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VI

Complex Syllable Nuclei in Vietnamese

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PREFACE

This study, Complex Syllable Nuclei in Vietnamese, is the sixth publication in the series Studies in the Phonology of Asian Languages. It is a result of a research project sponsored by the Office of Naval Research, whose financial support of the project is gratefully acknowledged. This volume serves as a technical report for the contract NR 049-183, Nonr 228(28).

The first volume of the series, Acoustic Phonetics of Korean, Technical Report No. I, was devoted to the acoustic-phonetic study of Korean vowels. The second volume was Duration of Korean Vowels; the third, Acoustic Characteristics of Korean Stop Consonants; the fourth, Vietnamese Vowels; and the fifth, Acoustic Features in the Manner-Differentiation of Korean Stop Consonants. The present volume, VI, is devoted to the study of complex syllable nuclei in Vietnamese. Studies on other phonological features of Korean, Vietnamese, and other Asian languages are in progress and the results will be reported in the near future.

Much of the experimental work of this study was carried out by Michael Earle, while the editorial work was done by Haruo Furukawa and Sylvia Buck.

Mieko S. Han

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Chapter 1

PROBLEMS IN THE ANALYSIS OF VIETNAMESE COMPLEX SYLLABLE NUCLEI

In volume IV of this series, Studies in the Phonology of Asian Languages: Vietnamese Vowels, the eleven simple vowel phonemes of the Hanoi dialect of Vietnamese were studied and described. Formant 1 and Formant 2 of the eleven vowels were measured and analysed; the domains of the vowel phonemes relative to one another were studied; tonal and consonantal influences on vowel quality were noted; and a study on the inherent duration of each of the eleven vowels was carried out.

The eleven simple vowels occur as syllable nuclei carrying one of the six phonemically distinct tones. In addition to these simple vowels, there are certain other sequences which also occur as syllable nuclei. Such sequences are found in the following examples.

1) The sequences spelled:

yê-	as in	"yêm"	(to salt or pickle)
-iê-	as in	"tiên"	(immortal)
-ia	as in	"tia"	(jet; ray)

These three sequences all seem to have similar phonetic qualities in that they all sound like a high front unrounded vowel [i] which changes to a mid front vowel slightly more

centralized than [e]. This sequence is tentatively transcribed [Iɜ].

2) The sequences spelled:

-ưở- as in "tưởng" (bean sauce)

-ưạ as in "tựa" (preface)

These two sequences both sound like a high central unrounded vowel [ɯ] which moves to a mid central unrounded vowel. Our tentative phonetic symbolization for this sequence is [ɯɨ].

3) The sequences spelled:

-uô- as in "tuồn" (to throng)

-ua as in "tua" (fringe)

These two sequences both sound like a high back rounded vowel [u] which moves to a mid back vowel slightly more centralized than [o]. Our phonetic symbolization for this sequence is [Uθ].

The first segments of each of these sequences [Iɜ], [ɯɨ], and [Uθ] have been analysed as /i/ /ɯ/ and /u/ by most analysts who have worked on Vietnamese phonology, but the second segments have caused disagreement. Auditory impressions of [ɜ], [ɨ], and [θ] vary depending on the hearer's own speech background. The American English speaker tends to hear all three as something like schwa [ə], while speakers of other language backgrounds may hear something else.

These three complex syllable nuclei are heard as being distinctly different from the combination of a vowel plus a semivowel. The stress on the second element of the sequences,

[Iɜ], [ɯɪ], and [Uθ], is heard as being at least equal to the stress on the first element. This suggests the presence of two target vowel qualities rather than a vowel plus a semivowel.

With regard to articulatory characteristics, all three sequences have tongue movement from higher to lower position. It is observed that the second segment of [Iɜ] is pronounced with the lips noticeably less spread than they are for [e]. The second segment of [Uθ] has much less lip rounding than [o].

The several analysts who have worked on Vietnamese phonology disagree in the analysis of these three complex syllable nuclei. The analyses of Nguyễn Đình Hoà, Lê-Văn-Lý, Murray B. Emeneau, and Laurence C. Thompson concerning the complex syllable nuclei in Vietnamese are summarized in the following paragraphs. It will be noted that their interpretations vary considerably. Only those portions of their works which deal explicitly with the phonemic analysis of the problem are presented here. One liberty which has been taken in presenting their analyses is the modification of their phonemic notation to make it conform to that used in this work. This was done to facilitate the understanding of the points of difference between these analysts and to enable one to compare their analyses.

Hoà[1] analyses the above mentioned complex nuclei as "vowel clusters" that are composed of /i/, /ɯ/, /u/ plus the

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[1]Nguyễn Đình Hoà, Speak Vietnamese (Rev. ed.; Rutland & Tokyo: Charles E. Tuttle Co.: Publishers, 1966).

phoneme /ʌ/. Therefore,

"tiên" is analysed as /tiʌn/

"tươn" is analysed as /tɯʌn/

"tuôn" is analysed as /tuʌn/

According to Hoà's analysis, the second segment of each of the three complex nuclei is regarded as being the same phoneme [ʌ] in all three cases.

Emeneau's analysis[1] is similar to that of Hoà's. Emeneau describes the clusters in question as involving movement from the higher vowels /i, ɯ, u/ to /ʌ/. He interprets the clusters phonetically as [i$\underset{\wedge}{\text{ʌ}}$][2], [ɯ$\underset{\wedge}{\text{ʌ}}$], and [u$\underset{\wedge}{\text{ʌ}}$] and phonemically as /iʌ/, /ɯʌ/, and /uʌ/, respectively.

On the other hand, Lê-Văn-Lý[3] analyses the sequences as [ie], [ɯə], and [uo] and stresses the "monophonematic" character of the sequences, saying that the two constituent elements [i] and [e], [ɯ] and [ə], and [u] and [o] are indissociable, thus proving that they are single phonemes. This makes the total inventory of Vietnamese vowels as follows:

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[1]Murray B. Emeneau, "Studies in Vietnamese (Annamese) Grammar," University of California Publications in Linguistics, VIII (1951), 10ff.

[2][$\underset{\wedge}{\text{ʌ}}$] = unstressed [ʌ]

[3]Lê-Văn-Lý, Le Parler Vietnamien (2nd ed.; Saigon: Bổ Quốc-Giá Giáo-Duc, 1960).

/i/	/ɯ/	/u/[1]
/ie/	/ɯə/	/uo/
/e/	/ə/	/o/
/ɛ/	/ʌ/	/ɔ/
	/A/ /a/	

Laurence C. Thompson[2] views a "vowel cluster" as that which contains two dissimilar vowels in sequence, neither of which is enough less prominent than the other to qualify as a semivowel. In Thompson's analysis the sequences spelled "-ia," "-ưa," "-ua" in final position are /i, ɯ, u/ followed by /ʌ/, while the sequences spelled "-iê-," "-ươ-," "-uô-" in medial postion are /i/ + /e/, /ɯ/ + /ə/, and /u/ + /o/, respectively.

The main point of disagreement in the various analyses seems to spring from the varying interpretations of the phonetic quality of the second segment in question. The first question is, then, are the sequences [Iɜ], [ɯɪ], [Uθ] three separate phonetic movements from three high vowels to three mid vowels as diagramed below,

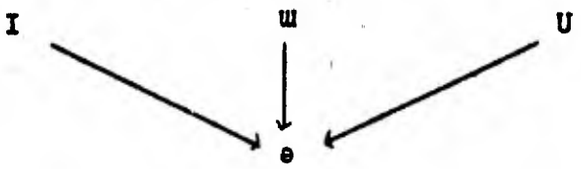
I	ɯ	U
↓	↓	↓
ɜ	ɪ	θ

---

[1]Note that this table is from Văn-Lý, Le Parler Vietnamien, pp. 43-44, but the symbols have been changed to follow those used in this study.

[2]Laurence C. Thompson, A Vietnamese Grammar (Seattle: University of Washington Press, 1965), pp. 30ff.

or are the three segments tentatively described as [ɜ], [ɨ], [ə] phonetically similar enough to be interpreted as one mid central vowel [ə], as the following diagram shows?



Also, are the differences between the sequences spelled -ia, -u̯a, and -ua in open syllables and those spelled -iə̯-, -uə̯-, and -uə̯- in closed syllables so great that they should be considered as two different syllable nuclei, or is the difference a conditioned one?

In order to arrive at a satisfactory phonetic and phonemic interpretation of these complex nuclei, techniques of acoustic-phonetic analysis with the aid of the sound spectrograph were applied. In this way the impressions based on hearing were re-examined and re-evaluated. Data obtained by the spectrograph offer objective facts concerning speech sounds, while human interpretation of these sounds is often subjective, being influenced by the speaker's language background.

The major part of investigation of this study will be concerned with determining the target qualities of the complex nuclei segments, i.e., whether or not the second segments of these nuclei are actually all one vowel or three different vowels, and what are the conditioned variants, if any.

After a careful examination a phonemic interpretation of the complex nuclei will be proposed.

Chapter 2

MATERIALS AND TECHNIQUE

This chapter describes briefly the materials and technique used in the analysis, the results of which will be described in subsequent chapters.

Informants

The four informants who supplied data for analysis are the same as those who assisted in our previous study of Vietnamese Vowels, Vol. IV of this series. Biographical sketches of these informants are briefly presented here.

Informant 1 Nguyễn Hữu Quảng--male, age 30, was born in Haiphong and lived 18 years in Hanoi. He moved to South Viet Nam in 1954 and there attended the University of Saigon. From 1962 through 1965, he resided, as a student, in the United States. His native language is the Hanoi dialect of Vietnamese and he is also fluent in French and English. QUANG believes that his residence in the Saigon dialect area has not affected his speech, as his language habits were already well established by the time he moved to South Viet Nam.

Informant 2 Pham Gia Huấn--male, age 21 , was born in the the vicinity of Hanoi. His family moved to Paris, France, at

the time he entered primary school. Though his formal education was conducted in French, Vietnamese was used at home and with friends. His parents were born in Hanoi and lived there until they moved to Paris. He returned to Saigon for his secondary school education and resided there for seven years before coming to the United States in 1962. HUAN speaks both the Hanoi and Saigon dialects but distinguishes the two. According to another native speaker of the Hanoi dialect, the Saigon dialect has not affected HUAN's original Hanoi dialect.

Informant 3 Pham Thị-Ánh Tuyết--female, age 22, sister of HUAN, was born in the vicinity of Hanoi. She had one year of school there before going to Paris with her family. French was used in her formal education, and Vietnamese was used at home. Her secondary education was received at a French school in Saigon where she lived for several years before coming to the United States in 1962. In addition to the Hanoi dialect, she speaks the Saigon dialect, French, and English; but, she feels that her Hanoi dialect is not affected by these other languages.

Informant 4 Phàm Van Đồng--male, age 22 , is not related to HUAN and TUYET. His parents came from North Viet Nam, and the Hanoi dialect was always used in his home. For business reasons his family moved frequently around Northern and Central Viet Nam. DONG was born in Đa Nang but moved early in his life to the North. His elementary and high school education was received in either Vietnamese or French, according to the

school attended. DONG attended the University of Saigon for one year and came to the United States in 1962. Because of his frequent changes of residence, DONG is familiar with the Hué and Saigon dialects of Vietnamese, in addition to the Hanoi dialect; but, he regards the latter as his native dialect and feels that he clearly distinguishes the three. He is also fluent in French and English.

Tape Recordings

The prepared scripts were recorded by the informants in a sound proof booth using an AKG C-60 condenser microphone with a pre-amplifier and an Ampex PR-10 single-track tape recorder. Speech was recorded on Scotch or Ampex magnetic tape at a speed of 7.5 inches per second.

Since the informants were experienced in making tape recordings, they were relaxed and relatively at ease in front of the microphone. They were asked to use their normal speech tempo and to pronounce the words as they used them in their everyday speech. As the informants had assisted in drafting the recording scripts, the material was in their own handwriting and they had a certain degree of familiarity with the content of each script. This familiarity enabled them to read smoothly and without hesitations, lapses, or errors. As a part of each recording session, the informants listened to the tapes that they had recorded, checking the script as they listened. This ensured that each utterance recorded passed

the test of acceptability to the native speaker.

The Spectrograph and Spectrograms

An Ampex PR-10 single-track tape recorder was used to reproduce the recorded speech which was channeled directly into a modified model 661A Sound Spectrograph (Kay Sona-graph).

The sound spectrograph is a device which can analyse a sound segment of up to 2.4 seconds in duration. The sound segment is recorded on a disc inside the machine which repeats it constantly while a band-pass filter scans it, moving up the frequency scale from zero to 8000 cycles per second.

The signal from the scanning filter is transmitted to a stylus which is in contact with specially sensitized paper attached to a revolving drum. The resulting artifact is called a sound spectrogram and is a permanent record of the recorded speech segment. The spectrogram shows frequency in the vertical dimension, duration in the horizontal dimension, and gives a rough indication of intensity by the relative darkness of various portions of the spectrogram.

The spectrogram can be made with the band-pass filter set at either 45 or 300 cycles per second which produces narrow-band and wide-band spectrograms, respectively. It is also possible on this machine to record the portion from 0 to 4000 cps twice, one above the other, once with narrow-band and once with wide-band. As the essential features of vowels are realized in this frequency range and as each band-width has

certain advantages, composite spectrograms were most frequently used in this study.

Formants and Formant Measurement

Vowels are characterized by their relatively great resonance compared to consonants. This resonance is strengthened in various areas according to the configurations of the articulatory organs characteristic of each speech sound. These areas of strengthened resonance are called FORMANTS. Each vowel has a characteristic formant pattern, and it has been demonstrated experimentally that the first two formants carry most of the information about the qualities of vowels. In this study, measurements of the first two formants are studied in detail.

While it is easier to identify formants on a wide-band spectrogram, it is possible to be more accurate in the measurement of narrow-band spectrograms. This is the chief benefit of the composite spectrogram.

The procedure for measurement is to measure from the zero line, which is a part of every spectrogram, to the exact center of the formant. On a good narrow-band spectrogram, it is possible to measure reliably to within ±25 cps. In almost all cases, it is possible to measure to within ±50 cps.

The steady state of a vowel is defined as that portion of the vowel in which the formants are parallel to the zero line. When there is a steady state of a vowel present, measurements are made at that point in time. Movements of formants

associated with initial and final consonants are called TRANSITIONS. Typically, there is a transition from an initial consonant to the steady state of the vowel and a transition from the steady state of the vowel to the final consonant. In some cases there is no steady state of the vowel since the transition from the initial consonant through the vowel to the final consonant is continuous. In this case the mid-point of the vowel is arbitrarily selected as the point of measurement on the assumption that, at this point, the effect of the initial and final transitions cancel each other out.

Amplitude

The Kay Sona-graph comes with an attachment for measuring and recording on a spectrogram the amplitude contour of a given utterance of up to 2.4 seconds in duration. This contour appears in reference to a base line on the upper portion of the spectrogram. However, there are many factors affecting the amplitude display and care must be taken to avoid invalid comparisons between two amplitude contours.

For our purposes, the amplitude display was referred to only as an aid in distinguishing the most prominent segment of the syllable and in comparing the relative amplitudes of different portions of a single syllable.

CHAPTER 3

TARGET QUALITIES OF COMPLEX NUCLEI

To provide a basis for the analysis of the complex nuclei [Iɜ], [ɯɪ], and [Uθ], the eleven simple vowels of each informant were re-examined. Our previous study revealed that vowel formant measurements are influenced considerably by neighboring consonants and the accompanying tone. We, therefore, obtained measurements of the eleven simple vowels in a fixed environment which could serve as the basis for comparison with the complex nuclei. Any two phonemically identical sounds may differ phonetically even in the same environment; but, if the environment is specifically limited, similar phones will recur within a small domain definable by a boundary. In the analysis that follows, the relative domains of the eleven simple vowels and also the relative domains of the vowel target qualities of the complex nuclei were obtained. These were then compared with each other to determine the phonetic qualities of the complex nuclei in question.

The eleven simple vowels and three complex nuclei were recorded in the environment /t - n/ with level tone /-/ by the informants. This phonetic environment was selected for several reasons. First, /n/ and /t/ are the only consonants which can

occur after every vowel; and, /n/ was preferred to /t/ because /t/ occurs only with rising tone /ˊ/ and drop tone /ˌ/, while /n/ occurs with all six tones. The initial consonant /t/ was then selected because most of the /t - n/ syllables form real words in the Vietnamese language. These syllables were therefore familiar to the informants and could be spoken without hesitation.

The frame sentence "I say the word ( ); ( ), ( ), ( )." was used, the test word being uttered four times; e.g., /tōy dɔ̄k cɯ̃ tān; tān, tān, tān./ Narrow-band spectrograms were made of five recordings, resulting in 20 sets of Formant 1 and Formant 2 measurements for each vowel. These measurements were then plotted on a formant chart to establish the domain of each of the simple vowel phonemes. The same procedure was followed in making spectrograms, measurements, and charts for the complex syllable nuclei. Then the charts of the complex nuclei were compared to the charts of the simple vowels.

Because Informants 1 and 2 left us before the experiments had been completed, only a limited number of their recordings and spectrograms were available. Informants 3 and 4 furnished most of the data used in this analysis.

Table 1 shows the formant measurements of the eleven simple vowels of Informant 4 in the environment /t - n/ with level tone.

Figure 1 is the corresponding representation on the formant chart of the F1 and F2 measurements presented in Table 1.

The domain of each vowel is represented by twenty occurrences of that vowel in the environment indicated. The formant chart used in this study is the same as that used in our previous study, Vol. IV of this series. The reason for the choice of this formant chart was explained on pp. 69-72 of Vol. IV.

Table 2 represents the F1 and F2 measurements of the eleven vowels of Informant 3 in the environment /t - n/ with level tone. As is known to most workers in acoustic phonetics, it is quite difficult to obtain accurate formant measurements of a female voice since a soprano or alto voice has wide formant bands and widely spaced harmonics which make it difficult to identify the exact frequency value of the formants. To overcome these difficulties and to reduce marginal errors, a large amount of data was utilized and extra care was taken in measuring.

Figure 2 represents the domains on the formant chart of the eleven vowels in the environment /t - n/ with level tone spoken by Informant 3.

As can be seen in Figure 2, the domains of Informant 3's vowels cover a much greater area than do those of Informant 4. Given the above-mentioned characteristics of the female voice, this is to be expected. However, in order to show that these domains are truly representative, we prepared additional material to show the effect of the six tones on the formant measurements of vowels in isolation and, also, material to show the effect of initial consonants on vowel formants.

TABLE 1

Formant measurements of simple vowels in the environment /t - n/: Informant 4 cycles/second

Vowel [i] with tone [-]

Word	1 F1 F2 F3	2 F1 F2 F3	3 F1 F2 F3	4 F1 F2 F3
tīn	300 2350 3100	300 2500 3050	300 2300 3100	300 2250 3000
	300 2400 3200	300 2350 3150	300 2250 3100	300 2350 3100
	300 2400 3100	300 2300 3200	325 2350 3000	300 2250 3000
	300 2450 3150	325 2350 2950	350 2300 3050	325 2300 3000
	300 2350 3000	300 2350 3000	300 2350 3050	300 2250 3000

Vowel [e] with tone [-]

Word	1 F1 F2 F3	2 F1 F2 F3	3 F1 F2 F3	4 F1 F2 F3
tēn	600 2100 2850	550 2050 3000	550 2000	600 2000
	550 2100 2850	550 2050 2900	550 2100 2800	600 2000 2800
	650 2100 2800	625 2100 2850	650 2100 2800	650 2000 2850
	600 2100 2850	600 2100 2800	600 2100	600 2000 2800
	650 2150 2900	650 2100 3000	650 2100 2950	650 2050 2850

Vowel [ɛ] with tone [-]

Word	1 F1 F2 F3	2 F1 F2 F3	3 F1 F2 F3	4 F1 F2 F3
tɛ̄n	700 2000 2900	700 1900 2800	700 1900 2850	700 2000 2900
	750 2000 2850	700 2050 2950	700 2000 2950	750 1900 2800
	700 1900 2850	750 1950 2850	700 2100 2850	700 1950 2800
	700 2000 2800	700 2000 2800	700 2000 2800	700 2000 2800
	750 2100 2850	750 1950 2800	750 2000 2850	750 1950 2800

Vowel [a] with tone [-]

Word	1 F1 F2 F3	2 F1 F2 F3	3 F1 F2 F3	4 F1 F2 F3
tān	900 1500	900 1450	900 1400	900 1350
	900 1550	900 1500	900 1450	900 1450
	900 1500	900 1550	900 1500	900 1450
	900 1550	900 1500	900 1450	900 1500
	900 1550	900 1500	900 1500	900 1500

Vowel [ʌ] with tone [-]

Word	1 F1 F2 F3	2 F1 F2 F3	3 F1 F2 F3	4 F1 F2 F3
tʌ̄n	825 1400	825 1500	825 1500	850 1500
	850 1400	850 1400	850 1450	850 1450
	850 1500	850 1450	850 1400	850 1400
	850 1500	900 1400	900 1500	900 1500
	900 1500	850 1550	900 1450	900 1450

Vowel [ʌ] with tone [-]

Word	1 F1 F2 F3	2 F1 F2 F3	3 F1 F2 F3	4 F1 F2 F3
tʌ̄n	750 1500	775 1400	750 1350	750 1400
	700 1500	700 1450	700 1450	700 1400
	750 1400	750 1350	750 1350	750 1350
	750 1400	750 1350	750 1350	750 1400
	750 1500	750 1450	750 1400	750 1350

Vowel [o] with tone [-]

Word	1 F1 F2 F3	2 F1 F2 F3	3 F1 F2 F3	4 F1 F2 F3
tōn	650 1400	600 1400	625 1300	600 1350
	600 1400	600 1350	600 1250	575 1350
	650 1400	625 1400	600 1400	650 1450
	600 1400	600 1400	600 1400	600 1350
	600 1400	600 1400	600 1400	600 1400

Vowel [ʊ] with tone [-]

Word	1 F1 F2 F3	2 F1 F2 F3	3 F1 F2 F3	4 F1 F2 F3
tʊ̄n	500 1400 2800	500 1450 2800	475 1400 2800	500 1350 2850
	550 1500 2800	550 1400	550 1450	550 1450 2900
	550 1450 2900	550 1450 2900	550 1450 2850	550 1450 2900
	525 1400 2900	525 1450 2850	550 1400 2750	550 1450 2900
	550 1400 2900	550 1400 2800	550 1350 2950	550 1350 2850

Vowel [ɔ] with tone [-]

Word	1 F1 F2 F3	2 F1 F2 F3	3 F1 F2 F3	4 F1 F2 F3
tɔ̄n	700 1000	700 950	700 950	700 1000
	700 1050	700 1100	700 1050	700 1000
	700 1050	700 1100	700 1050	700 1000
	700 1100	700 1000	700 1050	700 1050
	750 1050	750 1050	750 1050	750 1050

Vowel [o] with tone [-]

Word	1 F1 F2 F3	2 F1 F2 F3	3 F1 F2 F3	4 F1 F2 F3
tōn	550 1100	500 1000	500 1100	550 1100
	500 1000	500 1050	550 1000	550 1000
	600 1050	600 1050	600 1050	600 1050
	600 1050	600 1050	600 1050	575 1050
	550 900	550 950	550 1000	550 1000

Vowel [u] with tone [-]

Word	1 F1 F2 F3	2 F1 F2 F3	3 F1 F2 F3	4 F1 F2 F3
tūn	300 800	300 800	300 800	300 800
	300 800	325 800	325 800	350 800
	300 800	300 800	300 800	300 800
	300 800	300 800	300 850	300 850
	300 800	300 800	300 800	325 850

Blank spaces indicate where precise measurements were not obtainable.

