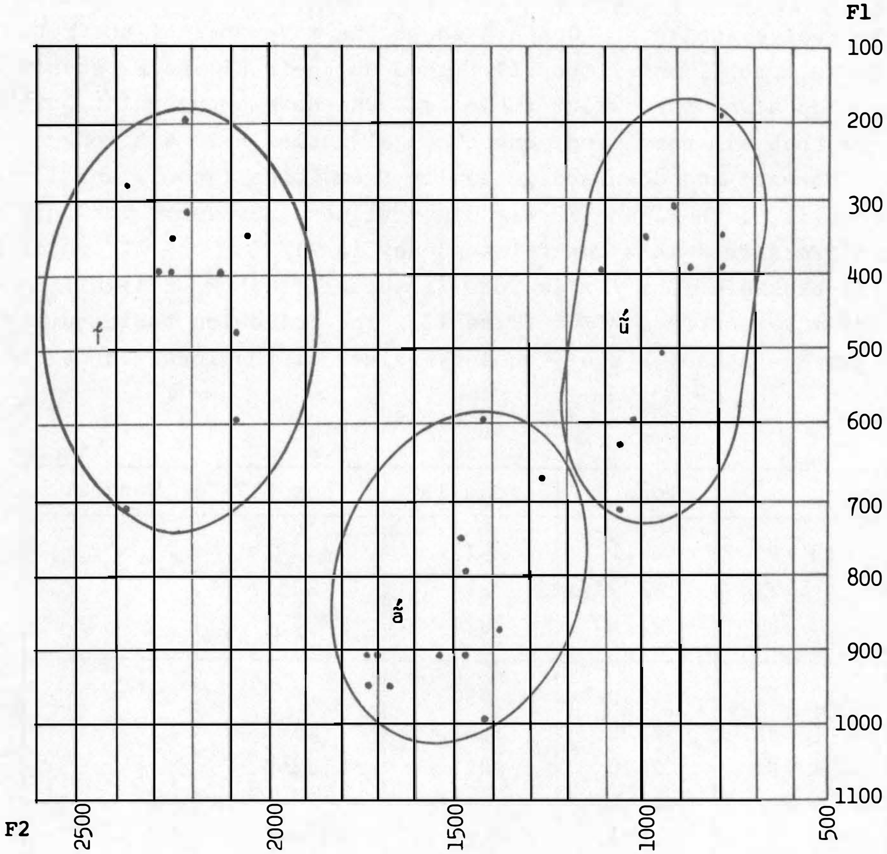
Graphs 2, 3, and 4 show their steady state positions in Tones I, II and III respectively, traced on their F1 and F2 frequency values, for all the twelve subjects. Graph 5 shows the movements of their positions from Tones I to II and II to III traced on their F1 and F2 steady state frequencies among the twelve subjects. One noteworthy point on this graph is that all nasalised monophthongal nuclei have a strong tendency to move forward and downward gradually from Tones I to II and II to III; that is, both F1 and F2 frequency values increase. The only case which differs from this general tendency is /ĩ/ in Tone III which moves slightly backward from /ĩ/ in Tone II though it shows a significant downward movement from /ĩ/ in Tone II. The following table summarises their average steady state frequency values of the lower three formants.

TABLE 9

		Tone I	Tone II	Tone III	Tone IV
[ĩ]	F1	411	415	441	
	F2	2209	2274	2257	
	F3	2821	2920	2877	
[ã]	F1	850	890	922	
	F2	1522	1558	1568	
	F3	2479	2471	2545	
[ũ]	F1	434	451	451	
	F2	929	1028	1067	
	F3	2620	2593	2554	