FIGURE 1

Simple vowels in the environment /t - n/

Level tone Informant 4

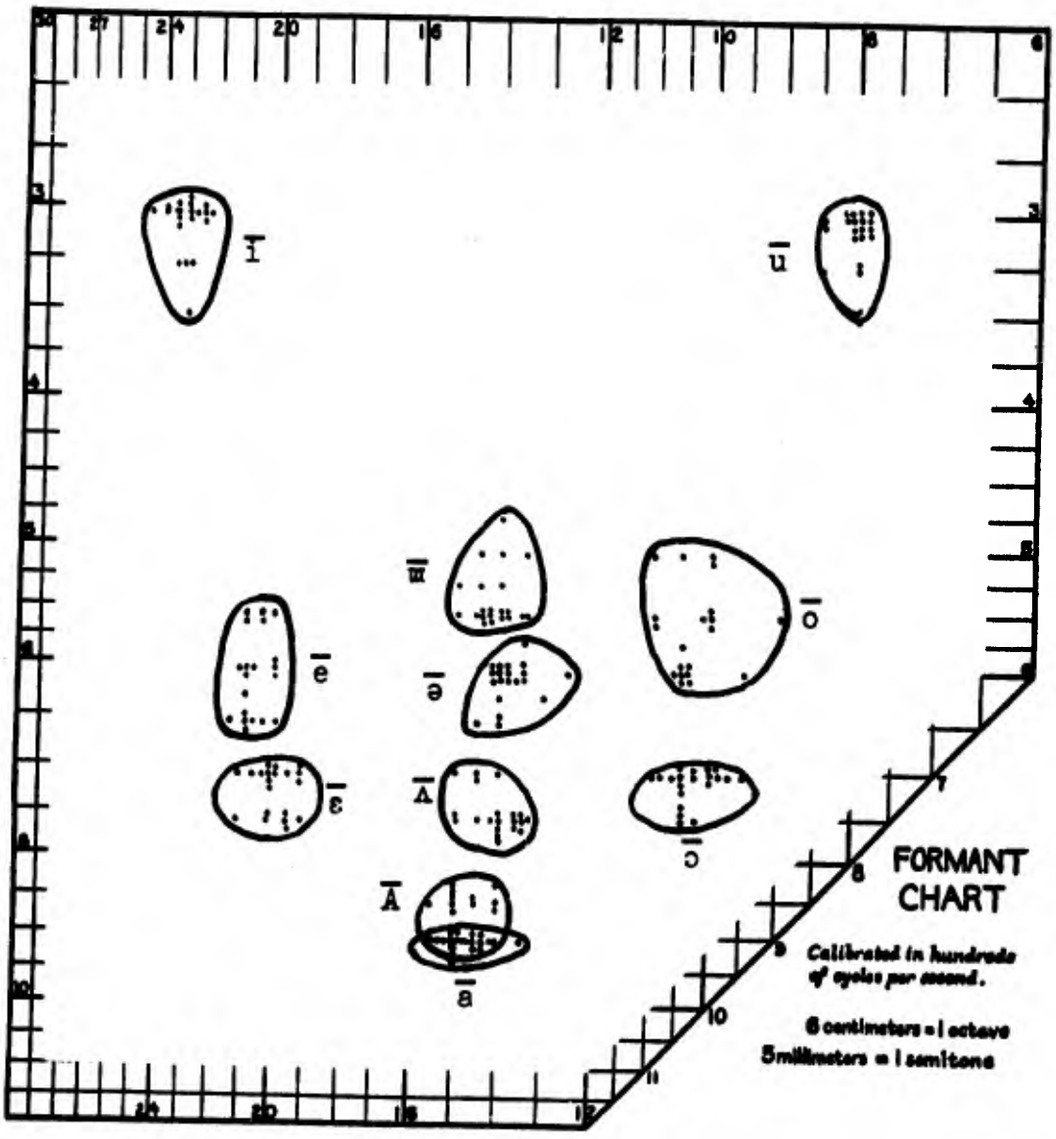


TABLE 2

Formant measurements of simple vowels in the environment /t - n/: Informant 3 cycles/second

Vowel [i] with tone [-]

Word	1 F1	F2	F3	2 F1	F2	F3	3 F1	F2	F3	4 F1	F2	F3
tĪn	400	2650		400	2850		400	2750		400	2800	
	400	2650		400	2700		400	2700		400	2700	
	400	2700		400	2700		400	2750		400	2750	
	400	2750		400	2700		400	2650		400	2750	
	400	2800		400	2750		400	2700		400	2700	

Vowel [e] with tone [-]

Word	1 F1	F2	F3	2 F1	F2	F3	3 F1	F2	F3	4 F1	F2	F3
tĒn	550	2500	3050	550	2550		550	2450		550	2450	3000
	525	2450		500	2550		500	2500		500	2550	
	525	2450		500	2550		525	2450		500	2350	
	550	2450		550	2400		550	2400		600	2400	
	550	2400		525	2400		500	2350		550	2400	

Vowel [a] with tone [-]

Word	1 F1	F2	F3	2 F1	F2	F3	3 F1	F2	F3	4 F1	F2	F3
tān	800	2300	3200	750	2350	3100	775	2350	3150	800	2350	3150
	750	2350	3100	800	2350	3150	800	2450	3200	800	2300	3150
	800	2400		800	2400	3150	800	2350	3150	800	2350	
	750	2350	3100	750	2400		750	2350		750	2400	
	750	2300		750	2350		775	2350		800	2350	

Vowel [a] with tone [-]

Word	1 F1	F2	F3	2 F1	F2	F3	3 F1	F2	F3	4 F1	F2	F3
tān	950	1650		950	1600		1050	1600		900	1650	
	1000	1650		950	1600		1000	1650		900	1550	
	1000	1700		1000	1700		900	1700		900	1700	
	950	1600		1000	1650		950	1700		900	1600	
	950	1650		950	1650		900	1600		900	1600	

Vowel [ʌ] with tone [-]

Word	1 F1	F2	F3	2 F1	F2	F3	3 F1	F2	F3	4 F1	F2	F3
tʌn	850	1750		850	1700		850	1700		800	1650	
	825	1650		850	1750		900	1750		800	1600	
	900	1850		900	1850		900	1550		800	1550	
	800	1650		800	1650		800	1600		850	1750	
	825	1650		800	1650		800	1650		800	1650	

Vowel [ʌ] with tone [-]

Word	1 F1	F2	F3	2 F1	F2	F3	3 F1	F2	F3	4 F1	F2	F3
tʌn	850	1450		800	1600		800	1600		800	1500	
	800	1650		750	1500		800	1600		800	1550	
	800	1850		800	1600		750	1550		800	1500	
	800	1650		750	1550		750	1550		750	1600	
	800	1650		750	1550		750	1550		800	1600	

Vowel [ɛ] with tone [-]

Word	1 F1	F2	F3	2 F1	F2	F3	3 F1	F2	F3	4 F1	F2	F3
	700	1350		700	1350		650	1350		650	1350	
	650	1350		650	1350		650	1350		650	1350	
	700	1350		650	1350		650	1350		650	1350	
	650	1350		650	1350		650	1300		650	1300	
	600	1350		650	1350		650	1350		650	1350	

Vowel [ɛ] with tone [-]

Word	1 F1	F2	F3	2 F1	F2	F3	3 F1	F2	F3	4 F1	F2	F3
tɛn	450	1450		550	1250		550	1250		550	1300	
	550	1350		400	1250		400	1250		550	1350	
	550	1400		550	1400		550	1400		525	1350	
	400	1450		500	1350		400	1200		550	1200	
	500	1400		550	1350		550	1350		525	1300	

Vowel [o] with tone [-]

Word	1 F1	F2	F3	2 F1	F2	F3	3 F1	F2	F3	4 F1	F2	F3
tōn	800	1050		750	1000		800	1050		750	1025	
	750	1050		800	1050		750	1025		800	1050	
	800	1050		750	1000		750	1000		750	1050	
	825	1100		800	1050		750	1050		800	1050	
	800	1050		750	1025		750	1025		750	1000	

Vowel [o] with tone [-]

Word	1 F1	F2	F3	2 F1	F2	F3	3 F1	F2	F3	4 F1	F2	F3
tōn	500	1100		500	1000		525	1000		500	1000	
	500	1050		525	1050		500	1050		500	1000	
	550	1050		550	1050		600	1000		600	1050	
	525	1050		525	1100		650	1050		525	1050	
	500	1050		650	1050		600	1000		600	1050	

Vowel [u] with tone [-]

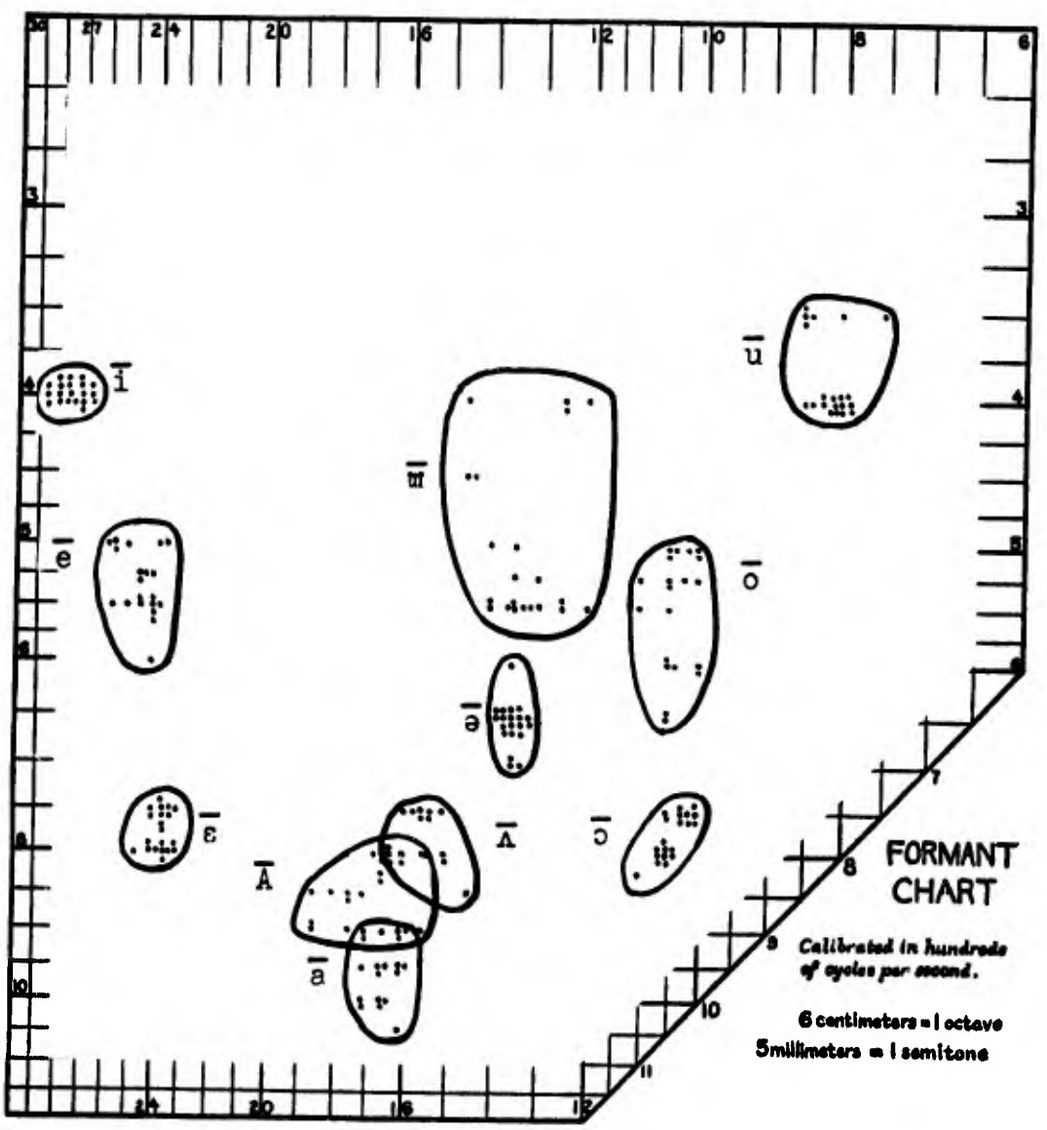
Word	1 F1	F2	F3	2 F1	F2	F3	3 F1	F2	F3	4 F1	F2	F3
tūn	400	850		400	825		400	800		400	800	
	350	850		350	850		350	850		400	800	
	400	800		400	825		400	800		400	800	
	350	800		400	800		350	750		400	850	
	350	850		400	800		400	800		400	800	

Blank spaces indicate where precise measurements were not obtainable.

FIGURE 2

Simple vowels in the environment /t - n/:

Level tone Informant 3



Informant 3 had previously made recordings of vowels in isolation with each of the six tones of Vietnamese. Although not all such isolated vowels are meaningful, this sort of exercise is quite common for students of Vietnamese. Since Informant 3 had often demonstrated these vowels and tones as a teacher of Vietnamese, she showed no hesitation in producing them for our study. Spectrograms were made from these recordings, and the F1 and F2 measurements were compiled.

Table 3 presents the F1 and F2 measurements of the vowels in isolation with each of the six tones. Figure 3 is the corresponding graphic representation of these F1 and F2 measurements on the formant chart.

In order to estimate the range of variation which might be associated with different initial consonants, Informant 3 was asked to record each vowel in various syllables composed of one initial consonant and the vowel with level tone. These syllables were recorded as a list of eighteen items in a fixed order, each stressed equally, e.g., /t$\bar{\text{i}}$, t$^{\text{h}}\bar{\text{i}}$, c$\bar{\text{i}}$, k$\bar{\text{i}}$ ..../ Table 4 represents the F1 and F2 measurements obtained from these recordings, and Figure 4 is the corresponding formant chart.

It must be noted that the two vowels /ʌ/ and /a/ occur only in closed syllables and so could not be included in this experiment. Figures 3 and 4 therefore present data for only 9 of the 11 simple vowels of Vietnamese.

TABLE 3

Formant measurements of simple vowels in isolation: Informant 3 cycles/second

Vowel [i] with all tones

Word	1 F1 F2 F3	2 F1 F2 F3	3 F1 F2 F3	4 F1 F2 F3
˥	300 2950	300 2750	300 3000	
˦	300 2900	400 2850	300 3100	300 2800
˧	275 2950	275 2950	275 2900	
˨˦	400 2800	400 2900	400 3050	
˩˧	350 2850	400 2750	400 2850	
˥˩	350 2900	350 2950	350 3000	
˦˥	400 2950	450 3000	400 3050	
˩	450 2800	400 2850	400 2800	

Vowel [e] with all tones

Word	1 F1 F2 F3	2 F1 F2 F3	3 F1 F2 F3	4 F1 F2 F3
˥	550 2600	550 2750	550 2700	
˦	550 2850	550 2700	550 2750	
˧	600 2650	600 2650	600 2650	
˨˦	650 2450	650 2600	600 2650	
˩˧	650 2550	550 2450	650 2550	
˥˩	700 2600	700 2550	700 2650	
˦˥	700 2550	650 2600	600 2550	

Vowel [ɛ] with all tones

Word	1 F1 F2 F3	2 F1 F2 F3	3 F1 F2 F3	4 F1 F2 F3
˥		900 2700	900 2700	900 2650
˦		850 2650	850 2550	850 2550
˧	850 2600	850 2650	850 2550	
˨˦	850 2500	750 2650	750 2600	
˩˧	900 2450	850 2500	850 2500	
˥˩	850 2400	900 2500	850 2450	
˦˥	850 2500	850 2450	850 2550	
˩	850 2500	800 2400	800 2450	

Vowel [æ] with all tones

Word	1 F1 F2 F3	2 F1 F2 F3	3 F1 F2 F3	4 F1 F2 F3
˥		600 1850	600 1850	600 1850
˦		550 1800	400 1150	400 1150
˧	450 1200	450 1800	450 1800	
˨˦	525 1350	525 1350	525 1800	
˩˧	400 1250	500 1300	500 1350	
˥˩	450 1100	500 1150	500 1800	
˦˥	475 1450	450 1350	450 1350	
˩	550 1350	600 1450	600 1400	

Vowel [A] with all tones

Word	1 F1 F2 F3	2 F1 F2 F3	3 F1 F2 F3	4 F1 F2 F3
˥		850 1450	850 1450	900 1450
˦		850 1600	850 1700	800 1650
˧	1150 1600	1150 1600	1000 1400	
˨˦	950 1550	950 1550	900 1600	
˩˧	1000 1600	1000 1450	1050 1600	
˥˩	1050 1650	1050 1600	1050 1550	
˦˥	1000 1550	950 1550	950 1500	
˩	900 1500	950 1500	950 1500	

Vowel [ɔ] with all tones

Word	1 F1 F2 F3	2 F1 F2 F3	3 F1 F2 F3	4 F1 F2 F3
˥	600 1000	600 1000	550 1150	
˦	650 1100	600 1000	600 1000	
˧	550 950	550 900	600 850	
˨˦	650 1100	650 1150	650 1100	
˩˧	700 1000	650 1000	650 950	
˥˩	650 1050	650 1150	585 1050	
˦˥	650 1050	550 1000	500 1000	
˩	650 1050	600 1000	500 1000	
˥	500 1050	500 1000	500 1000	
˦	500 1050	550 1000	500 1000	
˧	550 1050	600 1000	585 1050	

Vowel [ɛ] with all tones

Word	1 F1 F2 F3	2 F1 F2 F3	3 F1 F2 F3	4 F1 F2 F3
˥	750 1300	750 1250	650 1250	
˦	750 1350	750 1300	750 1300	
˧	750 1200	750 1450	700 1300	
˨˦	850 1300	800 1250	800 1200	
˩˧	850 1250	850 1250	850 1200	
˥˩	850 1350	850 1350	850 1400	
˦˥	850 1300	900 1400	900 1400	

Vowel [ɔ] with all tones

Word	1 F1 F2 F3	2 F1 F2 F3	3 F1 F2 F3	4 F1 F2 F3
˧	950 1150	950 1200	950 1150	
˨˦	900 1300	950 1250	900 1250	
˩˧	900 1100	900 1100	850 1150	
˥˩	850 1100	900 1150	900 1150	
˦˥	850 1250	900 1200	900 1200	
˩	850 1150	850 1150	850 1100	
˥		900 1200	850 1200	850 1150
˦		850 1150	850 1100	850 1100
˧	850 1100	850 1250	800 1100	850 1100
˨˦		750 1000	750 1000	750 1000
˩˧		800 1050	800 1050	800 1050
˥˩		800 1100	800 1050	850 1100
˦˥		800 1050	800 1050	800 1050
˩		750 1050	800 1050	800 1050
˥		800 1050	800 1050	800 1050
˦	800 1100	750 1050	750 1000	750 1000

Vowel [u] with all tones

Word	1 F1 F2 F3	2 F1 F2 F3	3 F1 F2 F3	4 F1 F2 F3
˧	400 1050	400 1050	400 1050	
˨˦	400 850	400 800	350 750	
˩˧	350 950	350 900	350 850	
˥˩	450 900	450 950	450 900	
˦˥	450 850	400 850	400 800	
˩	300 900	300 900	300 950	
˥	400 1000	400 1100	400 1000	
˦	400 1000	400 850	400 850	
˧	450 900	450 900	450 900	
˨˦	300 900	300 900	300 850	
˩˧	300 1000	300 1000	300 850	
˥˩	400 1150	450 1800	450 1150	
˦˥	300 1000	300 850	300 850	

Blank spaces indicate where precise measurements were not obtainable.

FIGURE 3

Simple vowels in isolation

All six tones Informant 3

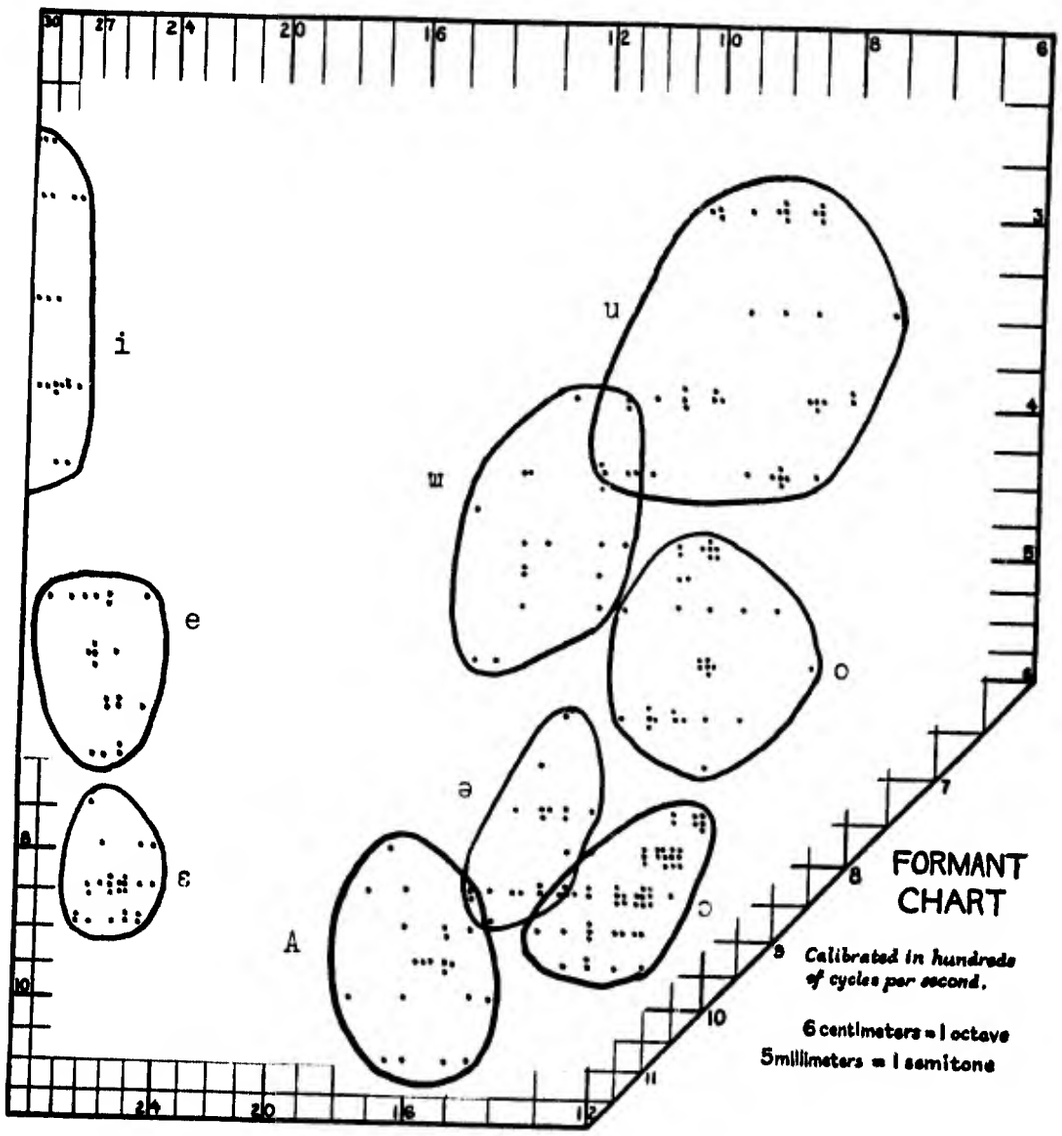


TABLE 4

Formant measurements of simple vowels in open syllables: Informant 3 cycles/second

Vowel [i] with tone [-]

Word	F1	F2
tī	300	2800
tʰī	275	2600
cī	400	2850
kī	300	2750
bī	300	2950
dī	275	2850
fī	250	2800
vī	250	2800
sī	400	2900
zī	300	2950
xī	250	2750
gī	400	2850
mī	400	2950
nī	300	2950
ɲī	350	2800
ŋī	350	2900
hī	275	2850
lī	350	2750

Vowel [ɵ] with tone [-]