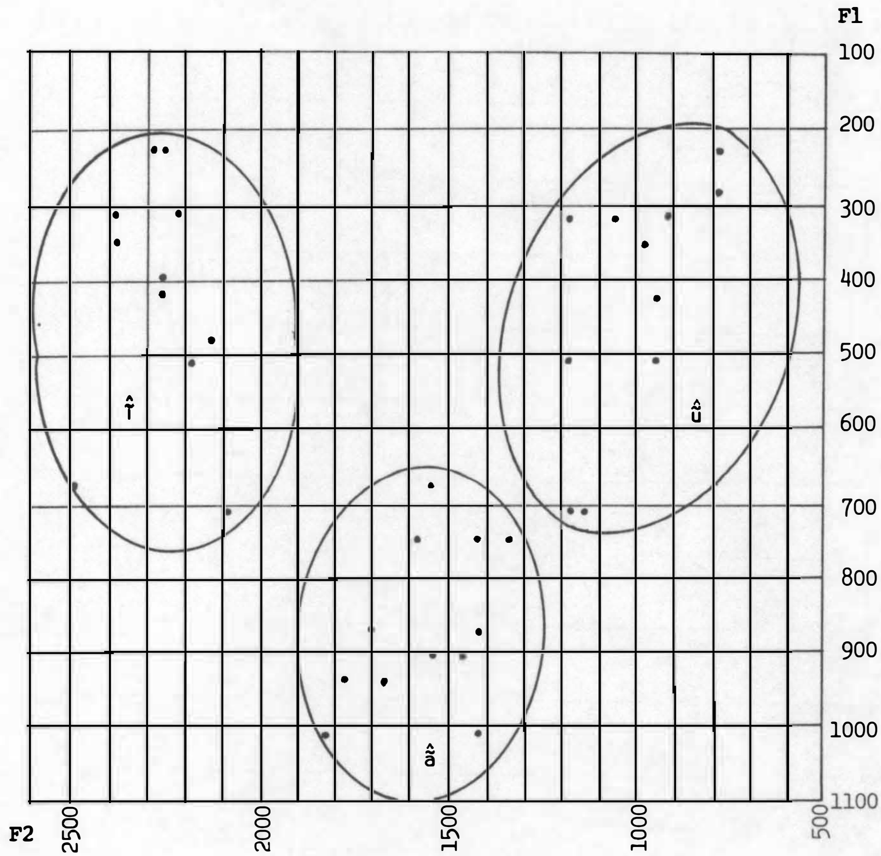
GRAPH 2

The Three Nasalised Vowels in Tone I



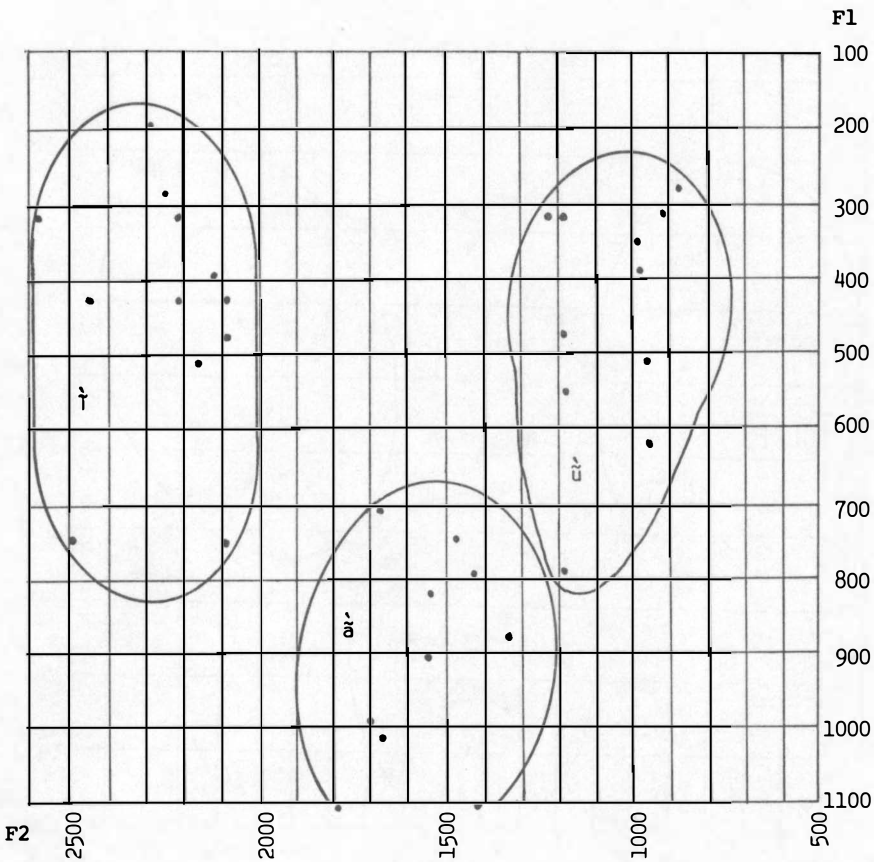
GRAPH 3

The Three Nasalised Vowels in Tone II



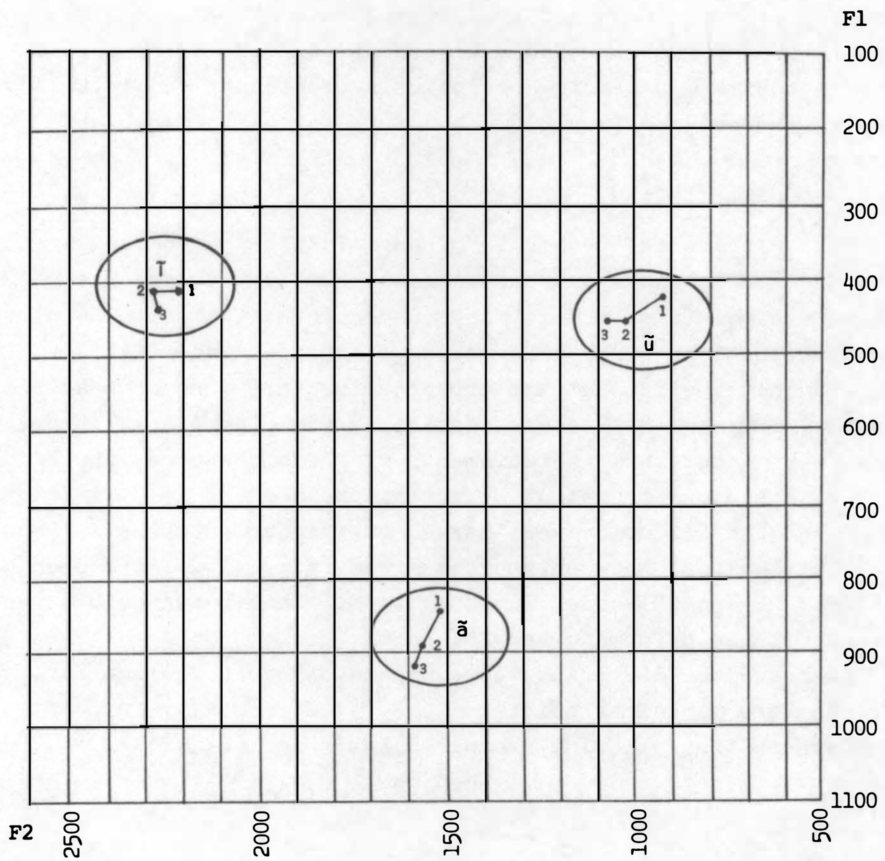
GRAPH 4

The Three Nasalised Vowels in Tone III



GRAPH 5

Movements of the Three Nasalised Vowels, in Different Tones, Traced on their Average F1 and F2 SS Values Calculated Among the Twelve Subjects



8.5. *DIPHTHONGAL NUCLEI*

One remarkable feature shown by the Burmese diphthongs on the sonagrams is that they hardly have any onglide and offglide whether they are glottalised or nasalised in any tone. If the diphthongs show occasional onglides and offglides, their lengths are usually very limited.

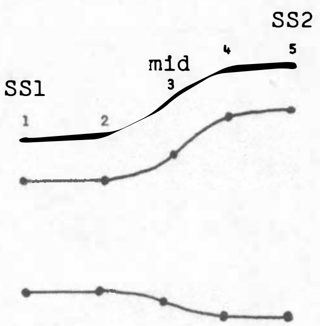
Another remarkable feature of the diphthongs is that their SS1 and SS2 are very distinct from one another both in nasalised and final-stop environments. In some cases the SS lengths may be extremely short, but they still maintain their own distinctive positions on the formant bars.

These two features show that unlike the monophthongal nuclei, the vowel qualities of the diphthongs are so strong that there is very little effect of the preceding or following consonant or glottalisation, on them, in [hṽvndá] or [hvvʔdá] (/hṼdá/ or /hVʔdá/) frame.

8.6. *METHOD OF MEASURING*

In order to trace the movements of the diphthongs from one steady state to the other, acoustic phoneticians usually measure onset, SS1, SS2 and offset points of the formants under investigation. As almost all the diphthongs in Burmese do not have onglides and offglides, it can be said that their onset and offset values are more or less the same as their SS1 and SS2 values respectively. Therefore, in order to investigate accurately the movements of the diphthongs, the writer had to devise his own method of measuring the diphthongs. Firstly the SS1 point and the SS2 point were marked on the formant bars. Then a point exactly halfway between the two steady states was marked on every formant (F1, F2 and F3) under investigation. Lastly two points, one between the middle point and the SS1 point, and the other between the middle point and the SS2 point, were marked on every formant bar. The five points were marked as point 1, 2, 3, 4, 5, serially from SS1 to SS2 as shown in the following example diagram for [ei].

[ei]



All the four diphthongs ([eiʔ], [auʔ], [ouʔ], [aiʔ]; and [ẽĩ], [ãĩ], [ãũ], [õũ]) occur in both nasalised and final-stop environments. In the nasalised environment, they occur only in the first three tones. What follows is an explanation of their movements from one SS to the other, traced on their average F1 and F2 frequencies measured at the five selected points.

[ẽĩ] and [eiʔ]

The movements of [ẽĩ] in Tone I and Tone II are more or less the same except that SS1 in Tone I is slightly lower than that in Tone II. The movement of [ẽĩ] in Tone III is lower (i.e. F1 increases) than those in Tones I and II especially at points 1, 2, 3, and 4. The movement of [eiʔ] is almost the same as [ẽĩ] in Tone III. (See Graphs 6 and 7).

[ãĩ] and [aiʔ]

The movements of [ãĩ] from SS1 to SS2 in the three tones and that of [aiʔ] are more or less the same (see Graphs 6 and 8).

[ãũ] and [auʔ]

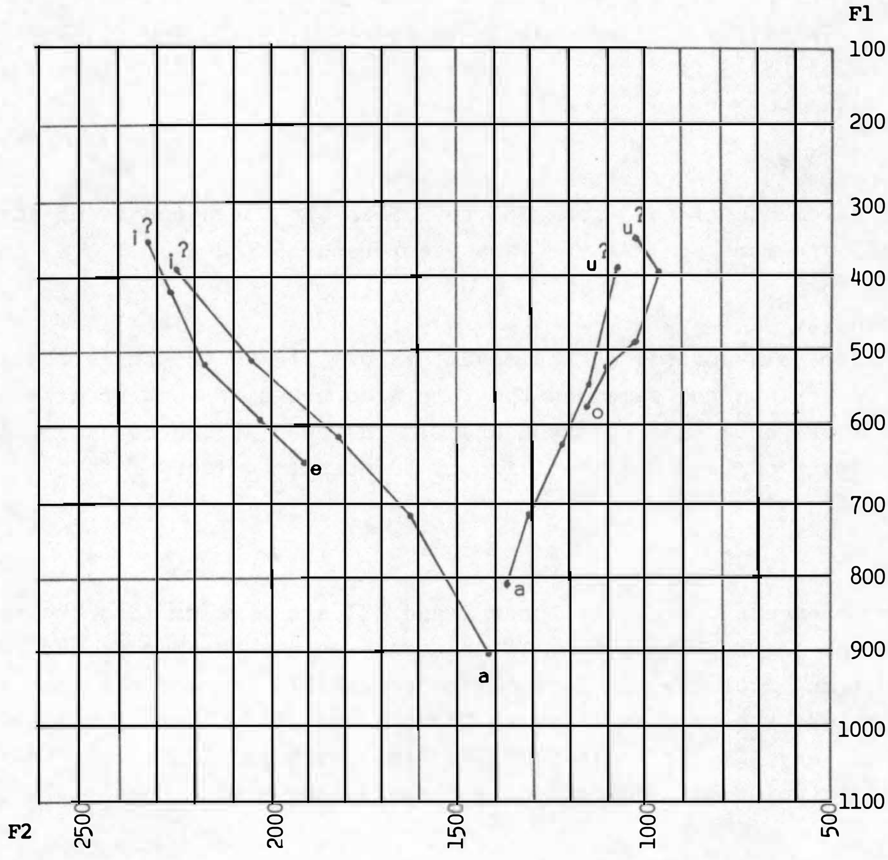
As with [ãĩ] and [aiʔ], the movements of [ãũ] in the three tones are more or less the same and they are also not different from the movement of [auʔ] (see Graphs 6 and 9). However it can be said that the movement of [ãũ] becomes slightly fronter from Tones I to II and II to III.

[õũ] and [ouʔ]

The movements of [õũ] in Tones I and III are more or less the same except for the fact that Tone III has some points further front. Points 1 and 2 of [ãũ] in Tone II are remarkably low and the rest are more or less the same as those in Tones I and III. The movement of [ouʔ] is very similar to that of [ãũ] in Tone I and III except that the SS2 point (point 5) moves slightly forward (see Graphs 6 and 10).