Word	F1	F2
tɵ̄	525	1350
tʰɵ̄	550	1350
cɵ̄	650	1300
kɵ̄	525	1300
bɵ̄	525	1300
dɵ̄	650	1400
fɵ̄	600	1350
vɵ̄	600	1300
sɵ̄	600	1400
zɵ̄	650	1600
xɵ̄	500	1350
gɵ̄	600	1500
mɵ̄	600	1300
nɵ̄	650	1450
ɲɵ̄	600	1500
ŋɵ̄	600	1500
hɵ̄	600	1250
lɵ̄	650	1500

Vowel [e] with tone [-]

Word	F1	F2
tē	550	2450
tʰē	550	2450
cē	525	2450
kē	550	2600
bē	525	2600
dē	500	2600
fē	525	2400
vē	525	2450
sē	500	2600
zē	500	2500
xē	500	2600
gē	500	2500
mē	500	2400
nē	500	2700
ɲē	500	2550
ŋē	500	2500
hē	500	2500
lē	500	2500

Vowel [ɛ] with tone [-]

Word	F1	F2
tɛ̄	800	2450
tʰɛ̄	750	2350
cɛ̄	750	2300
kɛ̄	750	2550
bɛ̄	750	2600
dɛ̄	700	2500
fɛ̄	750	2400
vɛ̄	700	2500
sɛ̄	700	2500
zɛ̄	750	2300
xɛ̄	750	2550
gɛ̄	700	2500
mɛ̄	750	2650
nɛ̄	700	2550
ɲɛ̄	700	2550
ŋɛ̄	700	2550
hɛ̄	700	2500
lɛ̄	700	2500

Vowel [ɔ] with tone [-]

Word	F1	F2
tɔ̄	800	1050
tʰɔ̄	750	1000
cɔ̄	750	1100
kɔ̄	800	1050
bɔ̄	750	1000
dɔ̄	850	1200
fɔ̄	750	1000
vɔ̄	750	1000
sɔ̄	850	1200
zɔ̄	850	1200
xɔ̄	800	1150
gɔ̄	800	1100
mɔ̄	750	950
nɔ̄	750	950
ɲɔ̄	750	950
ŋɔ̄	750	1000
hɔ̄	800	1150
lɔ̄	850	1200

Vowel [ɯ] with tone [-]

Word	F1	F2
tɯ̄	300	1500
tʰɯ̄	400	1450
cɯ̄	400	1400
kɯ̄	400	1450
bɯ̄	400	1450
dɯ̄	550	1500
fɯ̄	400	1400
vɯ̄	400	1350
sɯ̄	550	1500
zɯ̄	550	1650
xɯ̄	400	1400
gɯ̄	400	1500
mɯ̄	400	1350
nɯ̄	400	1650
ɲɯ̄	400	1600
ŋɯ̄	500	1400
hɯ̄	350	1600
lɯ̄	500	1600

Vowel [ʌ] with tone [-]

Word	F1	F2
tʌ̄	750	1750
tʰʌ̄	750	1800
cʌ̄	750	1750
kʌ̄	750	1750
bʌ̄	850	1650
dʌ̄	950	1700
fʌ̄	850	1500
vʌ̄	950	1550
sʌ̄	700	1650
zʌ̄	850	1800
xʌ̄	950	1650
gʌ̄	950	1800
mʌ̄	800	1650
nʌ̄	800	1850
ɲʌ̄	700	1850
ŋʌ̄	700	1850
hʌ̄	800	1650
lʌ̄	900	1600

Vowel [u] with tone [-]

Word	F1	F2
tū	400	850
tʰū	400	850
cū	400	825
kū	400	950
bū	400	850
dū	425	950
fū	400	850
vū	400	825
sū	425	800
zū	400	850
xū	400	900
gū	425	800
mū	400	1000
nū	425	850
ɲū	425	800
ŋū	400	1000
hū	400	850
lū	425	950

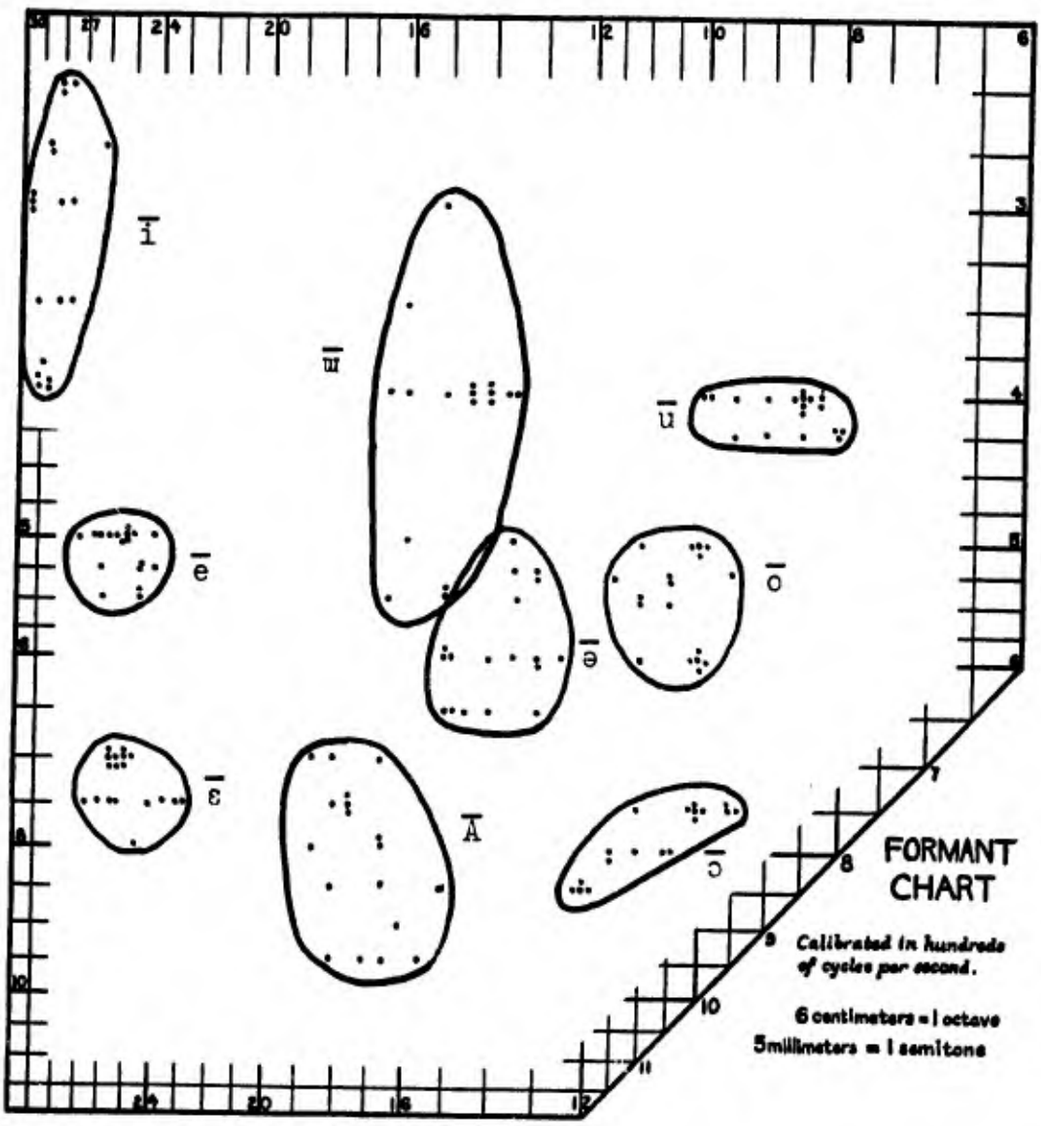
Vowel [o] with tone [-]

Word	F1	F2
tō	550	1100
tʰō	525	1050
cō	550	1100
kō	525	950
bō	600	1000
dō	600	1000
fō	600	1000
vō	600	1000
sō	600	1000
zō	550	1050
xō	525	1050
gō	525	1150
mō	500	1000
nō	500	1000
ɲō	500	1000
ŋō	500	1000
hō	500	1100
lō	600	1100

FIGURE 4

Simple vowels in open syllables

Level tone Informant 3



In looking at Figures 2, 3, and 4, one gets the impression that the vowel domains in these three figures show some difference. This is due to the previously mentioned characteristics of the formant bands of a female voice which make the identification of the center of formants very difficult. However, a careful comparison reveals that the relative positions of the vowel domains in each chart are comparable, and also that the vowels in the /t - n/ environment represented in Figure 2 seem to represent accurately the relative position of each vowel to the others. Figure 3 and Figure 4 may be regarded as extra data supporting 9 of the 11 vowel domains presented in Figure 2. In any event, the relative positions of /e/, /ə/, and /o/ which are of prime importance to this particular study are defined adequately. Therefore, the domains of /e/, /ə/, and /o/ as presented in Figures 1 and 2 will be used when comparing the phonetic qualities of simple vowels with the phonetic qualities of [ʒ], [ɨ], and [θ] in the following experiments.

Informant 1 had previously recorded syllables with the eleven simple vowels in the environment /t - n/ with level tone for a study of the inherent duration of vowels in Vietnamese. He left before we could make recordings of the complex nuclei in the same environment. However, from other recordings prepared by him, we selected some examples of syllables with complex nuclei in similar environments.

The measurements of Informant 1's simple vowels in the environment /t - n/ are reproduced in Table 5, and the graphic representation on a formant chart is seen in Figure 5.

Informant 2, also, had not recorded the desired material for this study before he left us. However, Informant 2's formant measurements were published in substantial amount in our Vol. IV and were useful as references in analysing his complex nuclei.

Spectrograms No. 1a - 11a show typical spectrograms of the simple vowels in the environment /t - n/ as spoken by Informant 4. The same vowels spoken by Informant 3, a female speaker, are shown in Spectrograms No. 1b - 11b. Typical spectrograms of the complex nuclei [Iɜ], [ɯɪ], and [Uθ] as spoken in the environment [t - n] are shown in Spectrograms No. 12a - b, 13a - b, and 14a - b, for Informants 4 and 3 respectively.

In the changing formants of the complex nuclei, there are no obvious points indicated at which the measurements should be taken. To determine the most reasonable points to be considered as the target or near target qualities of the complex nuclei, several steps were taken. Taking the complex nucleus [Iɜ], for example, first, the boundary between the two segments of the nucleus was identified with extreme care. Observation of steady states, upper formants, and amplitude contour, as shown in Spectrogram No. 15, served to identify the most logical point in time which could be considered as

TABLE 5

Formant measurements of simple vowels in the environment /t - n/: Informant 1 cycles/second

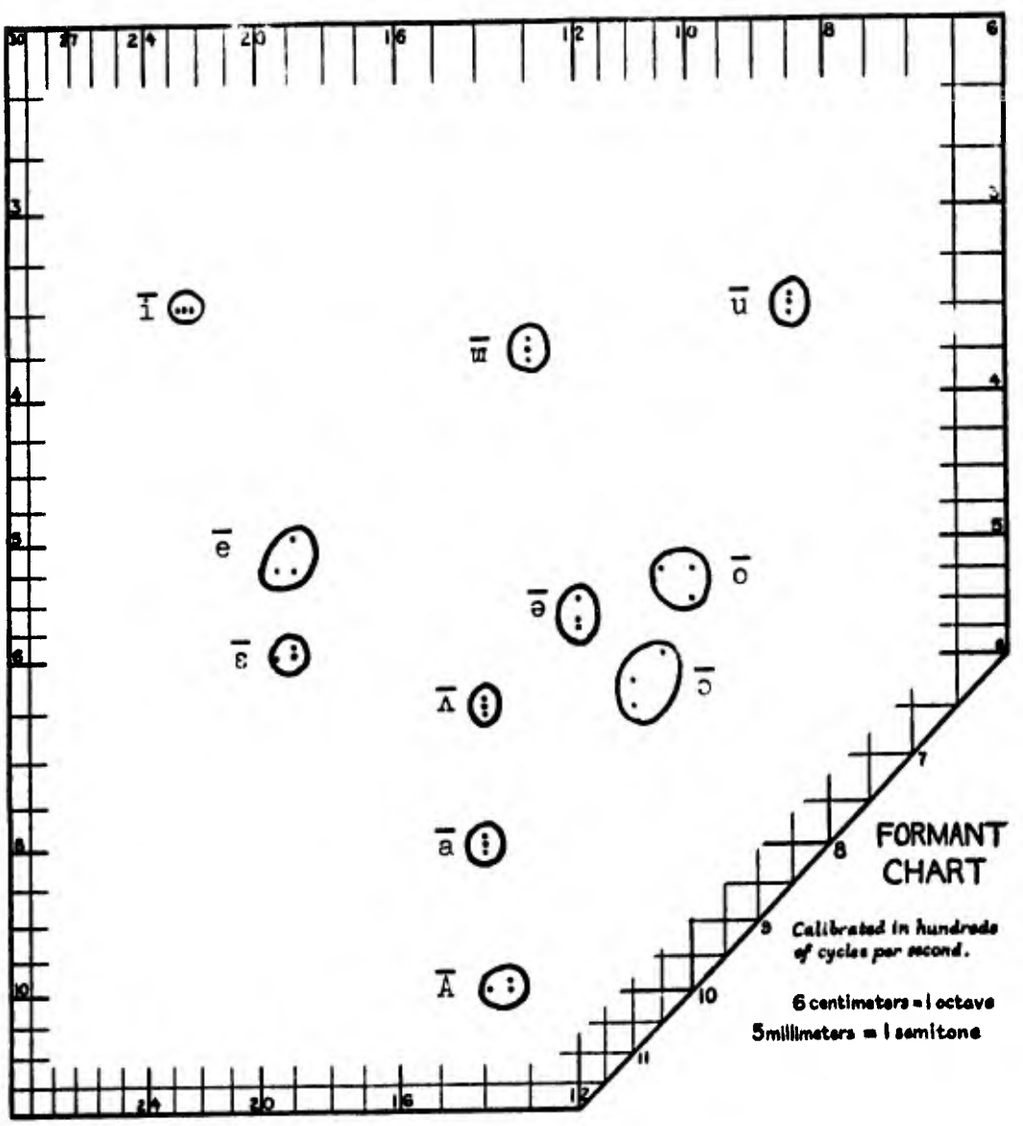
Word	1		2		3		4	
	F1	F2	F1	F2	F1	F2	F1	F2
tīn			350	2250	350	2250	350	2250
tēn			525	1900	500	1900	525	1950
tɛ̄n			600	1900	600	1900	600	1950
tān			800	1400	800	1400	800	1400
tĀn			1000	1350	1000	1350	1000	1400
tʌ̄n			650	1400	650	1400	650	1400
tə̄n			575	1200	575	1200	550	1200
tʊ̄n			375	1300	375	1300	375	1300
tɔ̄n			600	1050	650	1100	625	1100
tōn			525	1050	550	1000	525	1000
tūn			350	850	350	850	350	850

Blank spaces indicate where precise measurements were not obtainable.

FIGURE 5

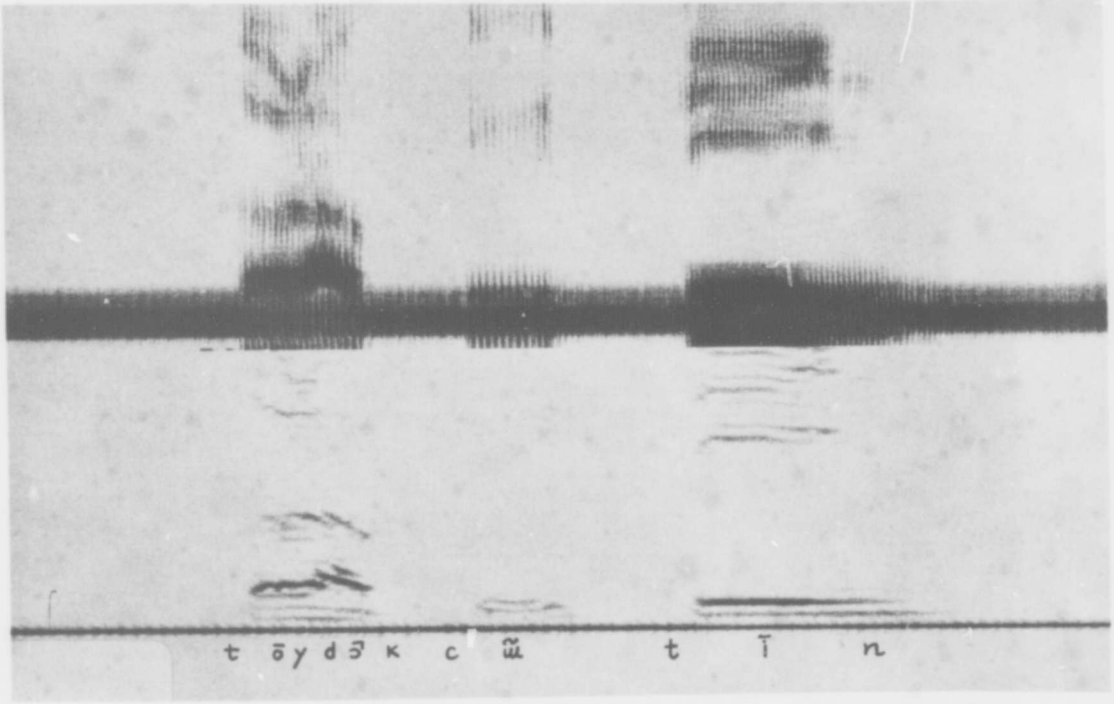
Simple vowels in the environment /t - n/