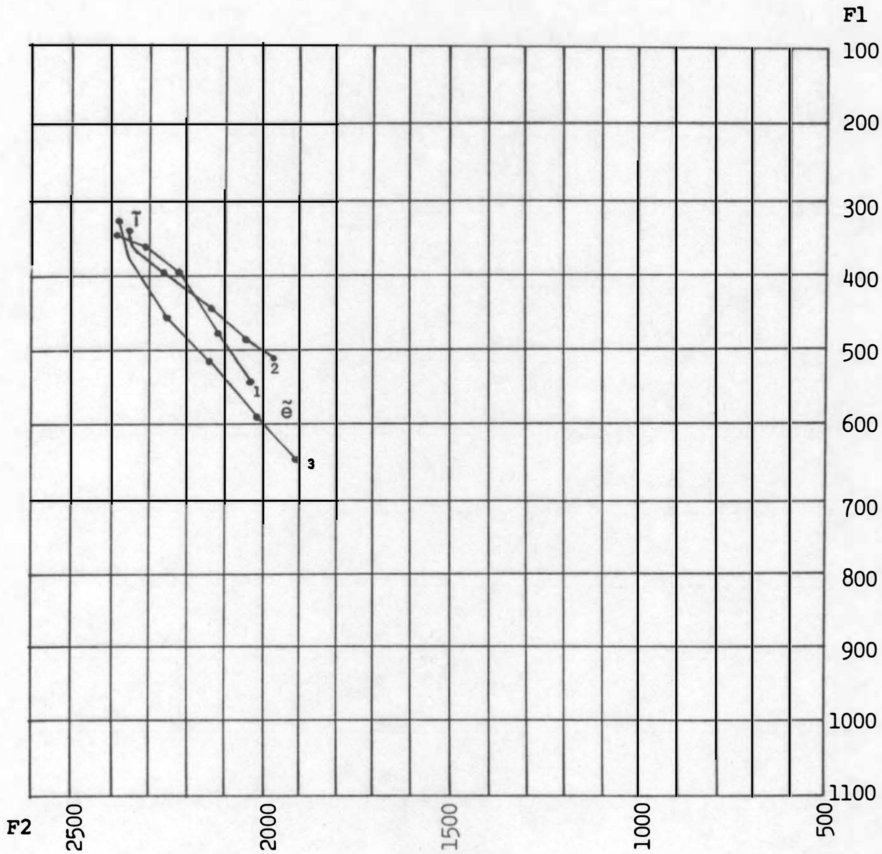
GRAPH 6

Movements of Glottalised Diphthongs
(Diphthongs in Tone IV), Traced on the Average
F1 and F2 Values at the Five Selected Points



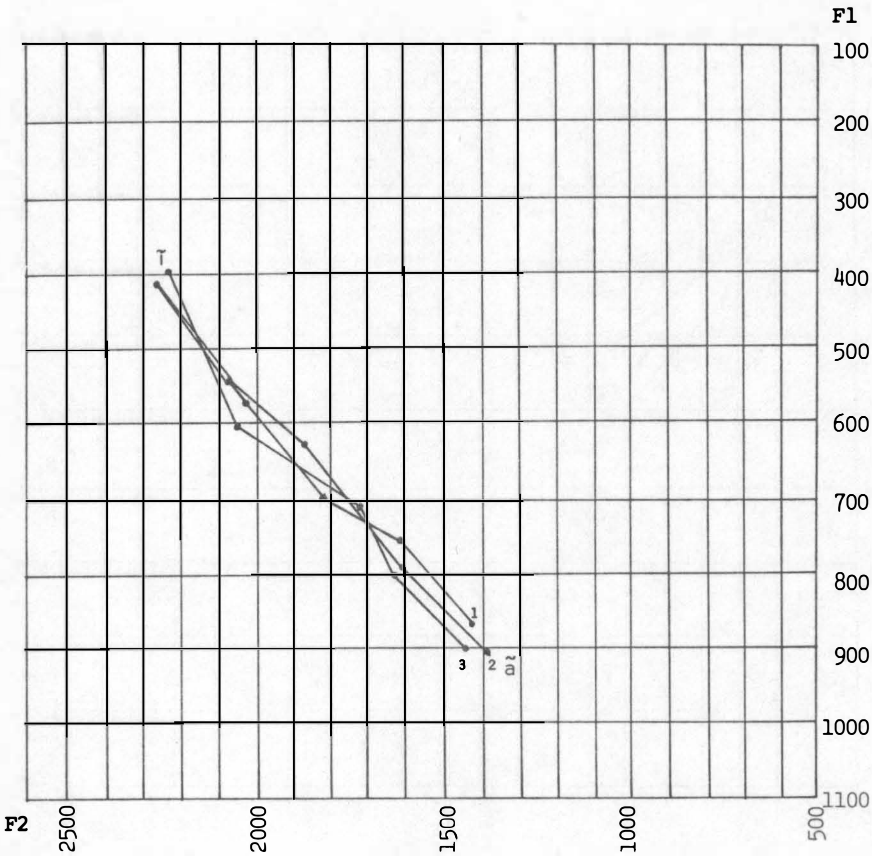
GRAPH 7

Movements of the Nasalised Diphthong [ẽĩ] in Different Tones, Traced on the Average F1 and F2 Values at the Five Selected Points