Level tone Informant 1

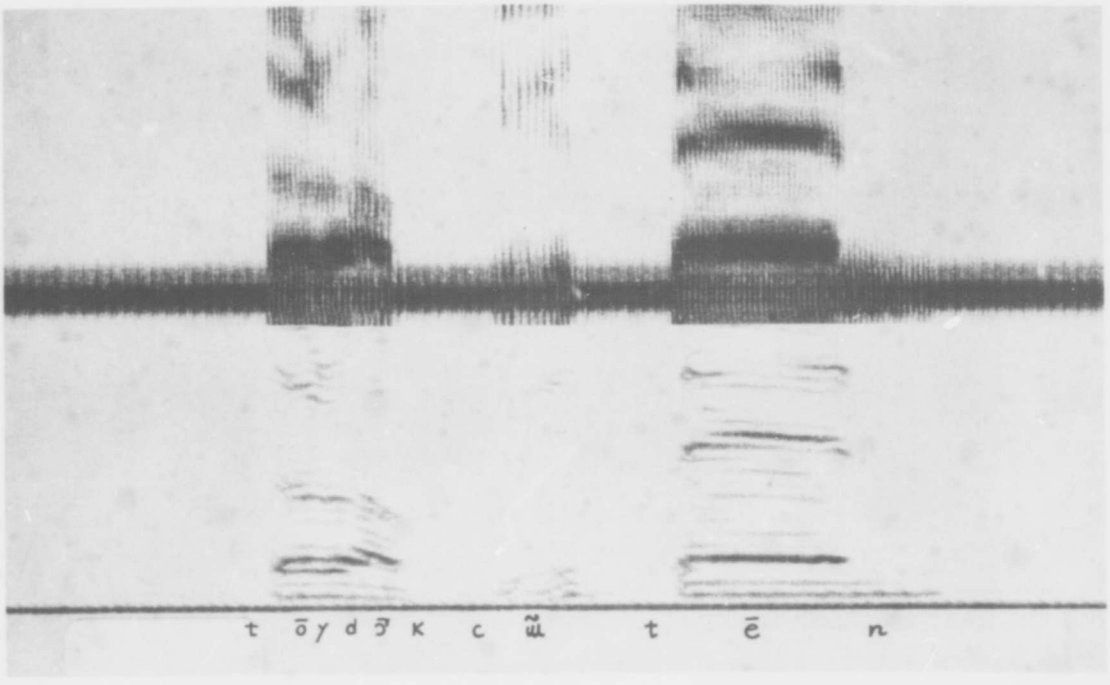


SPECTROGRAM NO. 1a

Informant 4

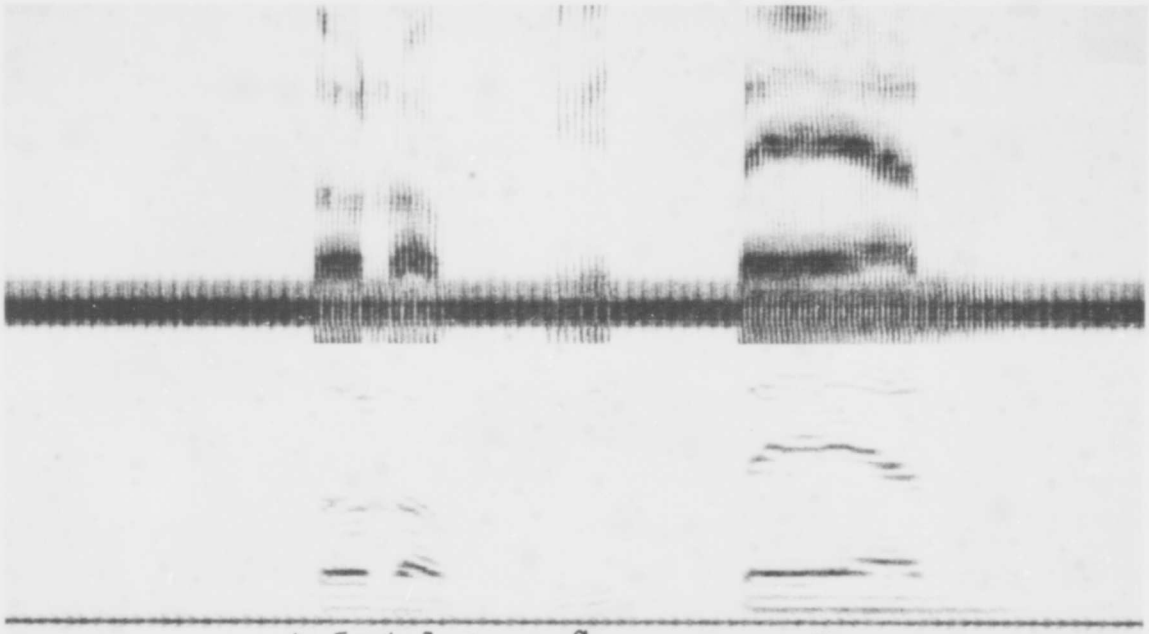


SPECTROGRAM NO. 2a

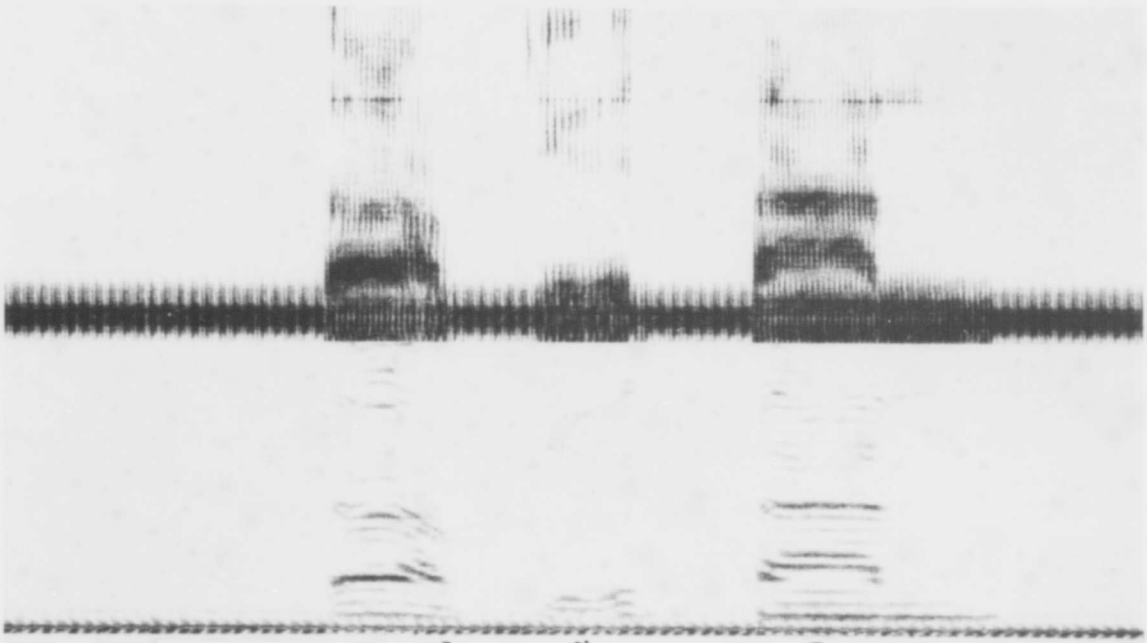


SPECTROGRAM NO. 3a

Informant 4

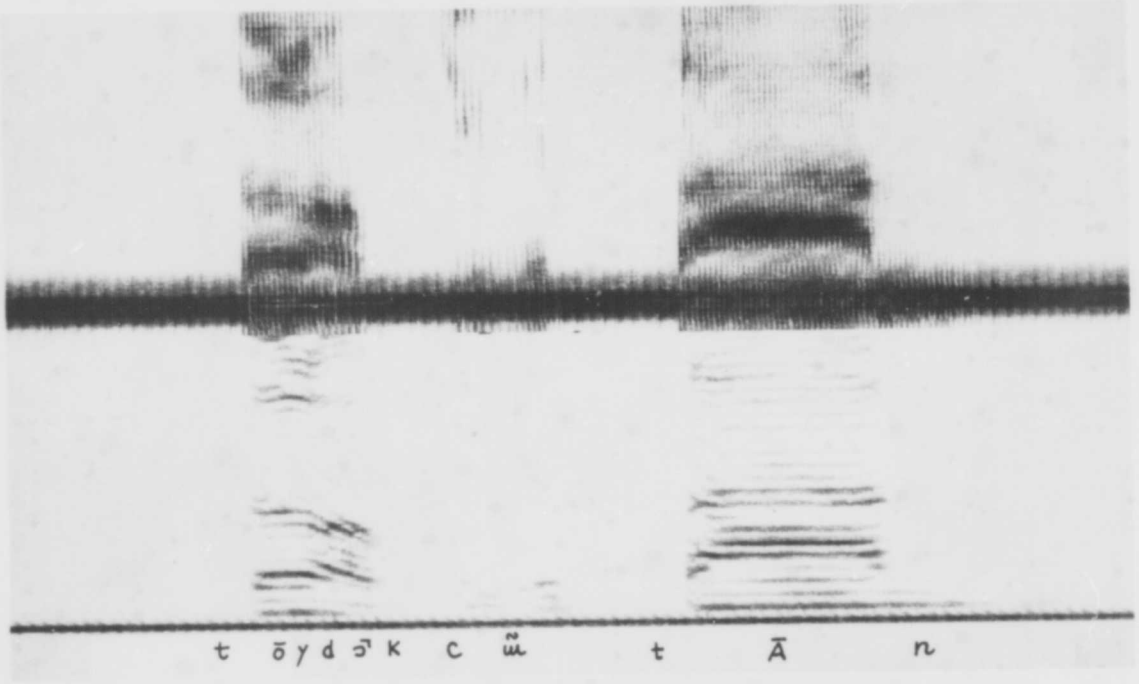


SPECTROGRAM NO. 4a

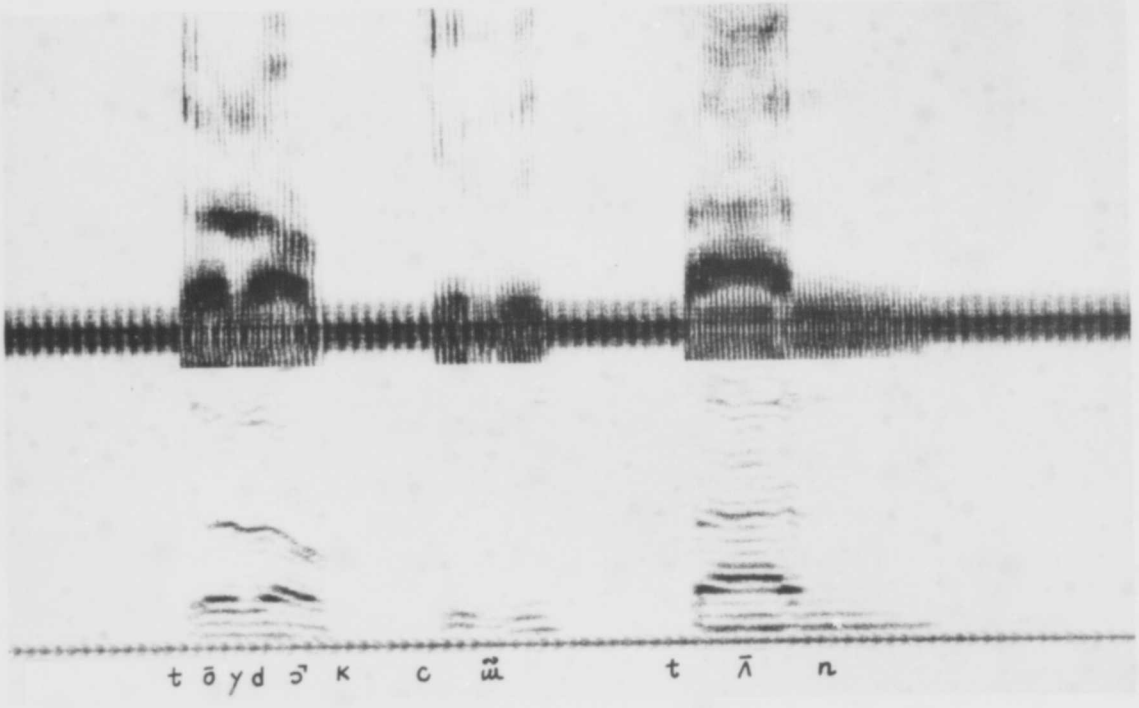


SPECTROGRAM NO. 5a

Informant 4

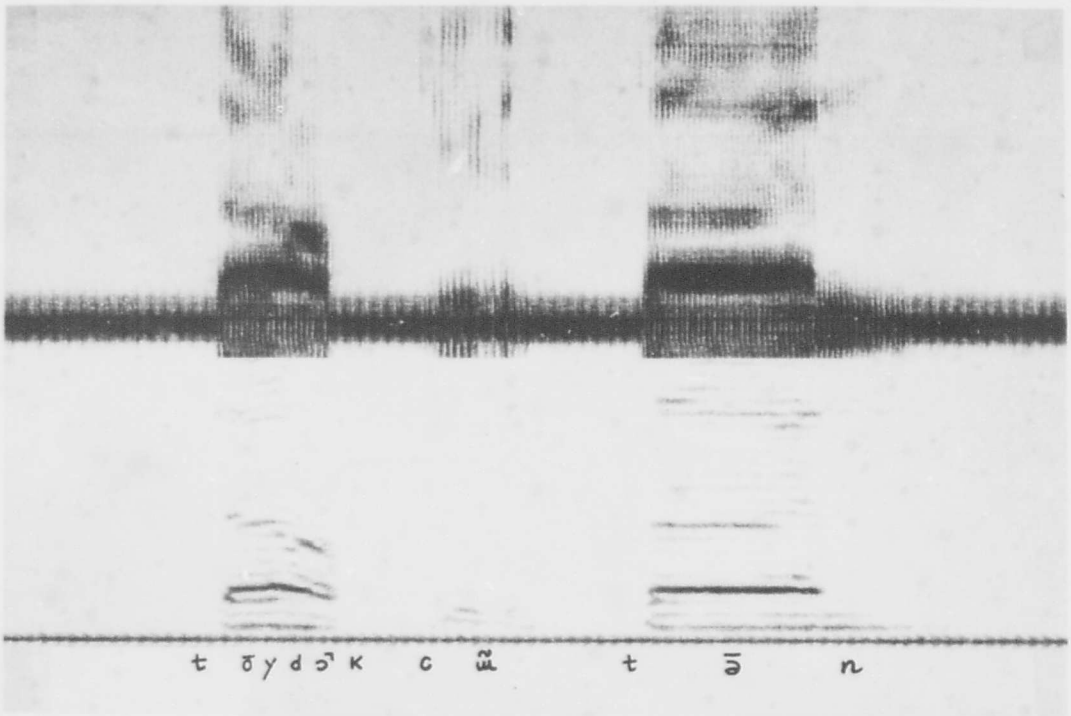


SPECTROGRAM NO. 6a

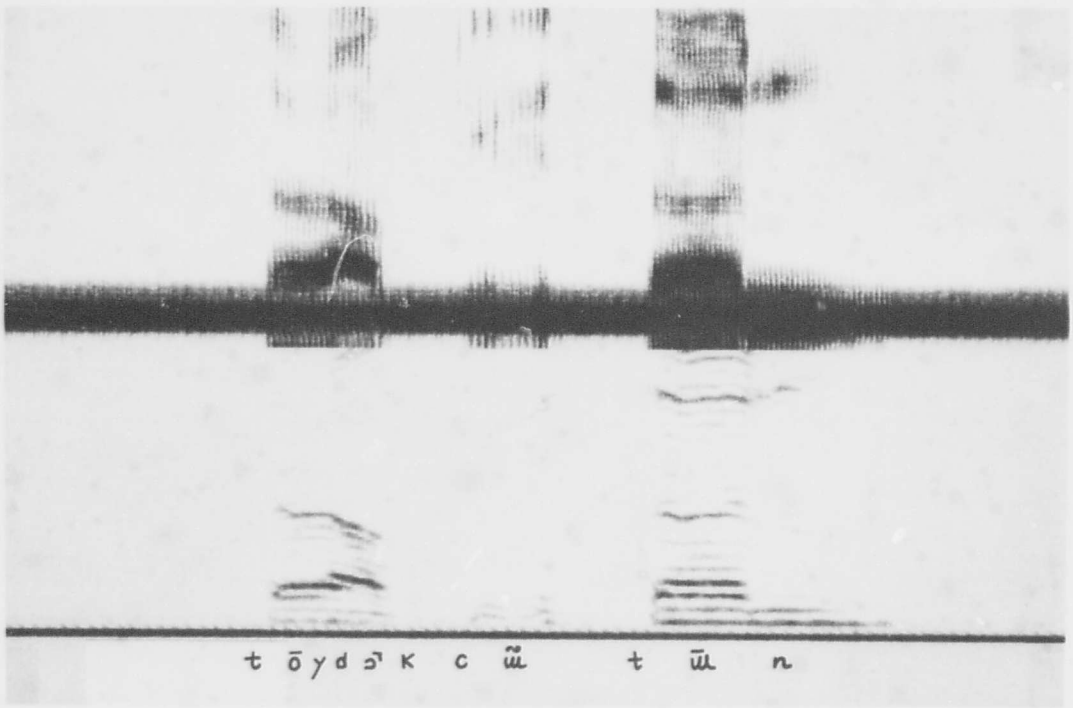


SPECTROGRAM NO. 7a

Informant 4

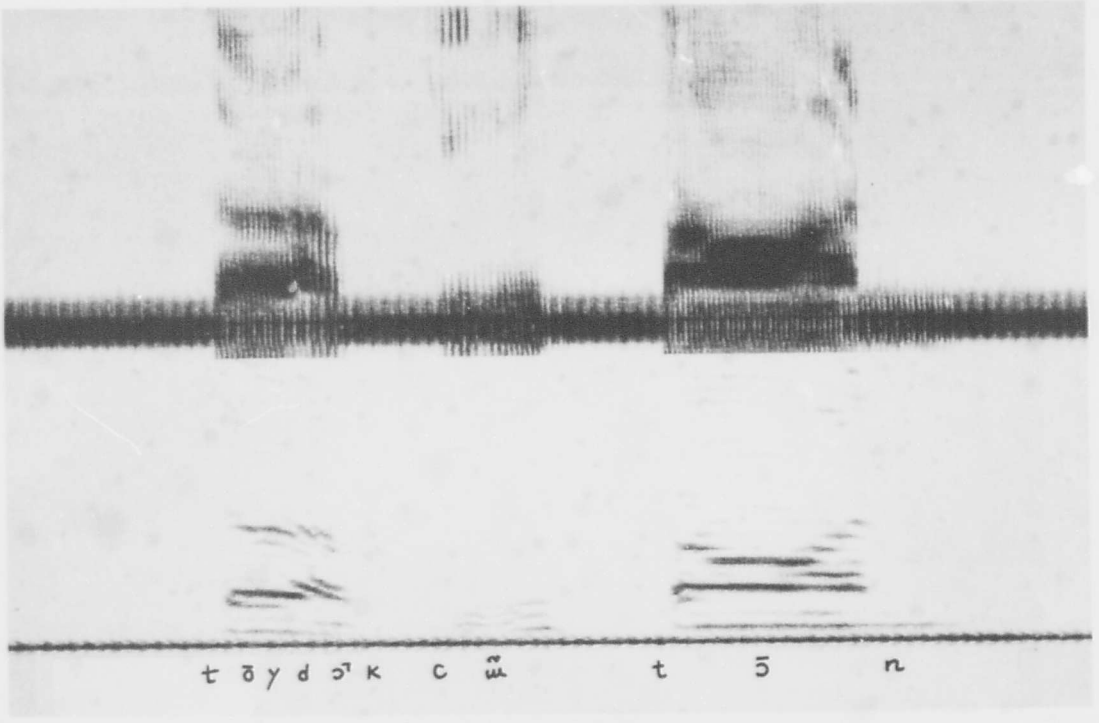


SPECTROGRAM NO. 8a

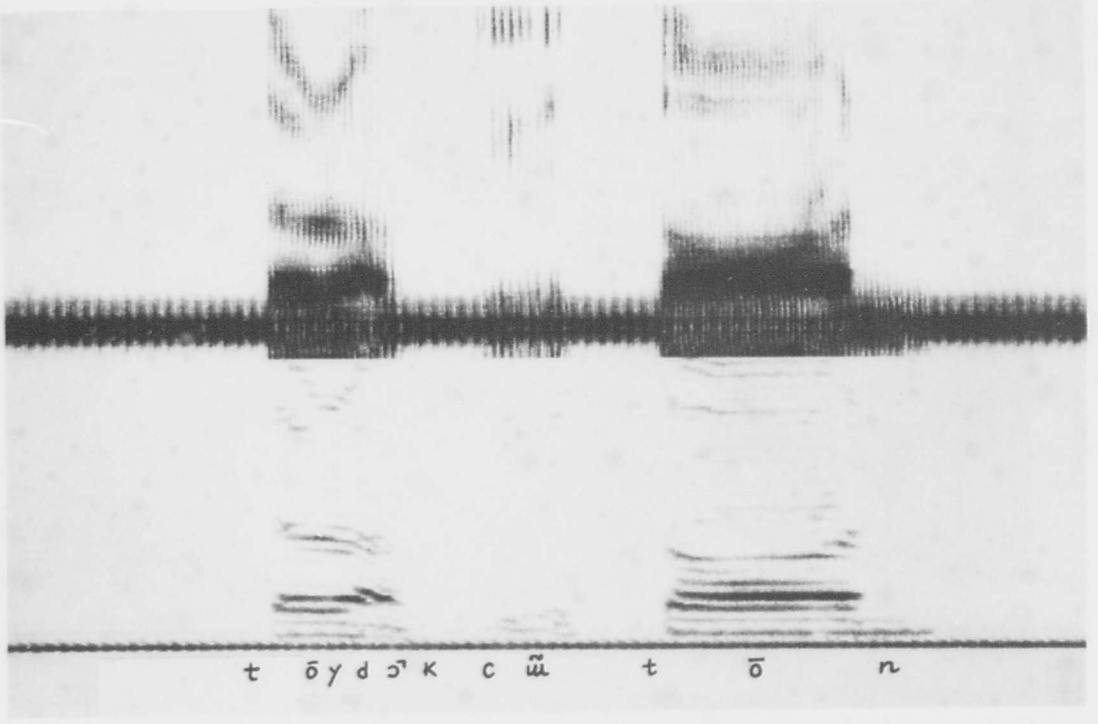


SPECTROGRAM NO. 9a

Informant 4

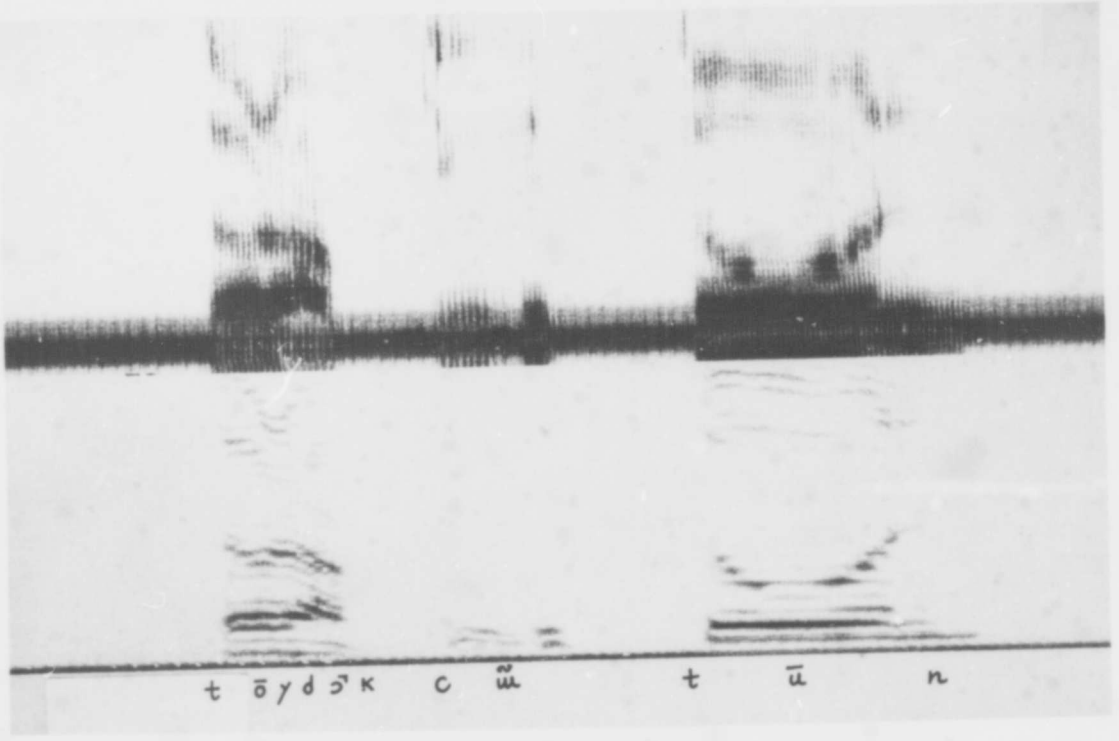


SPECTROGRAM NO. 10a



SPECTROGRAM NO. 11a

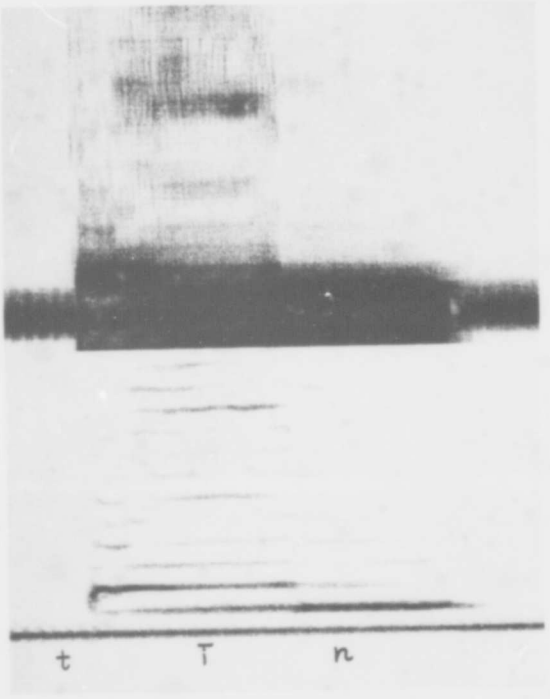
Informant 4

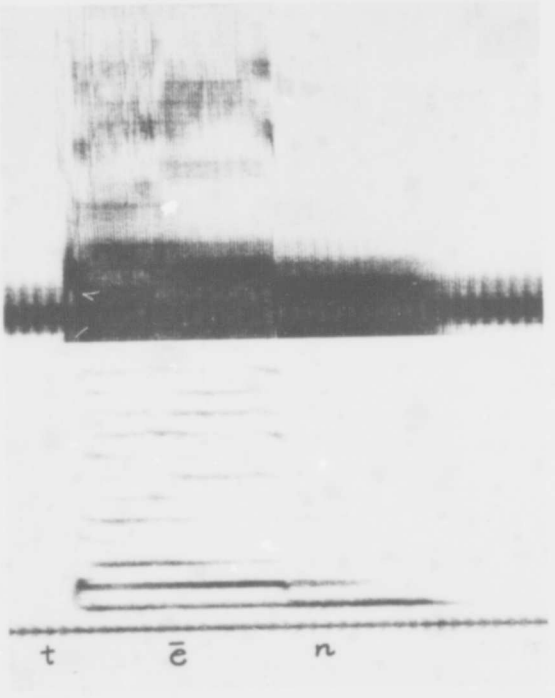


SPECTROGRAM NO. 1b

SPECTROGRAM NO. 2b

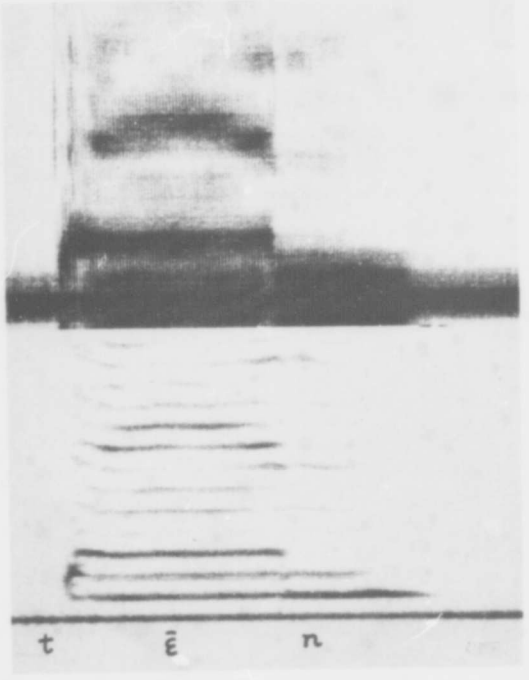
Informant 3

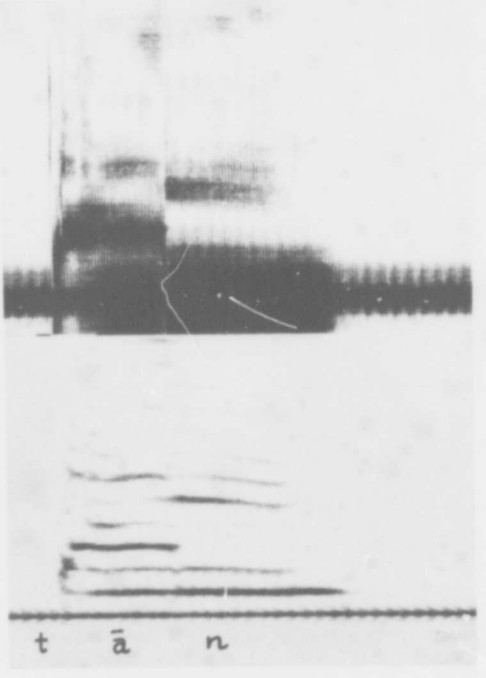




SPECTROGRAM NO. 3b

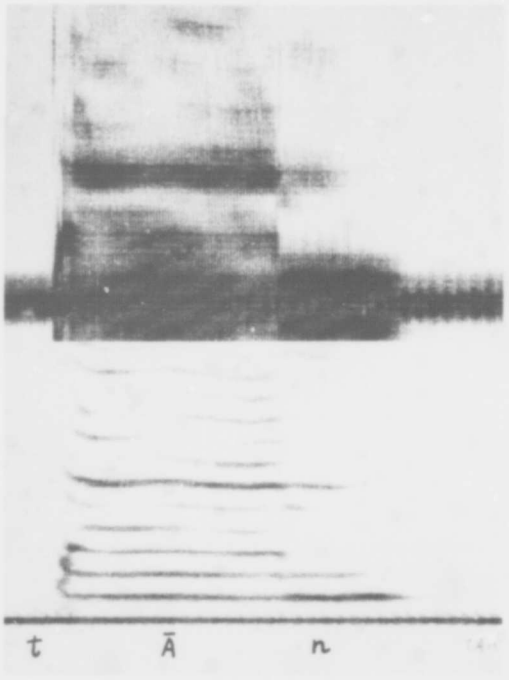
SPECTROGRAM NO. 4b





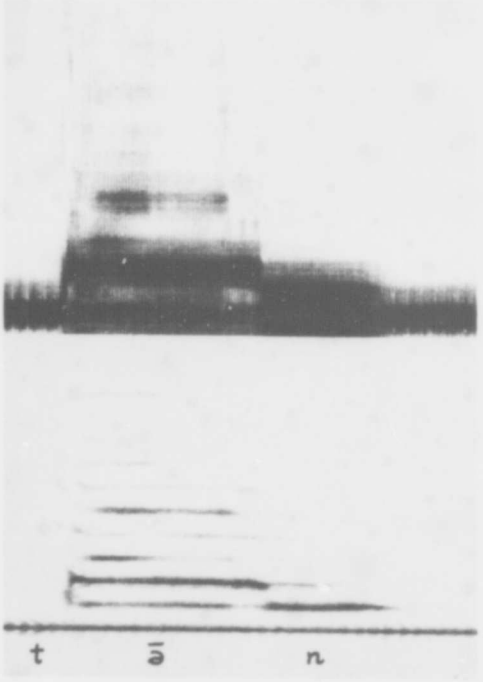
SPECTROGRAM NO. 5b

Informant 3

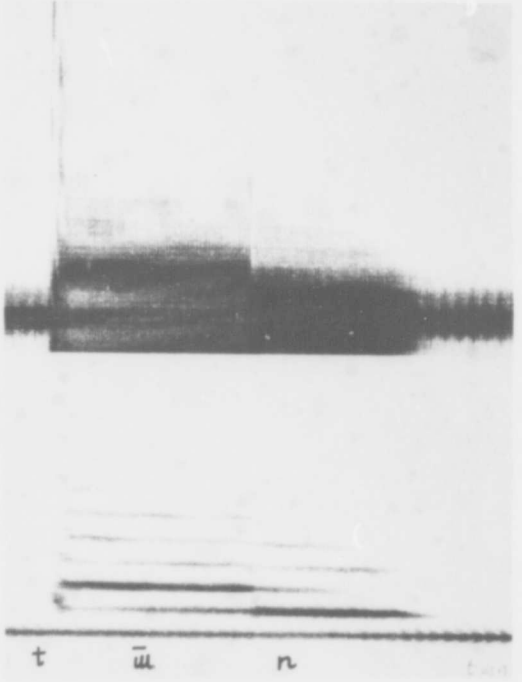


SPECTROGRAM NO. 6b

SPECTROGRAM NO. 7b



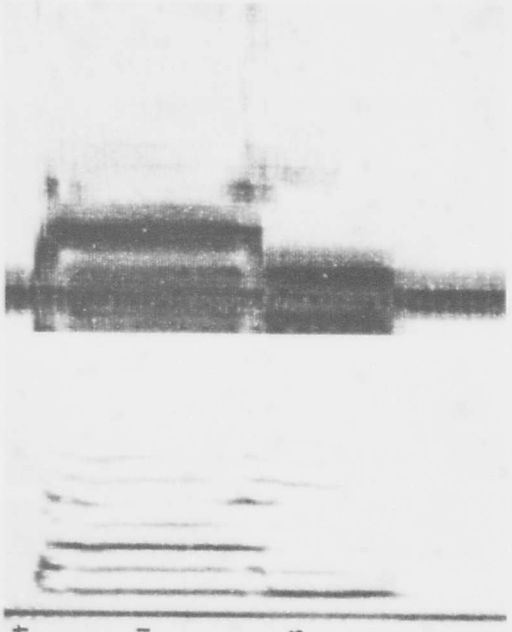
SPECTROGRAM NO. 8b

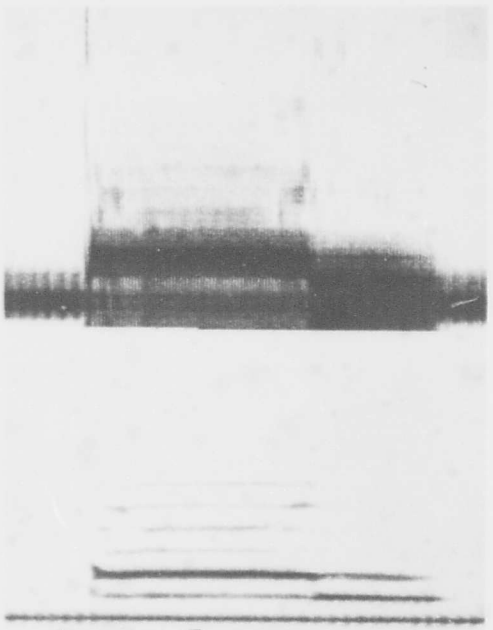


SPECTROGRAM NO. 9b

SPECTROGRAM NO. 10b

Informant 3





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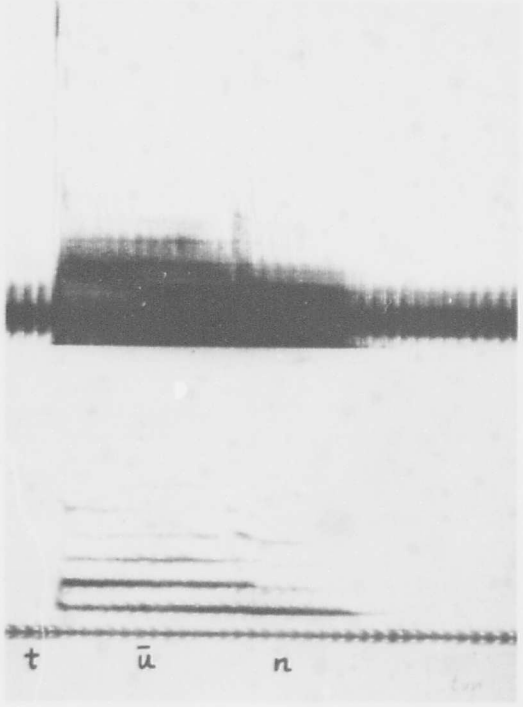
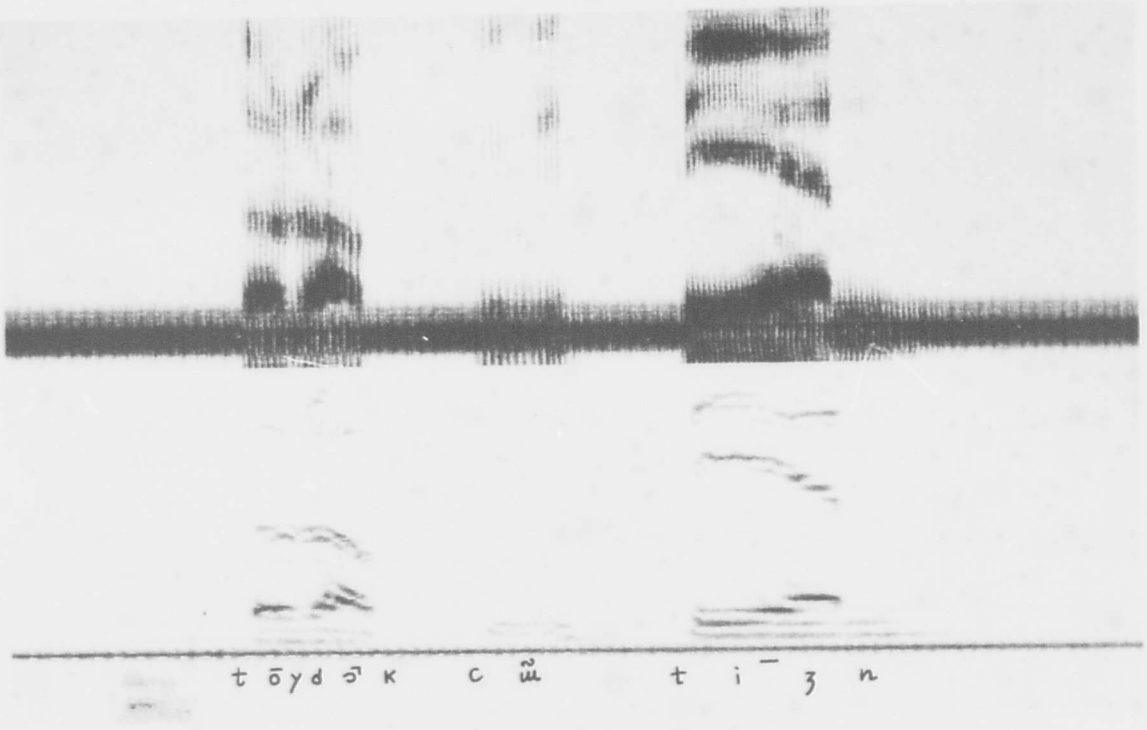
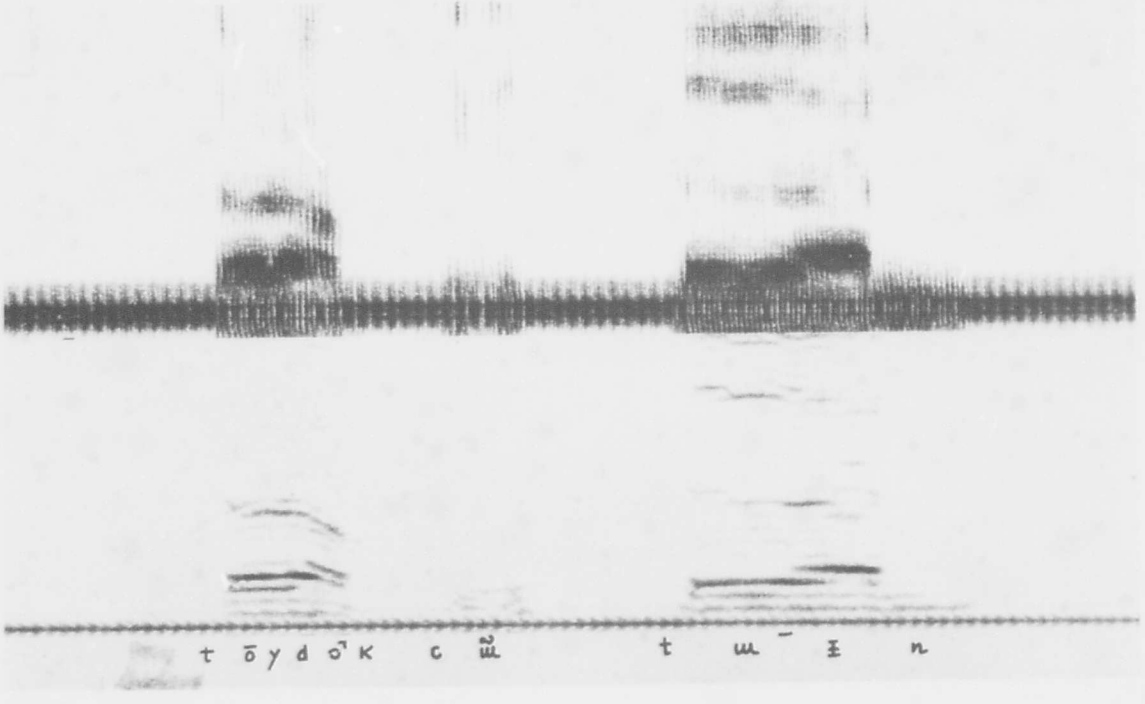


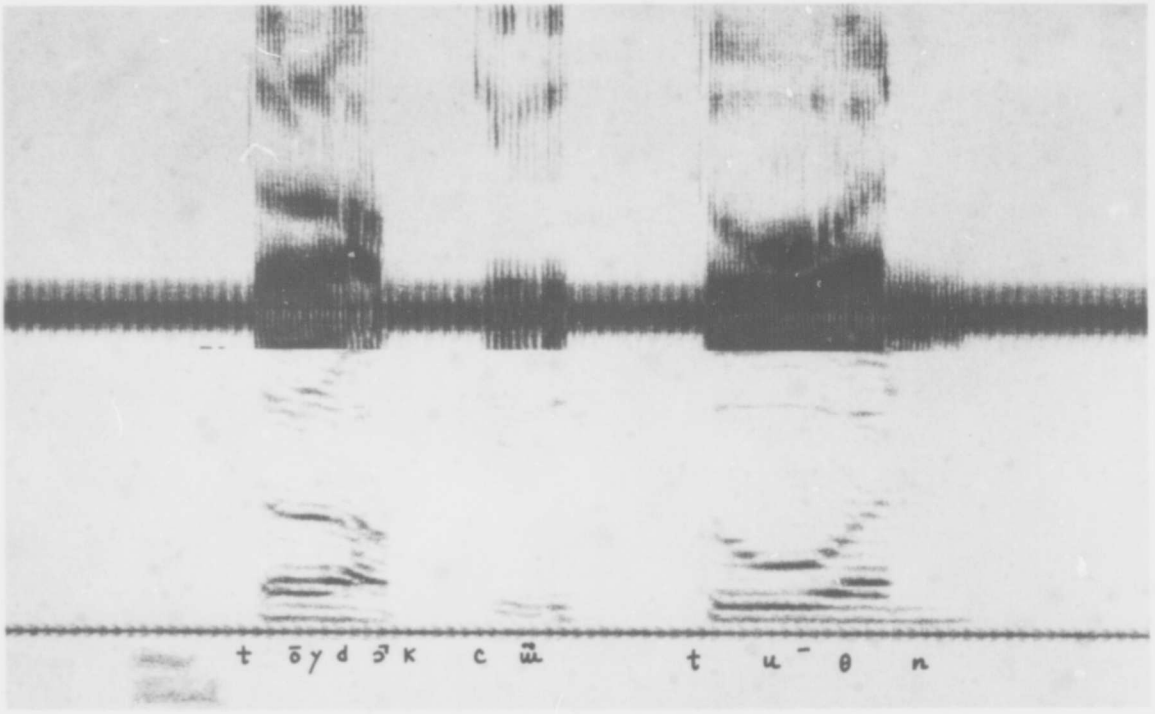
SPECTROGRAM NO. 12a Informant 4