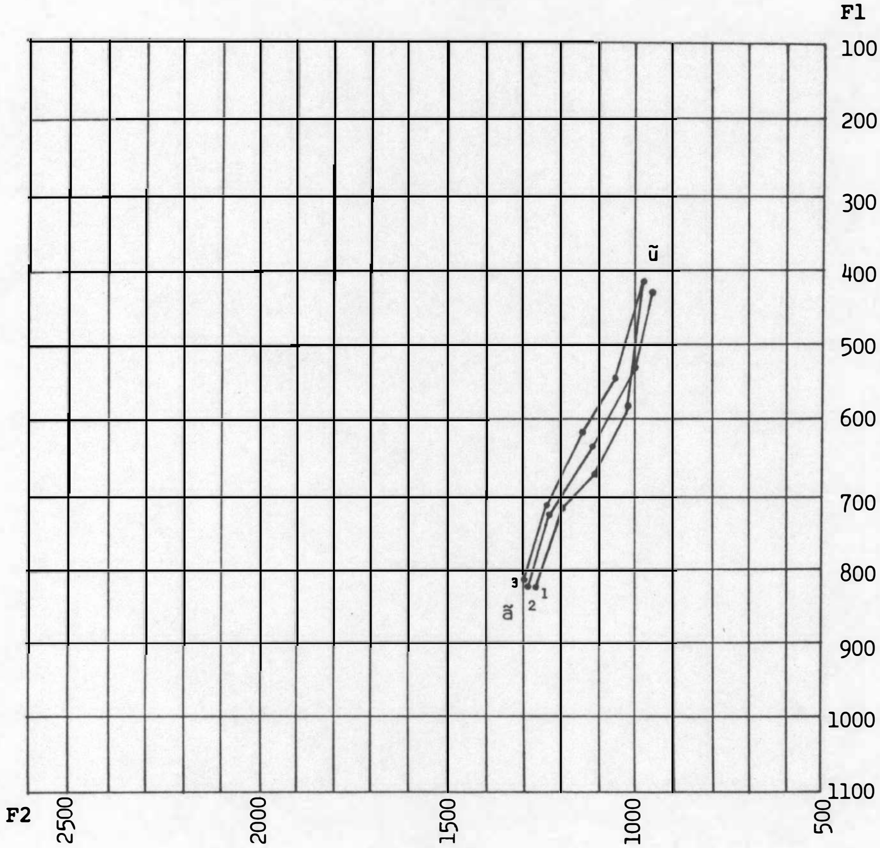
GRAPH 8

Movements of the Nasalised Diphthong [ãĩ] in Different Tones, Traced on the Average F1 and F2 Values at the Five Selected Points



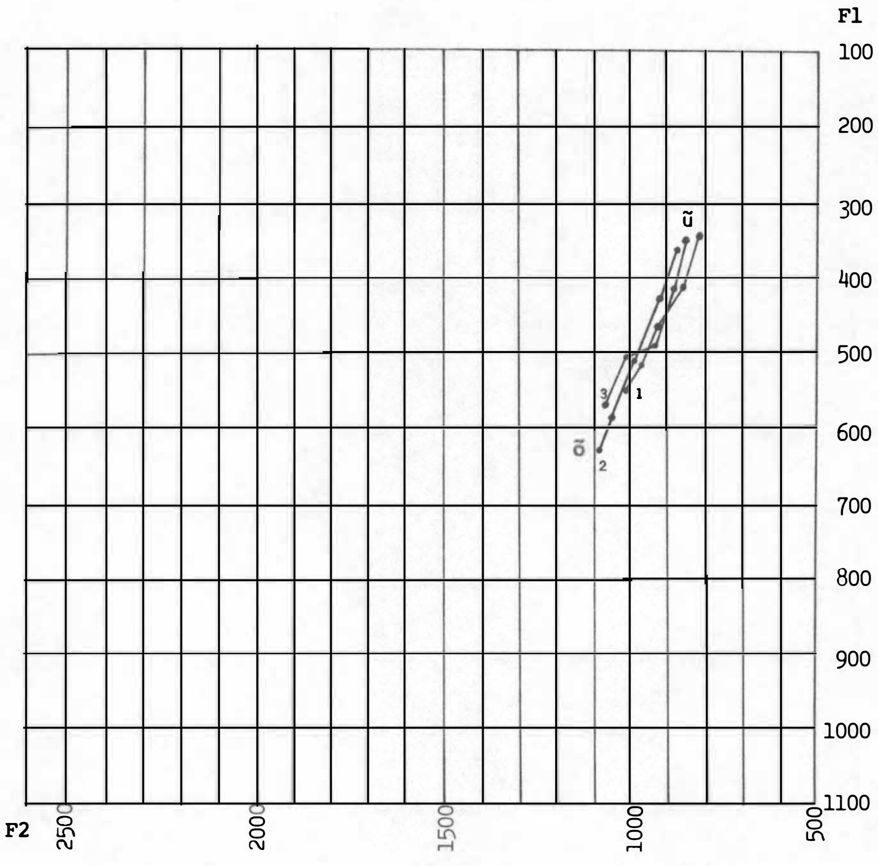
GRAPH 9

Movements of the Nasalised Diphthong [ãũ] in Different Tones, Traced on the Average F1 and F2 Values at the Five Selected Points