SPECTROGRAM NO. 13a

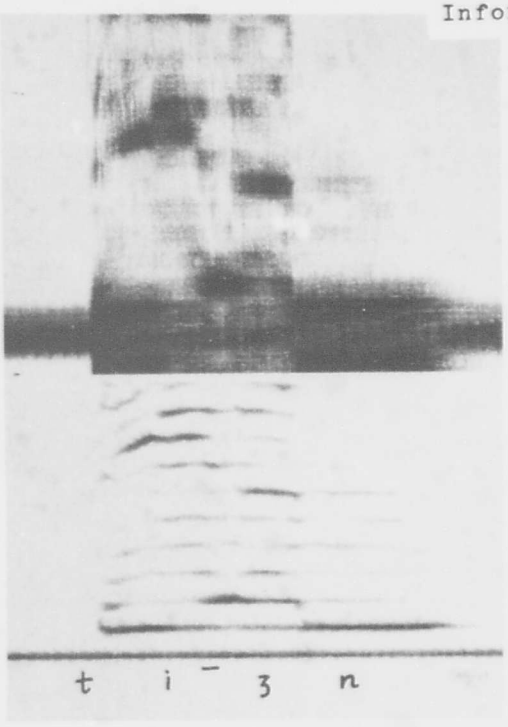


SPECTROGRAM NO. 14a Informant 4

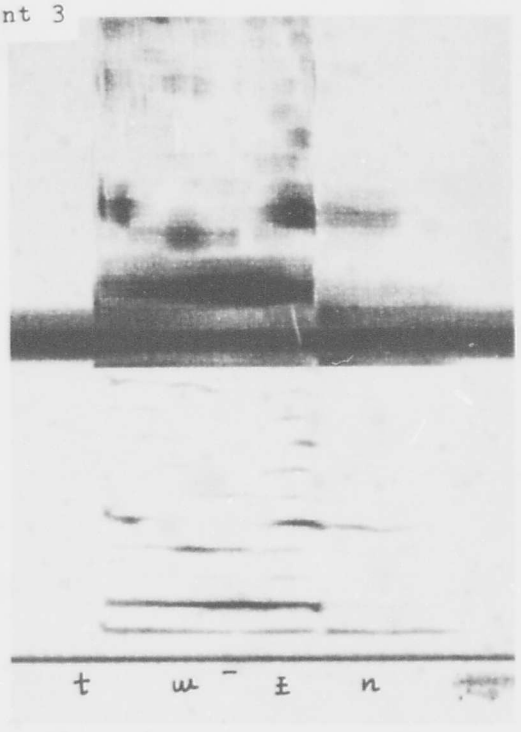


SPECTROGRAM NO. 12b

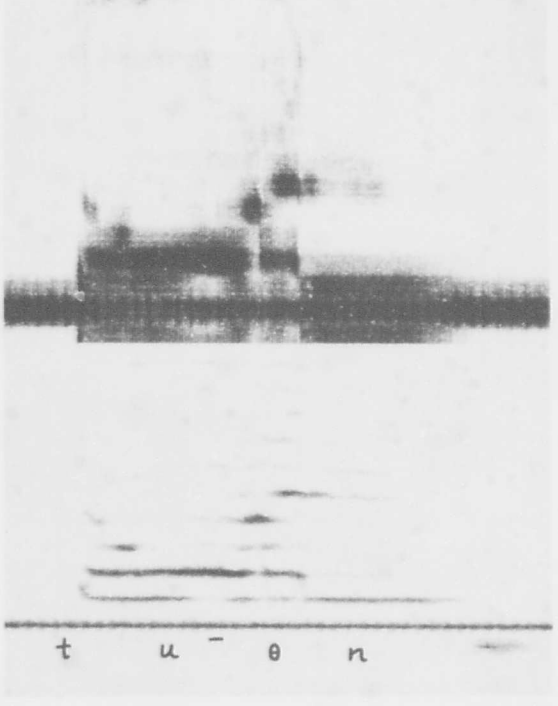
Informant 3



SPECTROGRAM NO. 13b



SPECTROGRAM NO. 14b



a boundary between the 2 segments. The mid-way point between the beginning of the formant and this boundary was then taken as the target quality of the first segment of the nucleus, [I]; and, the mid-way point between the boundary and the end of the formant was considered as the target of the second segment, [ɜ].

Recordings of [Iɜ], [ɯɪ], and [Uθ] in the environment /t - n/ were made using the same frame sentence /to͞y do͞k cɯ̃ t-n; t-n, t-n, t-n./

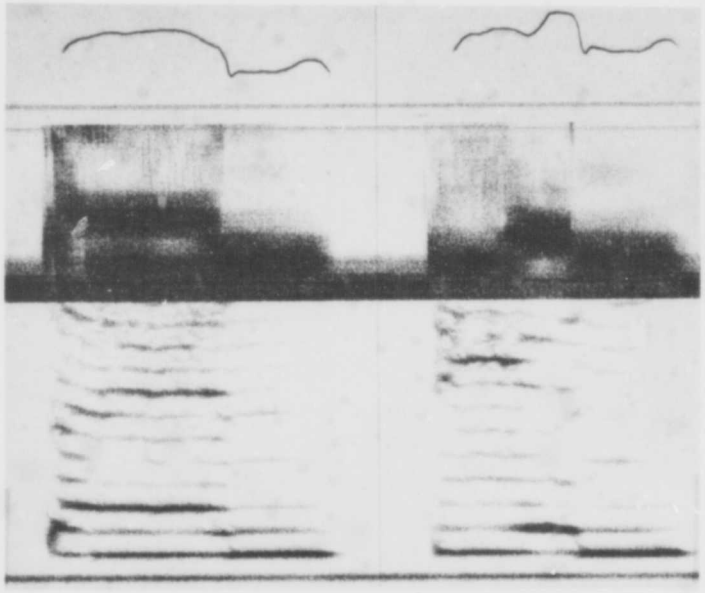
Informant 4's speech was examined first because it is easier to work with the formant measurements of a male voice. On listening carefully to the initial vowel qualities of the complex nuclei, it was found that they sound very much like /i/, /ɯ/, and /u/ respectively. To confirm this auditory impression with acoustic data, we measured F1 and F2 of [I] and [ɜ] in the word [tI͞ɜ͞n], of [ɯ] and [ɪ] in the word [tɯ͞ɪ͞n] and of [U] and [θ] in the word [tUθn]. These measurements are presented in Table 6.

Figure 6 is a composite graphic representation of the domains of the complex nuclei [Iɜ], [ɯɪ], [Uθ] and the domains of the simple vowels. The dots and the solid line circles represent the measurements of Table 6, while the broken line circles represent the domains of the simple vowels of the same speaker as obtained earlier and recorded in Table 1 and Figure 1.

SPECTROGRAM NO. 15

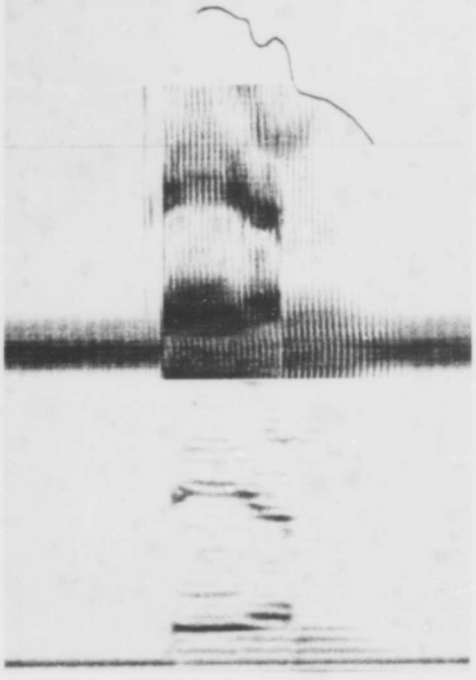
Amplitude contours of [ɛ] and [iʒ]

Informant 3



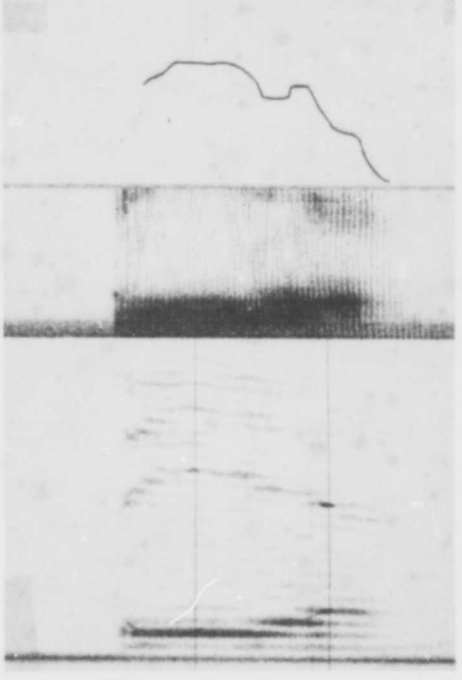
t ɛ n t i ʒ n

Informant 1



t i ʒ n

Informant 4



t i ʒ

TABLE 6

Formant measurements of complex nuclei in the environment /t - n/: Informant 4 cycles/second

Segment [i] with tone [-]

Word	1 F1 F2 F3	2 F1 F2 F3	3 F1 F2 F3	4 F1 F2 F3
tī̄n	300 2300 2950	300 2200 2950	350 2250 2900	350 2150 2950
	300 2350 2850	300 2300 3050	350 2250 2800	350 2200 2800
	300 2300 2850	300 2300 3000	300 2250 3000	350 2100 2900
	300 2300 2800	300 2300 3000	300 2250 2950	300 2400 2950
	300 2350 2950	300 2350 3000	300 2250 2900	300 2400 3000

Segment [ɪ] with tone [-]

Word	1 F1 F2 F3	2 F1 F2 F3	3 F1 F2 F3	4 F1 F2 F3
tɪ̄n	600 1950 2800	600 1950 2850	550 1950 2800	550 2000 2800
	550 2000 2800	550 2050 2850	575 1950 2800	550 2000 2800
	625 2000 2800	625 2000 2850	600 1950 2850	600 1900 2800
	600 1950 2750	600 1950 2750	600 2000 2800	600 2000 2850
	650 2000 2950	650 2000 2800	650 2000 2850	650 2000 2800

Segment [ɯ] with tone [-]

Word	1 F1 F2 F3	2 F1 F2 F3	3 F1 F2 F3	4 F1 F2 F3
tɯ̄n	450 1450	450 1400	450 1400	450 1400
	450 1400	450 1450	425 1350	450 1400
	450 1450	450 1350	450 1350	500 1400
	400 1350	450 1450	450 1400	400 1450
	450 1450	500 1500	450 1350	500 1300

Segment [ʉ] with tone [-]

Word	1 F1 F2 F3	2 F1 F2 F3	3 F1 F2 F3	4 F1 F2 F3
tʉ̄n	550 1500	550 1450	550 1450	600 1450
	600 1400	600 1400	600 1400	600 1400
	600 1400	600 1450	600 1400	600 1400
	650 1450	625 1450	600 1450	600 1450
	650 1450	600 1400	625 1450	650 1450

Segment [u] with tone [-]

Word	1 F1 F2 F3	2 F1 F2 F3	3 F1 F2 F3	4 F1 F2 F3
tū̄n	300 800	300 800	300 800	350 750
	325 750	325 800	350 750	325 750
	300 800	350 800	350 800	400 800
	350 800	400 850	350 850	350 800
	300 800	350 800	400 800	300 800

Segment [ɵ] with tone [-]

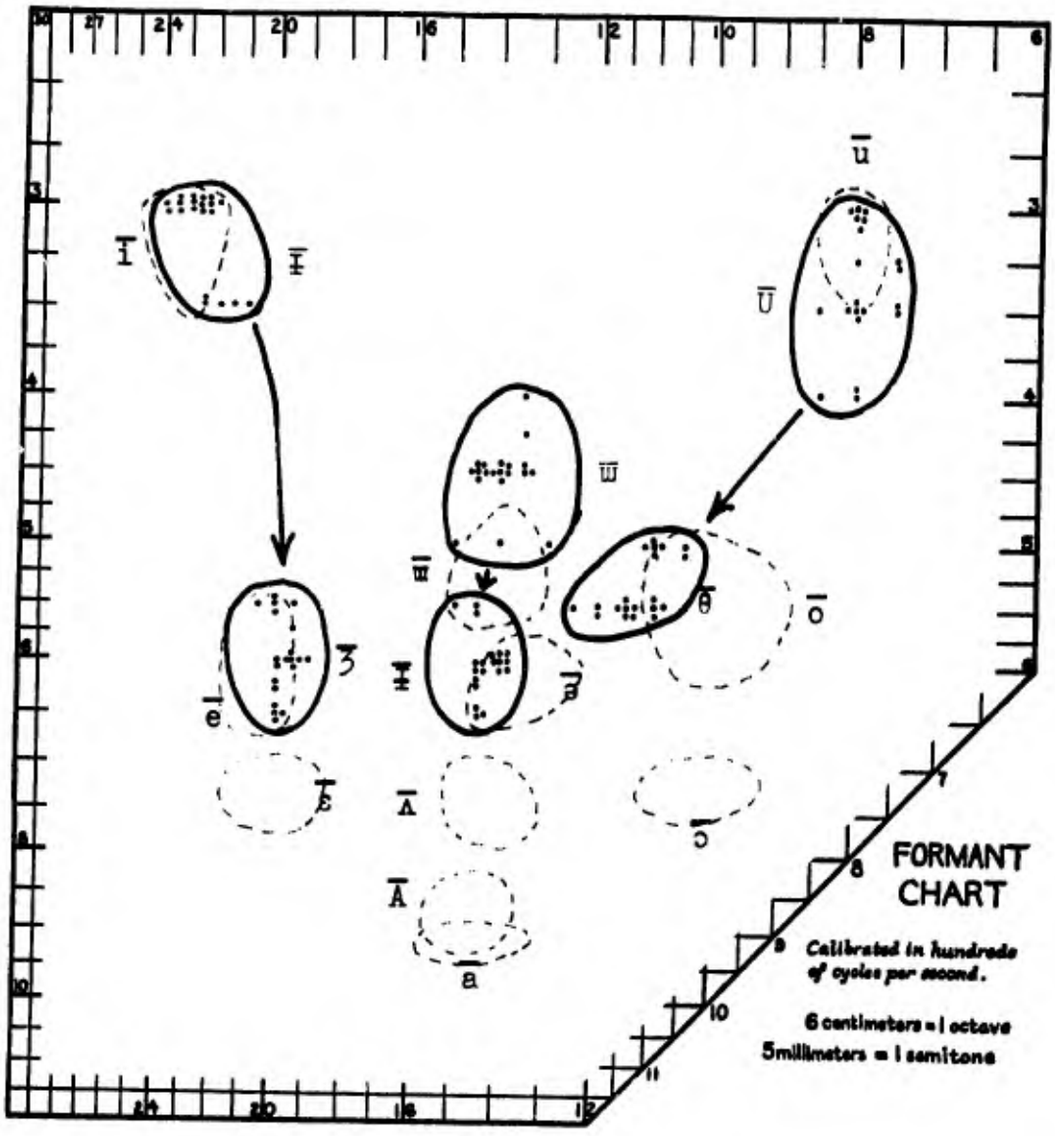
Word	1 F1 F2 F3	2 F1 F2 F3	3 F1 F2 F3	4 F1 F2 F3
tɵ̄n	550 1150	550 1250	500 1100	500 1100
	500 1100	500 1050	500 1100	500 1050
	550 1100	550 1100	550 1200	550 1150
	550 1150	550 1150	500 1100	550 1150
	550 1200	550 1100	550 1150	550 1100

Blank spaces indicate where precise measurements were not obtainable.

FIGURE 6

Complex nuclei compared with simple vowels in the environment /t - n/

Level tone Informant 4



As can be seen in Figure 6, the first segments of the complex nuclei [I̲ɜ], [ɯ̲ɪ], and [U̲θ] are phonetically similar to [i], [ɯ], and [u]. The acoustic data confirms the auditory impression shared by all analysts that the first segments of the complex nuclei [Iɜ], [ɯɪ], and [Uθ] are phonetically the same as [i], [ɯ], and [u] respectively. They are so phonetically similar, in fact, that we will hereafter transcribe them as [i], [ɯ], and [u] in our data.

In Figure 6, it is clearly observed that the formant measurements of [ɜ], [ɪ], and [θ] form three distinct areas. The domain of [ɜ] corresponds closely to that of /e/, [ɪ] corresponds roughly to that of /ɵ/, and the domain of [θ] is closer to that of /o/ than to any other vowel.

Having confirmed that the qualities of [I ɯ U] are the same as /i ɯ u/ of the simple vowels, we then focused our attention on the second elements only, in the formant analysis of the other informants. Using the same procedures,we measured F1 and F2 of [ɜ], [ɪ], and [θ] as spoken by Informant 3.

Table 7 represents F1 and F2 of [ɜ], [ɪ], and [θ] in [tī‾ɜ‾n], [tɯ‾ɪ‾n], and [tū‾θ‾n] as spoken by Informant 3. Figure 7 is the corresponding composite graphic representation of the domains of the second segment of the complex nuclei and the domains of the simple vowels. Solid lines circle the domains of [ɜ], [ɪ], and [θ] as presented in Table 7, while broken lines circle the simple vowel qualities presented in Table 2 and Figure 2.

In Figure 7 the analysis of [ɝ], [ɨ], and [θ] as being three phonetically different sounds is further supported. In Informant 3's speech, also, the domain of [ɝ] overlaps with /e/, [ɨ] overlaps with /ə/, and [θ] overlaps with /o/. Since /e/, /ə/, and /o/ are three distinct phonemes, it is reasonable to consider [ɝ], [ɨ], and [θ] as three different vocalic qualities of 3 different vowels rather than as a single phoneme, such as /ə/, with three allophones. The reason some English speakers hear all three sounds as /ə/ may be attributed to the linguistic habit of the native speakers of English to classify a rather wide range of mid-central vowel sounds as the phoneme /ə/.

Informant 1 had made a few recordings of complex nuclei before leaving us. In the limited amount of data available, we found a recording of the words, [t$\overline{\text{Iɝ}}$n], [t$\overline{\text{ɯɨ}}$n], and [t$\overline{\text{Uθ}}$n] spoken in our standard frame sentence. Spectrograms and measurements were made as presented in Table 8. Using the same techniques as those used in the experiments with Informants 4 and 3, the figures were converted into the graphic representation shown in Figure 8. Although no conclusion can be drawn from such small statistical data as that of Informant 1, it also seems to support the analysis of /ɝ/, /ɨ/, and /θ/ as three different sounds rather than one.

Through the acoustic phonetic analysis of the complex nuclei [Iɝ], [ɯɨ], and [Uθ] in the environment /t - n/, we

TABLE 7

Formant measurements of second segments of the complex nuclei in the environment /t - n/: Informant 3 cycles/second

Segment [ɜ] with tone [-]

Word	1 F1 F2 F3	2 F1 F2 F3	3 F1 F2 F3	4 F1 F2 F3
tɪ̄ɜn	600 1850	600 1900	600 1850	600 1850
	625 1850	575 1800	600 1850	600 1900
	600 1850	600 1850	600 1800	600 1950
	600 2000	600 2100	600 1850	600 1950
	575 2050	550 2000	600 1950	600 2100
	625 1950	650 1950	600 1900	600 1900
	600 1900	600 1900	600 1850	600 1850
	600 1900	600 1850	600 1850	600 1850
	600 1850	600 1850	600 1850	600 1850
	600 2000	600 1900	600 1850	625 1900

Segment [ɨ] with tone [-]

Word	1 F1 F2 F3	2 F1 F2 F3	3 F1 F2 F3	4 F1 F2 F3
twɨ̄n	600 1550	600 1550	600 1550	600 1550
	600 1550	600 1550	600 1550	600 1550
	600 1550	600 1550	625 1500	600 1550
	600 1550	550 1500	575 1500	600 1500
	600 1550	575 1500	600 1550	600 1500
	625 1500	650 1600	600 1600	625 1600
	625 1600	625 1450	600 1550	600 1550
	650 1600	600 1400	625 1550	600 1550
	650 1600	600 1600	600 1550	600 1550
	550 1500	600 1550	600 1550	600 1550

Segment [ɵ] with tone [-]

Word	1 F1 F2 F3	2 F1 F2 F3	3 F1 F2 F3	4 F1 F2 F3
tuɵ̄n	600 1250	600 1250	600 1250	600 1250
	600 1250	600 1250	600 1250	600 1250
	600 1250	600 1250	600 1200	575 1200
	600 1350	600 1200	550 1200	600 1200
	600 1250	575 1200	575 1300	550 1200
	600 1300	600 1300	600 1250	600 1300
	625 1300	625 1300	625 1300	600 1300
	600 1300	600 1300	600 1300	600 1250
	625 1300	600 1250	600 1300	600 1400
	575 1250	600 1250	600 1250	600 1250

Blank spaces indicate where precise measurements were not obtainable.

FIGURE 7

Second element of the complex nuclei compared with simple vowels in the environment /t - n/ Level tone Informant 3

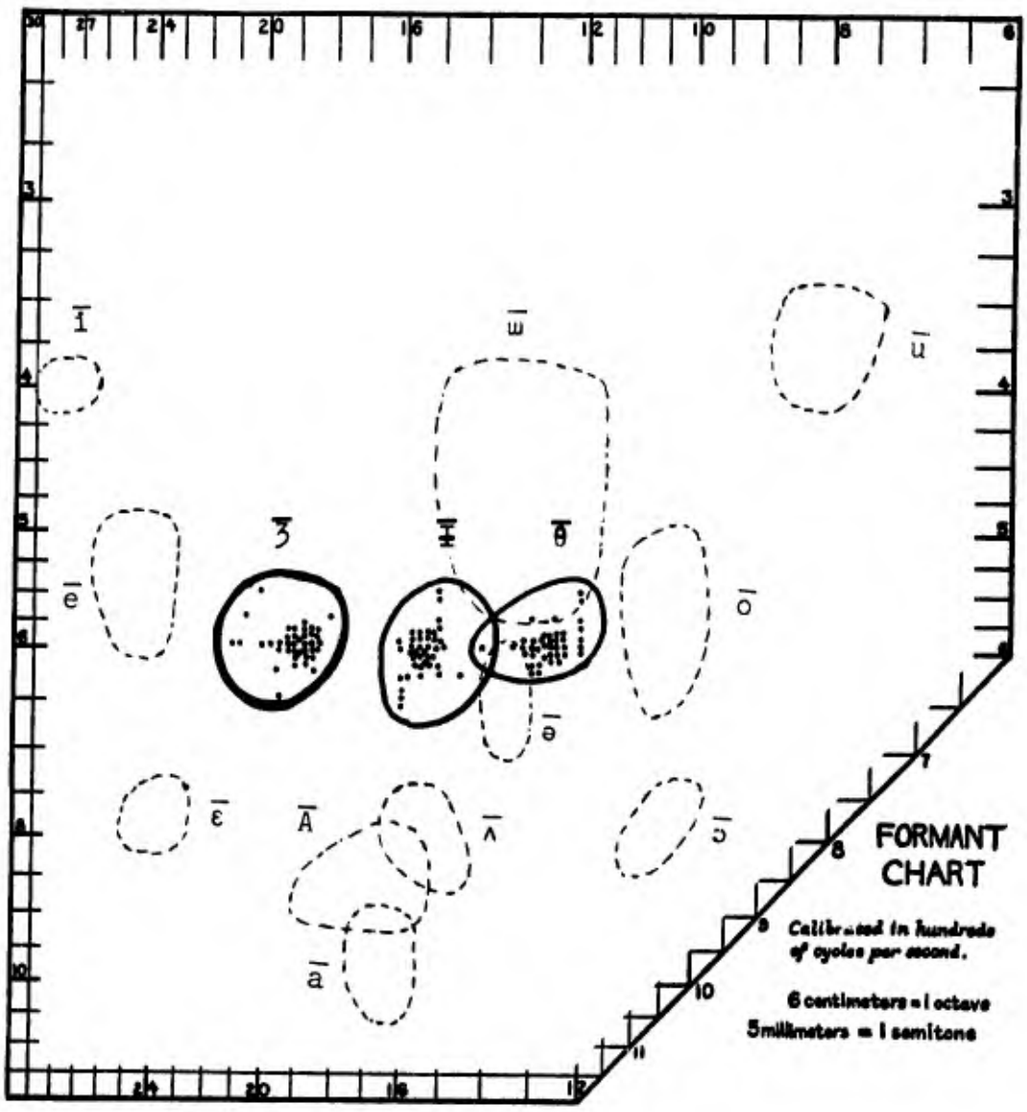


TABLE 8

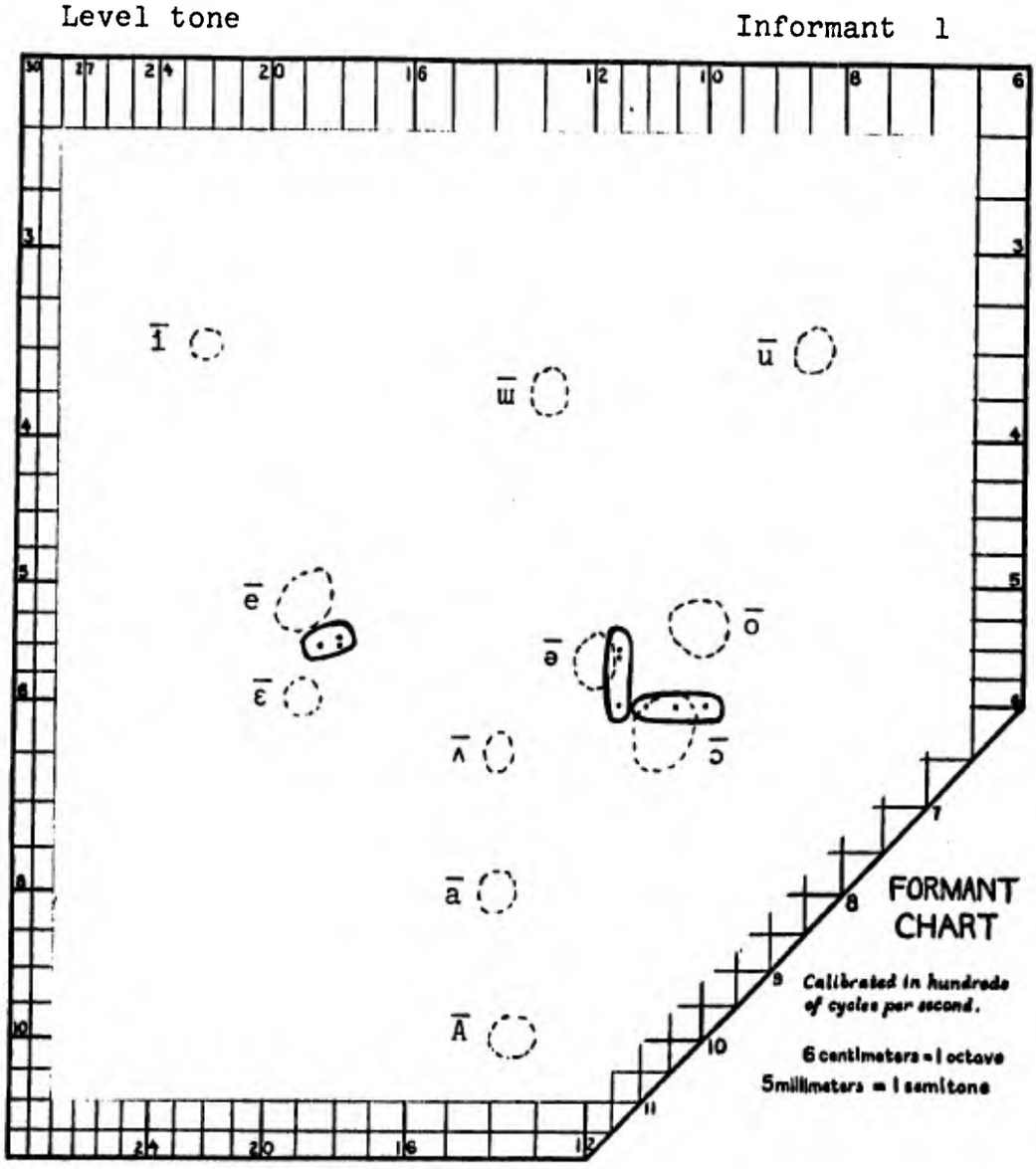
Second segments of the complex nuclei: Informant 1

Word	1 F1	1 F2	2 F1	2 F2	3 F1	3 F2	4 F1	4 F2
tɪ̄ʒn			550	1800	550	1800	550	1850
tɯ̄ɪ̄m			600	1150	550	1150	550	1150
tʊ̄θn			600	1050	600	1000	600	1100

Blank spaces indicate where precise measurements were not obtainable.

FIGURE 8

Second element of the complex nuclei compared with simple vowels



are led to the following conclusions:

1) The first segments, tentatively transcribed as [I], [ɯ], and [U] are phonetically similiar enough to [i], [ɯ], and [u] to be regarded as the same vowel qualities. The acoustic phonetic data confirms the auditory impression. The first segments of the complex nuclei are best analysed as /i/, /ɯ/, and /u/ respectively.

2) The second segments of [iɜ], [ɯɪ], and [uθ] in the environment /t - n/ with level tone occupy three distinctive domains on the formant chart. [ɜ] is more similar to /e/, [ɪ] is more similar to /ə/, and [θ] is more similar to /o/ than [ɜ], [I], and [θ] are to each other or to the domain of any one phoneme.

It might be possible to analyse [ɜ], [ɪ], and [θ] as one single phoneme on the basis of their distribution, since [ɜ] occurs only after /i/, [ɪ] only after /ɯ/, and [θ] only after /u/. On a distributional basis they could be assigned as allophones in complementary distribution. Such a phonemic analysis, however, lacks phonetic basis and is close to becoming merely a mentalistic game. After careful observation of the phonetic phenomena, we analyse [ɜ], [ɪ], and [θ] phonemically as /e/, /ə/, and /o/, making the complex nuclei phonemically: /ie/ /ɯə/ and /uo/.

Chapter 4

COMPLEX NUCLEI IN VARIED ENVIRONMENTS

As presented in the previous chapter, the acoustic-phonetic study of complex syllable nuclei led us to the analysis of the segments spelled "tiên", "tuởn", and "tuôn" as /t$\overline{\text{ie}}$n/, /t$\overline{\text{ɯə}}$n/, and /t$\overline{\text{uo}}$n/.

The purpose of the present chapter is to test our analysis of [ɜ], [ɪ], and [ɵ] as the three separate phonemes /e/, /ə/, and /o/ in more varied phonetic environments. Also, we will try to answer the question of whether the second segments of each of the following pairs are phonetically similar enough to be considered the same:

Open syllables	Closed syllables
"-ia"	"-iê-"
"-uở"	"-uở-"
"-ua"	"-uô-"

As noted earlier, Thompson analysed the second segments [ɜ], [ɪ], and [ɵ] in open syllables as all being the same phoneme /ʌ/, and those in closed syllables as being three separate phonemes /e/, /ə/, and /o/. Other analysts have interpreted the second segments of the pairs spelled "-ia" and "-iê-", "-uở" and "-uở-", and "-ua" and "-uô-" as being

phonemically the same. To arrive at a conclusive answer to this problem, it is necessary to study phonetic differences between the complex nuclei in open syllables and those in closed syllables.

For this study, the recording material was arranged according to syllable types and tones. Six tones, level /–/, rising /⁄/, broken /~/, falling /\/, curve /∨/, and drop /¬/, are contrastive in the Hanoi dialect of Vietnamese. A syllable in Vietnamese can be open or closed. The final consonants that occur following the three complex nuclei are summarized as follows:

	p	t	k	m	n	ŋ	w	y
[iɜ]	+	+	+	+	+	+	+	-
[wɨ]	+	+	+	+	+	+	+	+
[uθ]	-	+	+	+	+	+	-	+

The distribution of final /y/ and /w/ with complex nuclei is noteworthy. /y/ in Vietnamese follows only the central and back vowels and does not occur after /i/, /e/, /ɛ/, and [iɜ]. /w/ follows only the central and front vowels and does not occur after /u/, /o/, /ɔ/, and [uθ]. This distributional characteristic seems to suggest that [ɜ] is structurally parallel to the front vowel /e/, and [θ] is structurally parallel to the back vowel /o/. However, the phonemic status of /w/ and /y/ as consonants needs further study to confirm this interpretation. We, therefore, decided not to include /w/ and /y/ as consonants in our spectrographic analyses. Our analysis included: 1) open

syllable words grouped according to the six different tones and 2) closed syllable words with final consonants /p t k m n ŋ/, also grouped according to the six tones.