GRAPH 10

Movements of the Nasalised Diphthong [õũ] in
Different Tones, Traced on the Average
F1 and F2 Values at the Five Selected Points



Although the non-nasalised and nasalised monophthongal nuclei generally show the general tendency of moving forward and downward from Tones I to II, II to III and III to IV, the diphthongal nuclei do not. It is true that the movement of [e͠i] in Tone III is more fronted and lower than those of [e͠i] in Tones I and II and the movement of [a͠u] becomes more fronted from Tones I to II, and II to III. The movements of [a͠i] and [o͠u] from Tones I to II and II to III do not show any uniformity or consistency at all. Of the four stop-final diphthongal nuclei [auʔ] is the only one whose movement is more fronted than that of its nasalised counterpart [a͠u] in the first three tones. The following tables summarise the average frequencies of the stop-final and nasalised diphthongs in the three tones, measured at the five selected points for the twelve subjects.

TABLE 10

		SS1	TRANSITION			SS2
		Point 1	Point 2	Point 3	Point 4	Point 5
[eiʔ]	F1	652	596	515	415	341
	F2	1908	2039	2173	2267	2320
	F3	2711	2781	2827	2883	2893
[aiʔ]	F1	903	728	625	510	382
	F2	1427	1638	1829	2059	2256
	F3	2376	2472	2548	2643	2729
[auʔ]	F1	576	715	633	558	385
	F2	1377	1315	1229	1166	1087
	F3	2534	2531	2544	2530	2482
[ouʔ]	F1	576	527	491	395	349
	F2	1171	1107	1022	962	1038
	F3	2577	2601	2611	2558	2531

TABLE 11

		SS1	TRANSITION			SS2
		Point 1	Point 2	Point 3	Point 4	Point 5
[éi]	F1	542	473	397	365	349
	F2	2043	2130	2224	2315	2396
	F3	2715	2798	2800	2913	2897
[êi]	F1	516	480	454	395	345
	F2	1961	2056	2168	2267	2360
	F3	2712	2758	2798	2851	2930
[èi]	F1	652	583	524	461	339
	F2	1904	2036	2151	2264	2383
	F3	2442	2758	2898	2841	2893

TABLE 12

TABLE OF DEVIATION FROM TONE I

		SS1	TRANSITION			SS2
		Point 1	Point 2	Point 3	Point 4	Point 5
[êi]	F1	-26	+7	+57	+30	-4
	F2	-82	-74	-56	-48	-36
	F3	-3	-40	-2	-62	+33
[èi]	F1	+110	+110	+127	+96	-10
	F2	-139	-94	-73	-51	-13
	F3	-273	-40	+98	-72	-4

TABLE 13

		SS1	TRANSITION			SS2
		Point 1	Point 2	Point 3	Point 4	Point 5
[ái]	F1	876	754	692	567	408
	F2	1427	1618	1832	2033	2260
	F3	2419	2518	2600	2712	2829
[âi]	F1	919	797	629	563	402
	F2	1393	1605	1881	2089	2262
	F3	2455	2508	2574	2670	2818
[ài]	F1	899	790	711	602	395
	F2	1440	1625	1738	2050	2237
	F3	2366	2507	2570	2649	2787

TABLE 14

TABLE OF DEVIATION FROM TONE I

		SS1	TRANSITION			SS2
		Point 1	Point 2	Point 3	Point 4	Point 5
[âi]	F1	+43	+43	-63	-4	-6
	F2	-34	-13	+49	+56	+2
	F3	+36	-10	-26	-42	-11
[ài]	F1	+23	+36	+19	+35	-13
	F2	+13	+7	-94	+17	-23
	F3	-53	-11	-30	-63	-42

TABLE 15

		SS1	TRANSITION			SS2
		Point 1	Point 2	Point 3	Point 4	Point 5
[áu]	F1	833	714	675	576	428
	F2	1268	1197	1110	1037	981
	F3	2508	2514	2540	2534	2593
[âu]	F1	830	734	648	536	444
	F2	1285	1215	1123	1008	968
	F3	2557	2606	2649	2679	2692
[àu]	F1	826	714	619	550	421
	F2	1288	1232	1143	1059	978
	F3	2491	2534	2580	2603	2471