Table 9 represents F1 and F2 measurements of the second segment [ʒ] of [iʒ] in open syllable words as spoken by Informant 4. Figure 9 is the corresponding graphic representation. The [x] represents the measurements of [ʒ] with drop tone, while the dot [.] represents [ʒ] with all other tones. The occurrences of phones having an F1 measurement between 550-600 cps are identified as being either those with drop tone /¬/ or with broken tone /↜/. In our previous study, it was observed that drop tone consistently raised F1 measurements of simple vowels 50-100 cps, making the phones with drop tone appear much lower on the formant chart. In Figure 9, the same effect is observed on the formant measurements of [ʒ].

Table 10 summarizes the data obtained from the formant measurements of [ɪ] of [ɯɪ] in open syllables spoken by Informant 4. When converting the figures into the graphic representation on the formant chart as shown in Figure 10, it became apparent that on this vowel, also, the effect of the drop tone is clearly observable. It is interesting to note that the effect of drop tone on the segments [ʒ] and [ɪ] is very much like that observed on the simple vowels /e/ and /ə/.

It was noted in our previous study that drop tone has slightly less effect on back vowels than on front and central vowels. The extent of the drop tone effect on F1 measurements

TABLE 9

Formant measurements of complex nuclei segment [ɻ] Open syllable cycles/second

All tones Informant 4

Segment [ɻ] with tone [-]

Word	1 F1 F2 F3	2 F1 F2 F3	3 F1 F2 F3	4 F1 F2 F3
tɪ̄ɻ	450 2050	450 2000	450 2000	450 2050
tʰɪ̄ɻ	500 1900	450 1900	450 1950	450 1950
cɪ̄ɻ	400 2200	450 2150	450 2100	450 2000
kɪ̄ɻ	450 2050	450 2000	450 2050	450 2050
bɪ̄ɻ	450 2050	450 2000	450 2050	450 1950
lɪ̄ɻ	450 1900	450 1850	450 1900	450 1850
nɪ̄ɻ	450 2000	450 2000	450 2100	450 2050
ɲɪ̄ɻ	450 2000	450 2000	450 2000	450 2000
vɪ̄ɻ	450 2000	450 1850	450 1950	450 1850
zɪ̄ɻ	450 1900	450 1850	450 1900	450 1550
ɻɪ̄ɻ	450 2000	450 1900	450 1900	450 1900

Segment [ɻ] with tone [/]

Word	1 F1 F2 F3	2 F1 F2 F3	3 F1 F2 F3	4 F1 F2 F3
tɪ́ɻ	500 2000	500 1850	450 1900	450 1950
mɪ́ɻ	500 2000	450 1900	450 2050	450 2050
fɪ́ɻ	500 1850	500 1950	450 2000	450 1950
xɪ́ɻ	450 2050	450 2000	450 2000	450 2050

Segment [ɻ] with tone [ˇ]

Word	1 F1 F2 F3	2 F1 F2 F3	3 F1 F2 F3	4 F1 F2 F3
tʰɪ̀ɻ	450 2050	500 2000	450 2050	450 2100
cɪ̀ɻ	450 2150	500 2000	500 1950	450 2100
kɪ̀ɻ	500 2000	500 1900	500 1950	450 2000
bɪ̀ɻ	450 2000	450 1900	450 2000	450 2000
dɪ̀ɻ	450 1950	450 2000	450 1900	500 1850
lɪ̀ɻ	450 2000	450 1950	450 2000	450 2000

Segment [ɻ] with tone [~]

Word	1 F1 F2 F3	2 F1 F2 F3	3 F1 F2 F3	4 F1 F2 F3
cɪ̃ɻ	650 1950	550 1850	600 1850	600 1850
dɪ̃ɻ	600 1850	550 1800	550 1800	600 1850
nɪ̃ɻ	650 1900	550 1800	550 1900	600 1850
ɲɪ̃ɻ	600 1800	550 1900	600 1850	600 1850

Segment [ɻ] with tone [˜]

Word	1 F1 F2 F3	2 F1 F2 F3	3 F1 F2 F3	4 F1 F2 F3
ɻ̃ɻ	450 2000	550 1900	500 2000	400 2050
tɪ̃ɻ	500 2050	450 2050	400 2000	400 2000
dɪ̃ɻ	500 1900	450 1950	500 1950	500 2000
mɪ̃ɻ	550 2000	500 1950	500 2000	500 1950

Segment [ɻ] with tone [¬]

Word	1 F1 F2 F3	2 F1 F2 F3	3 F1 F2 F3	4 F1 F2 F3
bɪ̄ɻ	650 1650	650 1650	550 1750	550 1750
dɪ̄ɻ	650 1700	550 1750	550 1700	600 1750
lɪ̄ɻ	650 1650	600 1600	600 1600	600 1650

Blank spaces indicate where precise measurements were not obtainable.

FIGURE 9

[ʒ] in open syllables

All tones Informant 4

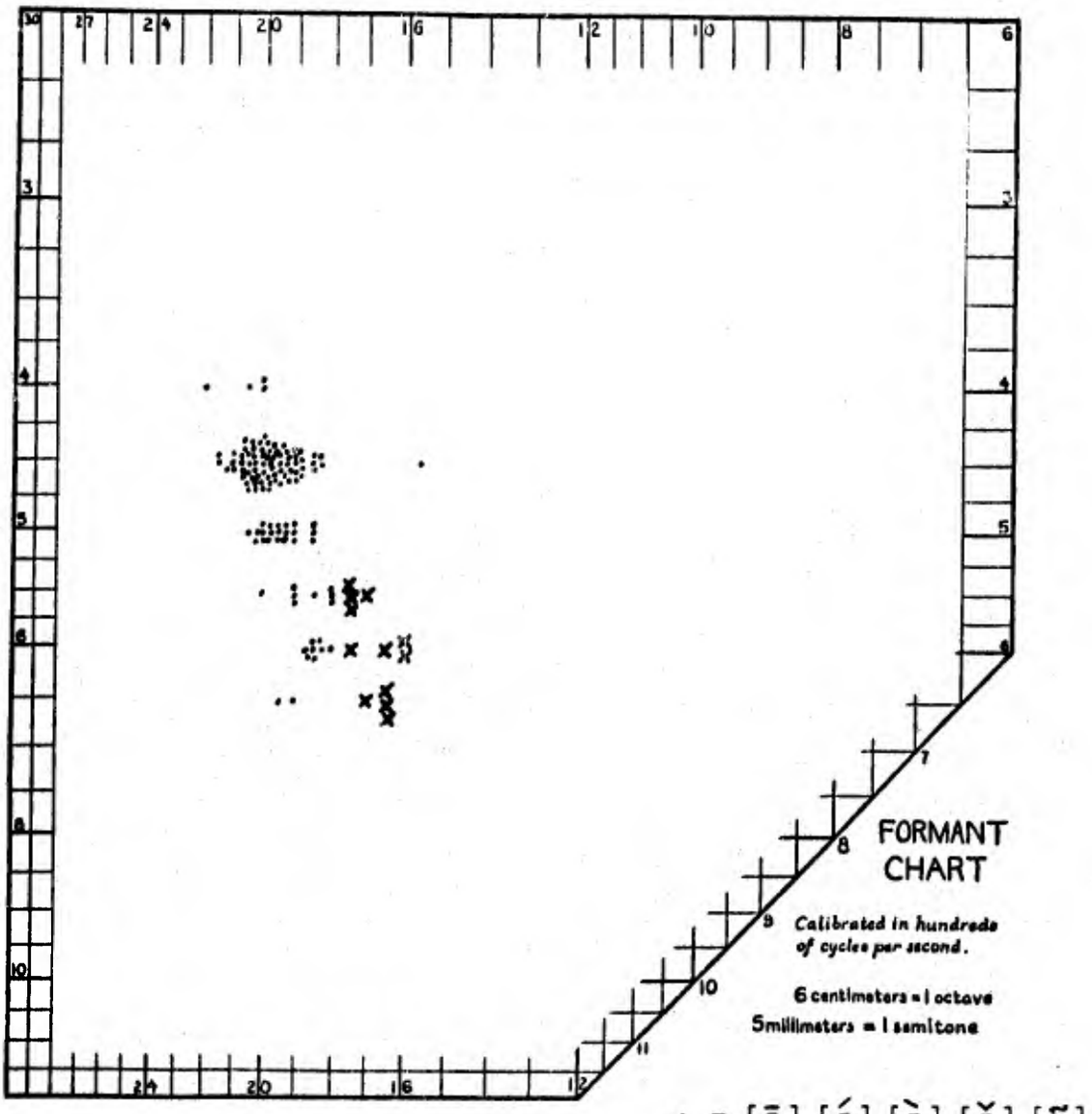


TABLE 10

Formant measurements of complex nuclei segment [ɨ] Open syllable cycles/second

All tones Informant 4

Segment [ɨ] with tone [-]

Word	1 F1	F2	F3	2 F1	F2	F3	3 F1	F2	F3	4 F1	F2	F3
wɨ	550	1450		550	1400		550	1400		550	1450	
tʰwɨ	550	1450		450	1450		450	1350		550	1350	
cwɨ	450	1500		500	1600		450	1650		500	1450	
kwɨ	450	1400		450	1400		450	1400		500	1450	
dwɨ	550	1350		450	1500		450	1500		500	1350	
mwɨ	500	1450		500	1450		450	1450		450	1450	
swɨ	450	1450		450	1450		450	1400		450	1400	
zwɨ	500	1500		500	1500		450	1550		450	1500	

Segment [ɨ] with tone [/]

Word	1 F1	F2	F3	2 F1	F2	F3	3 F1	F2	F3	4 F1	F2	F3
cwɨ	550	1500		450	1500		450	1500		450	1500	
kwɨ	600	1350		450	1350		500	1450		450	1450	
bwɨ	450	1400		450	1400		450	1350		450	1400	
dwɨ	500	1450		500	1600		500	1450		500	1500	
lwɨ	500	1500		500	1450		550	1400		500	1500	
mwɨ	500	1450		500	1450		500	1450		450	1400	
nwɨ	550	1350		500	1450		500	1450		450	1450	
ŋwɨ	600	1400		500	1500		500	1500		500	1350	
hwɨ	500	1450		500	1350		500	1350		500	1450	

Segment [ɨ] with tone [\]

Word	1 F1	F2	F3	2 F1	F2	F3	3 F1	F2	F3	4 F1	F2	F3
tʰwɨ	550	1350		500	1350		500	1350		500	1350	
cwɨ	500	1450		450	1400		500	1300		500	1400	
bwɨ	600	1350		500	1500		500	1550		450	1500	
lwɨ	500	1450		550	1450		550	1400		550	1450	
ŋwɨ	550	1450		500	1350		500	1350		550	1350	

Segment [ɨ] with tone [~]

Word	1 F1	F2	F3	2 F1	F2	F3	3 F1	F2	F3	4 F1	F2	F3
cwɨ	550	1500		550	1550		550	1500		550	1450	
bwɨ	600	1400		550	1450		550	1400		600	1450	
nwɨ	600	1450		550	1350		600	1350		550	1400	

Segment [ɨ] with tone [⌣]

Word	1 F1	F2	F3	2 F1	F2	F3	3 F1	F2	F3	4 F1	F2	F3
cwɨ	600	1400		550	1500		500	1450		500	1450	
kwɨ	600	1350		550	1400		550	1350		550	1400	
bwɨ	650	1350		550	1400		500	1450		550	1350	
mwɨ	550	1350		550	1350		550	1500		550	1400	
nwɨ	600	1350		550	1450		500	1500		500	1500	
ŋwɨ	600	1400		500	1500		550	1400		550	1450	

Segment [ɨ] with tone [¬]

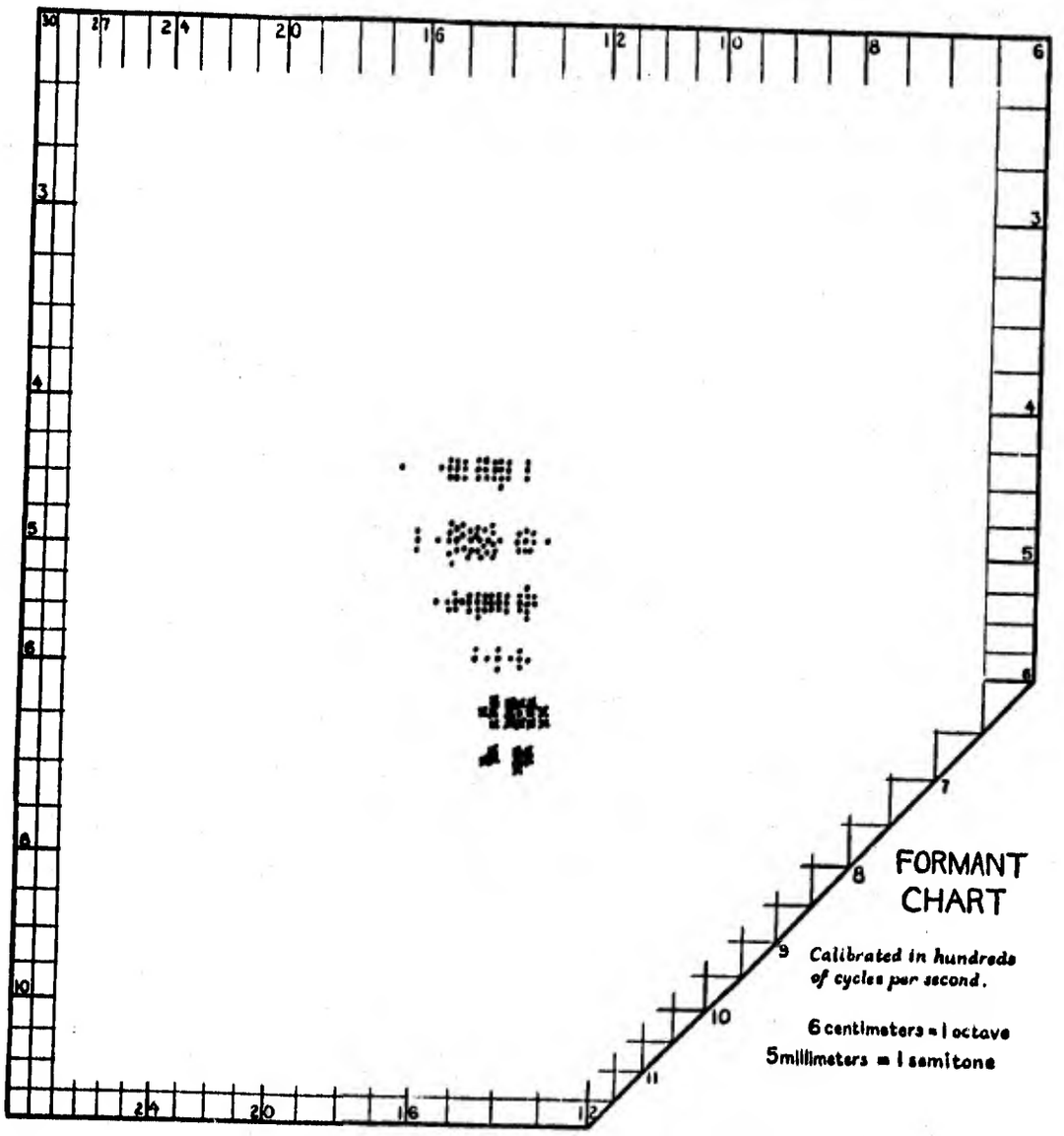
Word	1 F1	F2	F3	2 F1	F2	F3	3 F1	F2	F3	4 F1	F2	F3
wɨ	650	1300		700	1350		700	1350		700	1350	
twɨ	650	1300		650	1400		650	1400		650	1350	
kwɨ	700	1350		650	1350		650	1300		700	1400	
bwɨ	700	1400		650	1400		650	1350		650	1350	
lwɨ	700	1400		700	1350		650	1350		650	1350	
ŋwɨ	700	1350		650	1350		650	1350		650	1400	

Blank spaces indicate where precise measurements were not obtainable.

FIGURE 10

[ɨ] in open syllables

All tones Informant 4



of back vowels is approximately 50 cps. Table 11 summarizes the measurements of F1 and F2 of the segment [ɵ] of [uɵ] in open syllables. Figure 11 is the graphic representation of the same measurements. The effect of drop tone on the segment [ɵ] is seen to be very similar to that observed on the simple vowel /o/.

The domains occupied by [ʒ], [ɪ], and [ɵ] in open syllables are placed together on one formant chart as shown in Figure 11a. This chart shows that the three sounds do occupy three distinct areas even when the environments of the complex nuclei are enlarged to include all six tones and various initial consonants. This result gives further support to our analysis of [ʒ], [ɪ], and [ɵ] as three separate phonemes rather than one single phoneme.

TABLE 11

Formant measurements of complex nuclei segment [ə] Open syllable cycles/second

All tones Informant 4

Segment [ə] with tone [-]

Word	1 F1	F2	F3	2 F1	F2	F3	3 F1	F2	F3	4 F1	F2	F3
tɯ̃ə	500	1150		500	1150		500	1150		500	1100	
tʰɯ̃ə	500	1000		450	1000		450	1000		450	950	
dɯ̃ə	500	1000		450	1050		450	1050		500	1000	
kɯ̃ə	450	950		500	1050		450	1050		450	850	
gɯ̃ə	500	1000		550	1100		550	1100		500	1000	
mɯ̃ə	450	900		450	1000		450	900		450	950	
nɯ̃ə	450	950		450	950		450	1000		450	1000	
ɲɯ̃ə	450	1000		500	1000		550	1100		550	1100	
ɾɯ̃ə	500	1050		500	1000		500	1050		450	1050	
vɯ̃ə	500	1100		450	1100		450	1000		450	1000	
sɯ̃ə	450	1050		500	1050		500	1100		450	1100	
zɯ̃ə	450	1100		450	1050		450	1050		450	1050	
xɯ̃ə	450	1000		500	1100		500	1050		500	1100	

Segment [ə] with tone [/]

Word	1 F1	F2	F3	2 F1	F2	F3	3 F1	F2	F3	4 F1	F2	F3
ɯ̃ə	600	1100		550	1100		500	1100		550	1000	
tɯ̃ə	500	1150		500	1150		550	1100		500	1000	
dɯ̃ə	550	1150		500	1150		450	1100		500	1150	
bɯ̃ə	500	1050		450	1050		450	1100		450	1000	
lɯ̃ə	450	1100		500	1000		450	1000		450	1000	
mɯ̃ə	450	1050		450	1000		450	1000		450	900	

Segment [ə] with tone [˅]

Word	1 F1	F2	F3	2 F1	F2	F3	3 F1	F2	F3	4 F1	F2	F3
ɯ̃ə	550	1150		550	1050		550	1150		500	1100	
tʰɯ̃ə	600	1150		600	1150		550	1100		600	1100	
dɯ̃ə	500	1100		550	1100		550	1200		500	1100	
bɯ̃ə	550	1100		500	1100		500	1000		500	1000	
dlɯ̃ə	500	1100		450	1000		450	1000		500	1100	
lɯ̃ə	550	1150		550	1100		550	1100		550	1100	
mɯ̃ə	500	1000		500	1100		500	1000		500	1000	

Segment [ə] with tone [^]

Word	1 F1	F2	F3	2 F1	F2	F3	3 F1	F2	F3	4 F1	F2	F3
dɯ̃ə	550	1100		600	1050		600	1100		600	1150	
lɯ̃ə	600	1150		550	1150		500	1000		550	1150	
mɯ̃ə	550	1150		550	1100		550	1150		600	1150	

Segment [ə] with tone [ˇ]

Word	1 F1	F2	F3	2 F1	F2	F3	3 F1	F2	F3	4 F1	F2	F3
ɯ̃ə	600	1050		600	1100		550	1050		600	1050	
kɯ̃ə	550	1050		500	1050		550	1000		500	1000	
sɯ̃ə	600	1150		550	1100		550	1050		550	1050	
zɯ̃ə	550	1150		500	1100		550	1100		500	1000	

Segment [ə] with tone [¯]

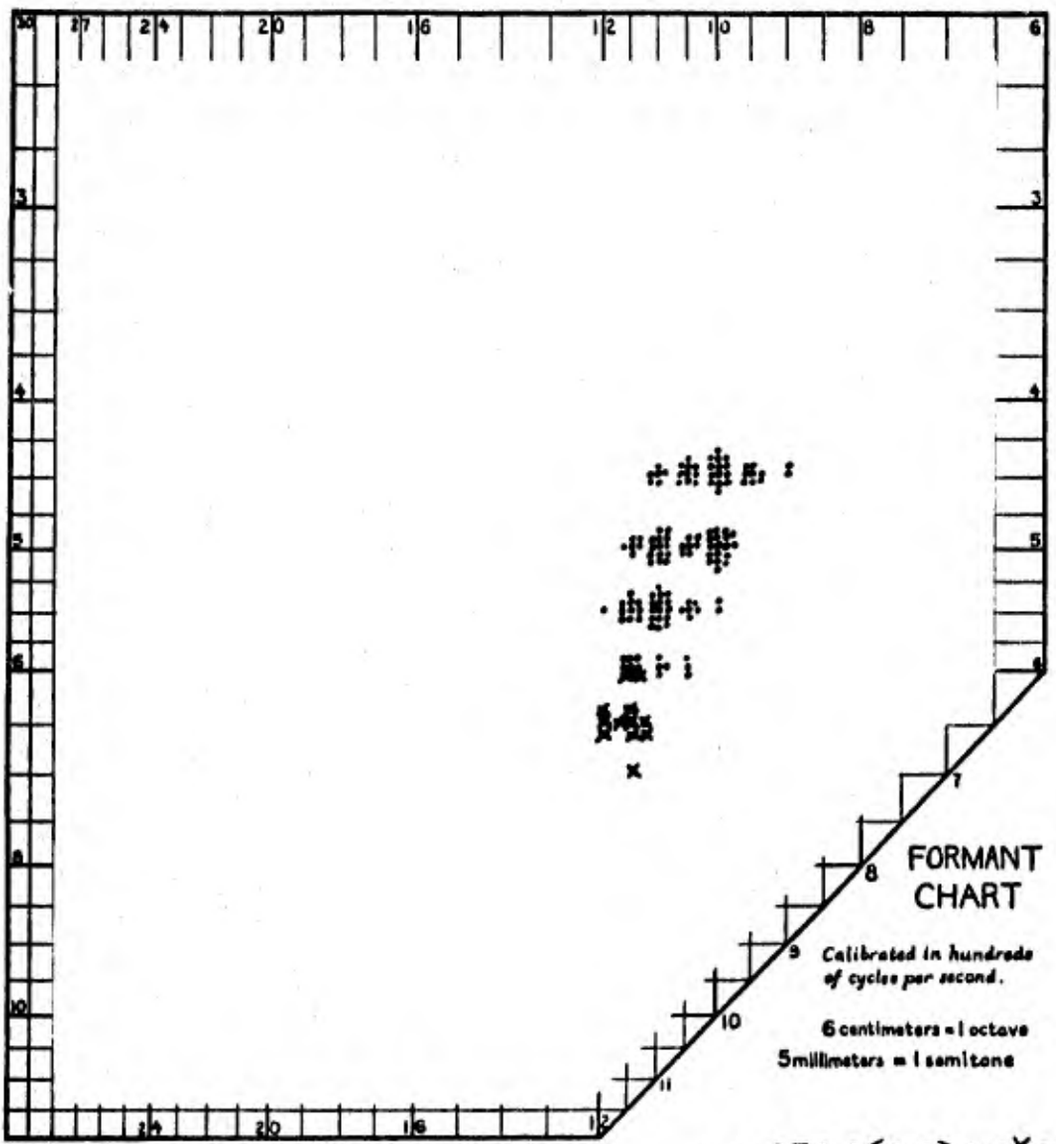
Word	1 F1	F2	F3	2 F1	F2	F3	3 F1	F2	F3	4 F1	F2	F3
ɯ̃ə	650	1150		650	1150		650	1200		650	1200	
bɯ̃ə	650	1150		650	1150		650	1150		650	1200	
lɯ̃ə	700	1150		650	1150		600	1150		600	1150	

Blank spaces indicate where precise measurements were not obtainable.