TABLE 16

TABLE OF DEVIATION FROM TONE I

		SS1	TRANSITION			SS2
		Point 1	Point 2	Point 3	Point 4	Point 5
[âu]	F1	-3	+20	-27	-40	+16
	F2	+17	+18	+13	-29	-13
	F3	+49	+92	+109	+145	+99
[àu]	F1	-7	nil	-56	-26	-7
	F2	+20	+35	+33	+22	-3
	F3	-17	+20	+40	+69	-122

TABLE 17

		SS1	TRANSITION			SS2
		Point 1	Point 2	Point 3	Point 4	Point 5
[óu]	F1	556	523	471	414	348
	F2	1034	978	929	866	823
	F3	2626	2610	2611	2629	2656
[ôu]	F1	569	507	484	421	355
	F2	1064	1011	942	889	856
	F3	2623	2671	2698	2698	2686
[òu]	F1	642	569	517	438	365
	F2	1090	1050	984	912	869
	F3	2560	2596	2613	2656	2609

TABLE 18

TABLE OF DEVIATION FROM TONE I

		SS1	TRANSITION			SS2
		Point 1	Point 2	Point 3	Point 4	Point 5
[ôu]	F1	+13	-16	+13	+7	+7
	F2	+30	+33	+13	+23	+33
	F3	-3	+36	+60	+69	+30
[òu]	F1	+86	+46	+46	+24	+17
	F2	+56	+72	+55	+46	+46
	F3	-66	-14	+2	+27	-47

9. GENERAL CONCLUSION FROM THE THREE EXPERIMENTS

Experiments 1 and 2 reveal that fundamental frequency and total length of the tones can be regarded as remarkably consistent features.

Experiment 3 shows that all monophthongal nuclei (nasalised and non-nasalised) show a strong tendency to have lower and more fronted allophones from Tones I to II and II to III, that is, F1 and F2 values increase. The diphthongal nuclei, however, do not show this general tendency, at least not as significantly as the monophthongal nuclei do. In other words, of the fourteen vocalic nuclei (seven basic vowels, three nasalised vowels and four diphthongs), ten (all monophthongal nuclei, that is, seven basic vowels and three nasalised vowels) show the tendency and four (all diphthongs), do not. As ten out of fourteen vocalic nuclei (71.4%) show the tendency, it is justified to regard this tendency of spectral quality as another consistent parameter of the tones.

Two other features of the tones, that is, fundamental frequency and total length, seem more consistent than the feature of spectral quality. Within the /hVdá/ test frame, the duration pattern of the tones seems to be more consistent than the fundamental frequency. Therefore it can be concluded that the duration pattern is the most consistent feature and the fundamental frequency is the second most consistent feature of the Burmese tones.

BIBLIOGRAPHY

BECKER, A.S.

1964 Burmese tonemics: a discussion of various points of view. In J.K. Yamagiwa, ed., *Papers of the CIC Far Eastern Language Institute*. Ann Arbor: University of Michigan.

BURLING, R.

1967 *Proto Lolo-Burmese*. Publication 43 of Indiana University Publications in Anthropology and Linguistics. Bloomington.

CORNYN, W.S.

1944 *Outline of Burmese grammar*. Language 20/4, supplement. Language dissertation No.38.

CORNYN, W.S. and D.H. ROOP

1968 *Beginning Burmese*. New Haven: Yale University Press.

FIRTH, J.R.

1933 Notes on the transcription of Burmese. *Bulletin of the School of Oriental Studies* 7/1:137-140.

1936 Alphabets and phonology in India and Burma. *Bulletin of the School of Oriental Studies* (Grierson memorial volume) 8/2:517-546.

McDAVID, R.

1945 Burmese phonemics. *Studies in Linguistics* 3/1:6-17.

OKELL, J.A.O.

1969 *A reference grammar of colloquial Burmese*. 2 vols. London: Oxford University Press.

STEWART, J.A.

1955 *A manual of colloquial Burmese*. 2nd edn. London: Luzac.

TAYLOR, L.F.

1920 On the tones of certain languages of Burma. *Bulletin of the School of Oriental Studies* 1/4:91-106.

THEIN TUN, U

1976 A survey and critique of previous studies on Burmese phonology. *Working papers of the Speech and Language Research Centre, Macquarie University*. January, 95-124.

TRUBETZKOY, N.S.

1968 *Introduction to the principles of phonological description.* Translated by L.A. Murray. The Hague: Martinus Nijhoff.

1969 *Principles of phonology.* Translated by Christaine A.M. Baltaxe. Berkeley and Los Angeles: University of California Press.

Thein-Tun, U. "Some Acoustic Properties of Tones in Burmese". In Bradley, D. editor, *Papers in Southeast Asian Linguistics No. 8: Tonation.*
A-62:77-116. Pacific Linguistics, The Australian National University, 1982. DOI:*10.15144/PL-A62.77*