FIGURE 11

[θ] in open syllables

All tones Informant 4



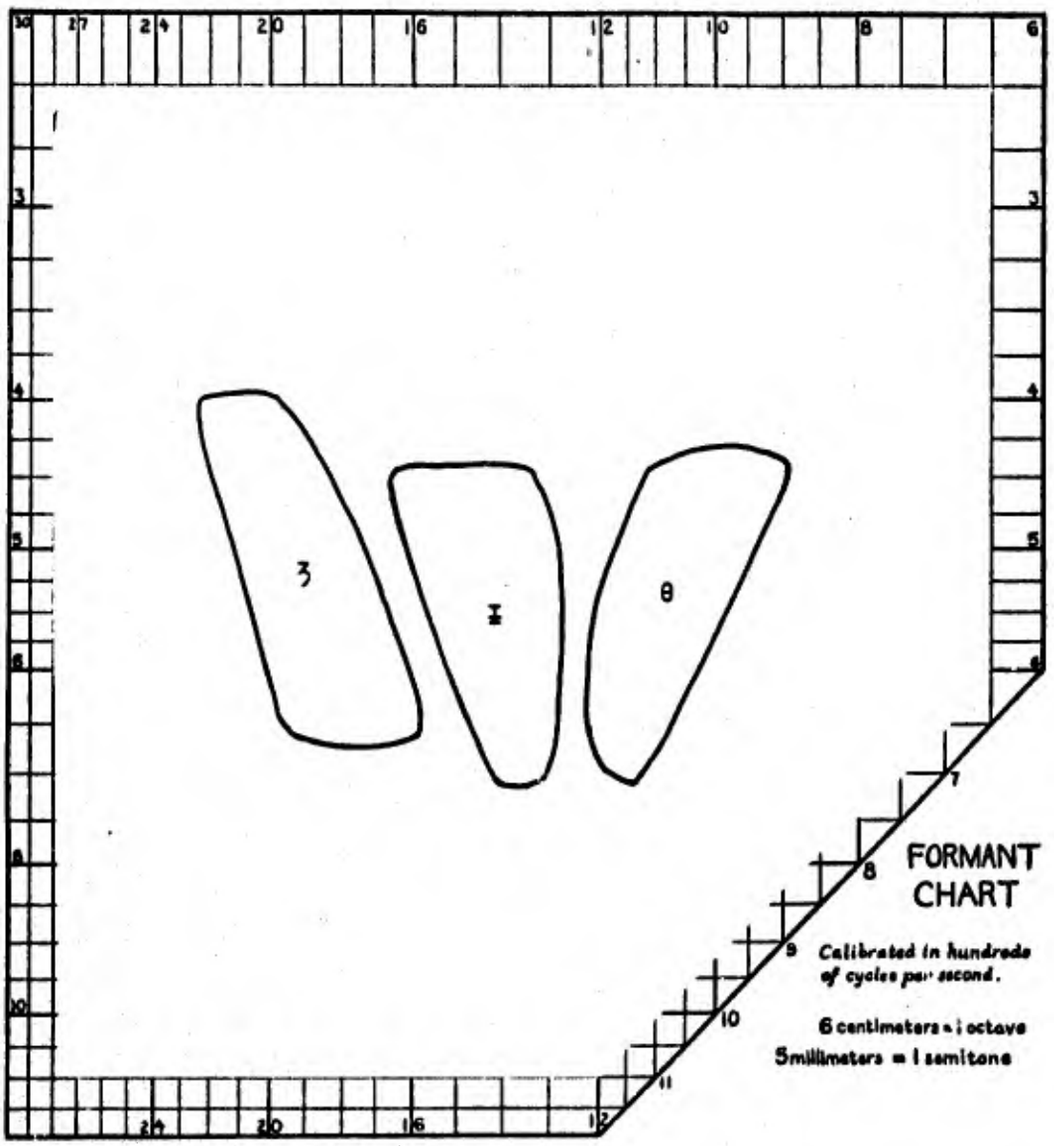
· = [θ̄] [θ́] [θ̀] [θ̌] [θ̃]

× = [θ̄]

FIGURE 11a

Domains of [-ʒ] [-ɪ] [-θ] in open syllables

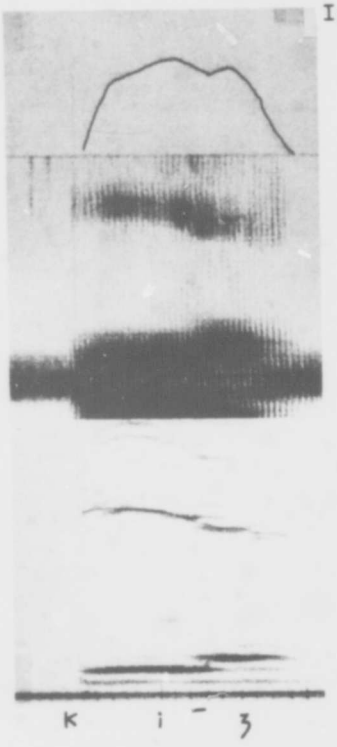
All tones Informant 4



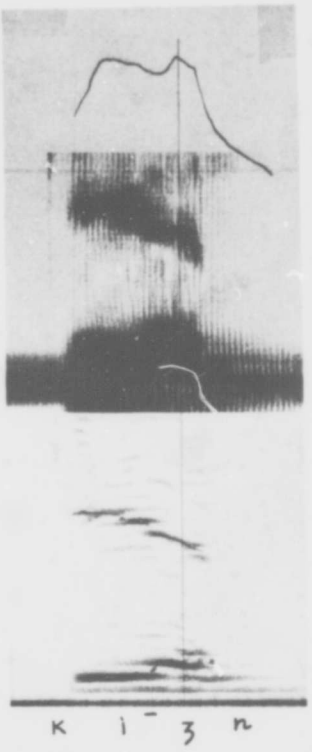
Different final consonants have varying effects on the quality of the syllable nuclei. These differences are observable in the frequency and shapes of formants. Spectrograms 16-19 illustrate the differences in formant shapes of [iɜ] in an open syllable, such as [kiɜ], and in closed syllables with the final consonants [-n], [-m], and [-ŋ], as in [kiɜ̄n], [kiɜ̄m], and [kiɜ̄ŋ]. As is easily seen on these spectrograms, the complex nuclei [iɜ] in the open syllable has a steady state of [i] and a steady state of [ɜ]. When there is such a steady state on the spectrogram of a vocalic quality, this point is taken as the most reasonable place to measure the formant. In the case of closed syllables, as seen on the spectrograms of [kiɜ̄n], [kiɜ̄m], and [kiɜ̄ŋ], the second segment [ɜ] is usually shorter than the first segment [i] and usually has no observable steady state. In the case of continually changing formants such as these, it is difficult to determine where the formant measurements should be taken, because a small difference in time may result in a large difference in F1 and F2 mesurements. For this reason, we applied the use of an amplitude display unit in determining the point where F1 and F2 measurements should be taken. Table 12 shows F1 and F2 measurements taken at intervals of two centiseconds along the relatively steady states of the formants of [i] and of [ɜ] in [kiɜ] and, also, those measurements taken along the continually changing formants of [i] and [ɜ] of [kiɜ̄n], [kiɜ̄m], and [kiɜ̄ŋ]. Figure 12a shows a diagrammed interpretation of the formant

SPECTROGRAM NO. 16

Informant 4



SPECTROGRAM NO. 17



SPECTROGRAM NO. 18

SPECTROGRAM NO. 19

TABLE 12

Formant measurements at intervals of 2 centiseconds

Complex nuclei [ɪ̄ɜ̄] Informant 4 cycles/second

Word	[kɪ̄ɜ̄]		[kɪ̄ɜ̄n]		[kɪ̄ɜ̄m]		[kɪ̄ɜ̄ŋ]	
csec.	F1	F2	F1	F2	F1	F2	F1	F2
0	300	2250	300	2350	300	2200	300	2200
2	300	2250	300	2350	350	2200	350	2200
4	300	2250	300	2350	350	2200	350	2200
6	300	2250	300	2300	350	2150	350	2200
8	300	2250	350	2250	350	2100	350	2150
10	300	2250	400	2100	350	2050	350	2150
12	300	2200	450	2050	400	1950	400	2000
14	300	2150	500	1950	500	1800	500	1950
16	350	2050	500	1900	500	1400	500	1750
18	450	2000	500	1850	550	1250	550	1550
20	450	2000					600	1500
22	450	2000						
24	450	2000						
26	450	2000						

Blank spaces indicate where precise measurements were not obtainable.

measurements, with an x marking the point of the amplitude peak of the segment [ɜ]. Figure 12b shows how these measurements would be interpreted on formant charts. Table 12 and Figure 12a and 12b show the varying effects of different final consonants on the complex nuclei.

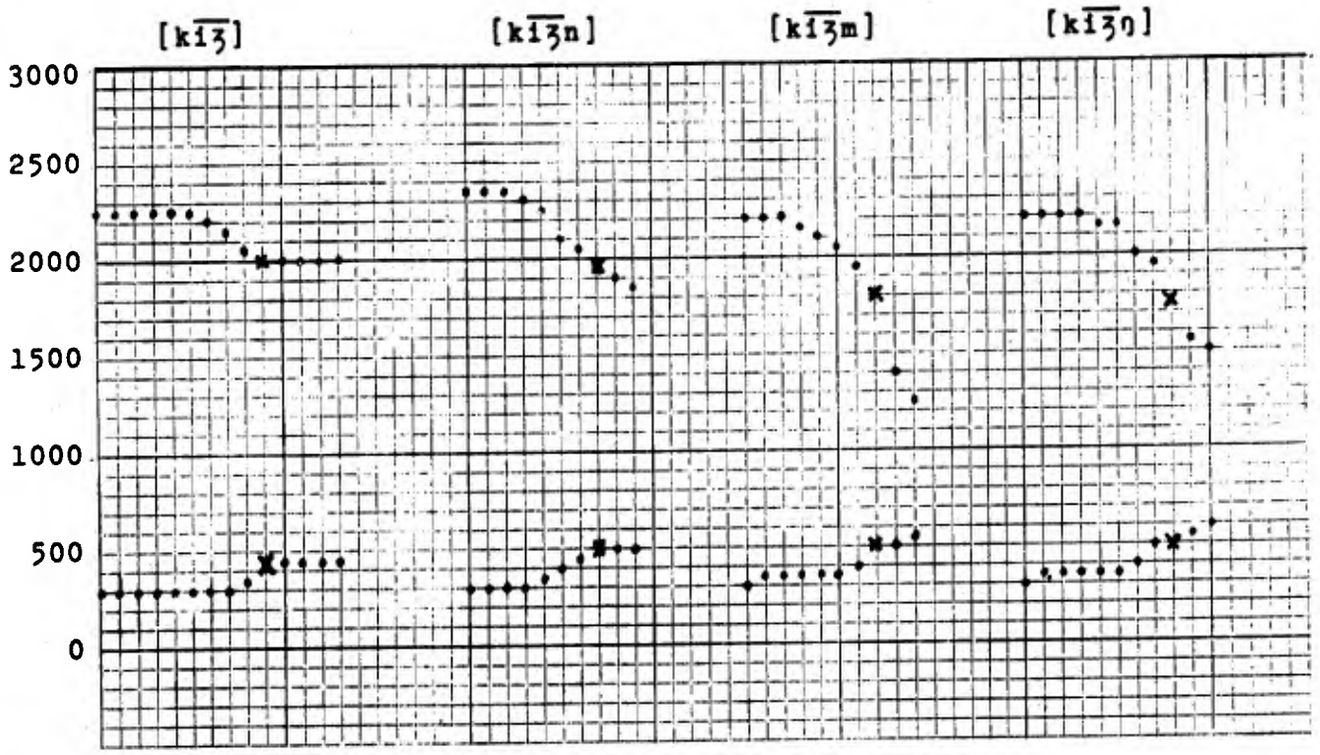
In a complex nucleus, there usually are two amplitude peaks; whereas, in a simple vowel nucleus, there is only one amplitude peak. The two amplitude peaks of a complex nucleus normally coincide in time with the mid-points of the first and the second segments of the nucleus. The mid-point and amplitude peak of the first segment also coincide with the steady state of that segment. This suggests that the point where the second amplitude peak occurs is the target point or near it, and therefore is the most logical place to measure F1 and F2 of the second segment. Using this reasoning, the measurements presented in the following tables were obtained at the point of the second amplitude peak.

Table 13 presents the F1 and F2 measurements of the segment [ɜ] of [iɜ] in closed syllables with /-m, -n, -ŋ, -p, -t, -k/ as the final consonants. All tones are represented here in the utterances spoken by Informant 4. Figure 13 is the graphic representation of the figures presented in Table 13. It may be noted that the domain of [ɜ] is slightly larger and more centralized in these examples than is the domain of [ɜ] in open syllables.

FIGURE 12a

F1 and F2 of complex nucleus [iʒ]
in different environments

Informant 4

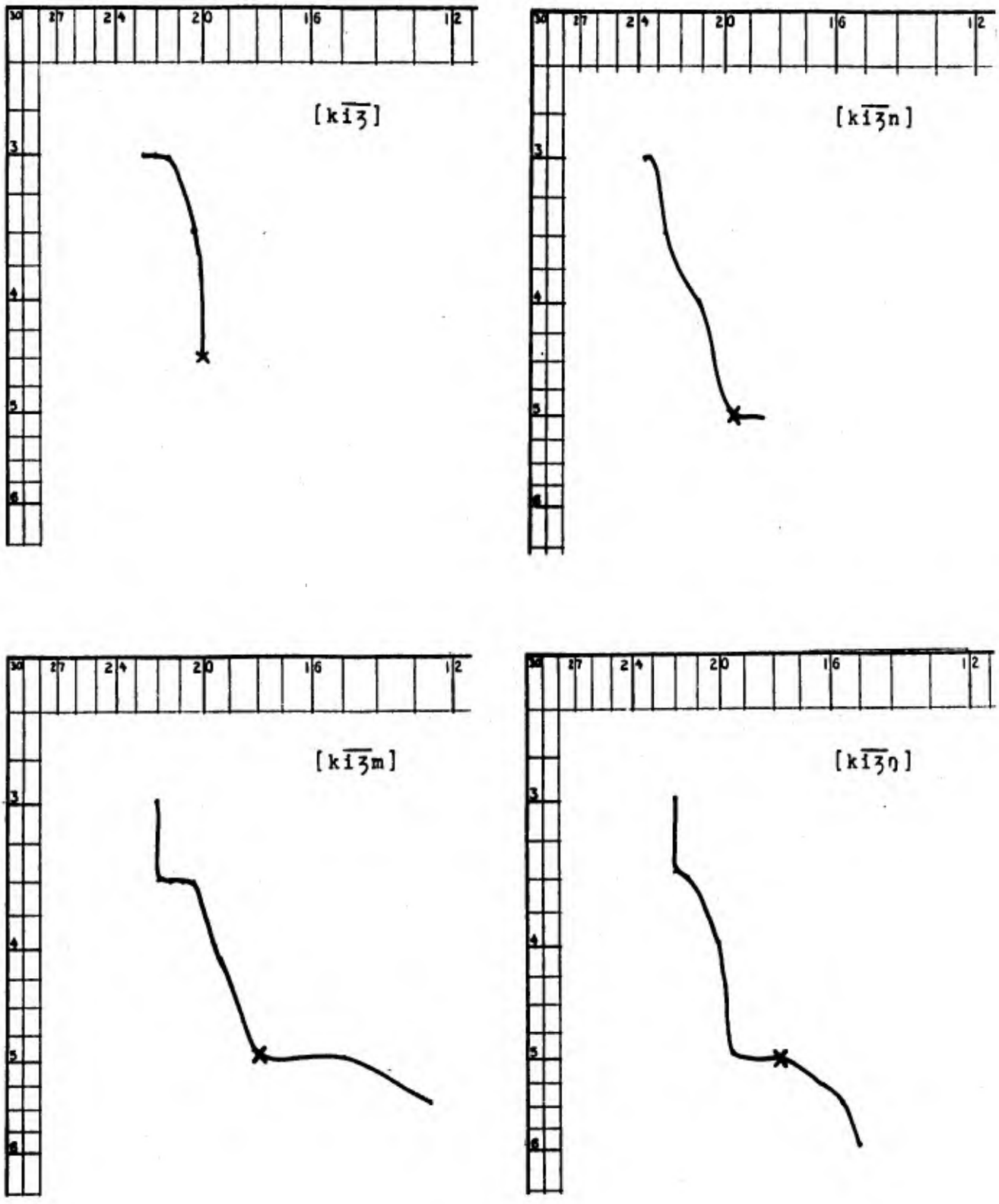


x marks the amplitude peak of segment [-ʒ]

FIGURE 12b

Formant movements in complex nucleus [iʒ]

Informant 4



x marks the amplitude peak of segment [-ʒ]

TABLE 13

Formant measurements of samples nuclei segment [ɻ] Closed syllable cycles/second
All tones Informant 4

Segment [ɻ] with tone [-]

Word	1 F1 F2 F3	2 F1 F2 F3	3 F1 F2 F3	4 F1 F2 F3
tʃʰɻ	500 1700	600 1500	600 1500	600 1500
tlʃɻ	600 1600	600 1500	550 1500	550 1500
klʃɻ		600 1500	550 1500	500 1550
llʃɻ	600 1550	600 1500	600 1500	600 1500
nlʃɻ		600 1600	550 1600	550 1600
qlʃɻ		550 1550	550 1600	500 1650
ʃɻn	500 1900	600 1900	550 1950	600 1900
tlʃɻn	500 1900	550 1900	550 1950	600 1850
klʃɻn	450 1950	500 1950	450 1950	450 1950
blʃɻn	550 1950	550 1900	500 1950	600 1850
dlʃɻn	550 1850	500 1900	500 1900	500 1900
nlʃɻn		550 1950	600 1900	600 1850
nlʃɻn	450 2000	450 2000	550 2000	450 1950
nlʃɻn		450 1950	450 1950	450 1950
qlʃɻn		550 1950	550 1900	550 1900
tʰlʃɻo	550 1600	550 1650	500 1600	550 1600
qlʃɻo		550 1600	550 1700	550 1550
klʃɻo		600 1600	550 1650	550 1700
qlʃɻo		550 1750	550 1750	550 1750
xlʃɻo		500 1800	450 1500	500 1550

Segment [ɻ] with tone [˥]

Word	1 F1 F2 F3	2 F1 F2 F3	3 F1 F2 F3	4 F1 F2 F3
tlʃɻm	650 1500	650 1500	600 1500	600 1550
tʰlʃɻm	600 1500	600 1500	550 1550	600 1600
llʃɻm	600 1400	600 1500	600 1450	600 1500
nlʃɻm	650 1450	600 1500	600 1500	600 1500
qlʃɻn	600 1900	600 1850	600 1900	600 1950
qʰlʃɻn	550 1850	550 1950	550 1900	600 1900
llʃɻn	600 1850	600 1850	600 1900	600 1900
nlʃɻn	600 1850	600 1900	600 1850	600 1950

Segment [ɻ] with tone [˦˥]

Word	1 F1 F2 F3	2 F1 F2 F3	3 F1 F2 F3	4 F1 F2 F3
llʃɻm	550 1500	600 1450	600 1400	600 1500
nlʃɻm	550 1550	550 1500	550 1550	550 1550
tlʃɻn	550 1900	550 1950	550 1950	500 2000
llʃɻn	550 1950	550 1900	550 1950	550 1900
nlʃɻn	550 1900	550 1850	550 2000	550 1950
nlʃɻo	600 1600	600 1750	600 1750	600 1800

Segment [ɻ] with tone [-]

Word	1 F1 F2 F3	2 F1 F2 F3	3 F1 F2 F3	4 F1 F2 F3
ʃɻm	600 1500	550 1550	550 1600	550 1600
tʰlʃɻm	650 1550	600 1550	650 1500	600 1500
llʃɻm	600 1450	550 1450	550 1500	550 1500
nlʃɻm	600 1500	550 1550	550 1500	600 1500
tʰlʃɻn	600 1900	550 1900	600 1900	550 1950
ʃɻo	650 1700	600 1800	550 1800	600 1750

Blank spaces indicate where precise measurements were not obtainable.

Segment [ɻ] with tone [ ]

Word	1 F1 F2 F3	2 F1 F2 F3	3 F1 F2 F3	4 F1 F2 F3
tlʃɻp	500 1700	550 1700	500 1750	550 1700
tʰlʃɻp	500 1650	550 1650	500 1650	550 1700
dlʃɻp	500 1700	500 1700	500 1700	550 1700
klʃɻp	500 1650	500 1750	500 1750	500 1750
nlʃɻp	500 1750	500 1800	500 1750	500 1750
ʃɻt	500 2000	500 2000	500 1950	500 1950
tlʃɻt	500 1900	550 1950	550 1950	550 1950
tʰlʃɻt	550 1900	500 1950	500 1850	500 1850
blʃɻt	500 2000	500 1950	500 1950	500 1900
nlʃɻt	500 2000	500 2000	500 1950	550 1850
tlʃɻk	500 1700	500 1750	550 1750	500 1800
tʰlʃɻk	500 1750	500 1750	500 1750	500 1750
dlʃɻk	550 1650	550 1750	500 1800	550 1700
blʃɻk	550 1750	550 1750	550 1850	500 1800
dlʃɻk	550 1700	500 1750	500 1800	500 1800
nlʃɻk	550 1800	500 1800	500 1750	500 1750
ʃɻm	450 1500	550 1600	550 1500	500 1600
tlʃɻm	550 1500	550 1500	550 1500	500 1500
klʃɻm	500 1550	450 1550	450 1750	450 1600
blʃɻm	550 1500	550 1500	550 1500	550 1500
llʃɻm	500 1550	500 1550	450 1600	550 1500
ʃɻn	550 1900	550 1950	550 1950	550 2000
tlʃɻn	500 1950	500 1950	500 1900	550 1900
tʰlʃɻn	550 1900	550 1900	500 1900	550 1900
llʃɻn	550 1900	500 1850	550 1900	550 1900
qlʃɻn	550 1950	550 1950	550 2000	550 1950
blʃɻo	550 1550	550 1600	550 1600	550 1600
blʃɻo	550 1600	550 1650	550 1750	550 1650
dlʃɻo	550 1600	500 1700	500 1700	550 1650
nlʃɻo	500 1600	450 1800	450 1800	450 1850
vlʃɻo	550 1650	550 1700	550 1700	500 1800

Segment [ɻ] with tone [-]

Word	1 F1 F2 F3	2 F1 F2 F3	3 F1 F2 F3	4 F1 F2 F3
tlʃɻp	600 1650	600 1750	600 1650	550 1650
dlʃɻp	550 1650	600 1550	550 1600	500 1700
klʃɻp	600 1700	550 1750	550 1600	500 1750
tlʃɻt	550 1750	550 1850	550 1800	550 1800
tʰlʃɻt	550 1800	550 1700	500 1750	550 1800
nlʃɻt	550 1850	550 1900	550 1900	550 1900
qlʃɻt	550 1800	550 1850	550 1800	550 1800
tlʃɻk	600 1700	550 1700	600 1700	600 1700
vlʃɻk	600 1650	600 1700	550 1750	550 1700
tlʃɻm	650 1400	600 1450	600 1450	650 1450
nlʃɻm	650 1450	600 1500	600 1500	600 1500
qlʃɻm	650 1450	600 1500	600 1500	600 1500
tlʃɻn	600 1850	600 1850	600 1800	600 1800
tʰlʃɻn	600 1850	600 1800	600 1850	600 1850
llʃɻn	700 1500	650 1500	700 1500	650 1500

FIGURE 13

[ʒ] in closed syllables

All tones Informant 4

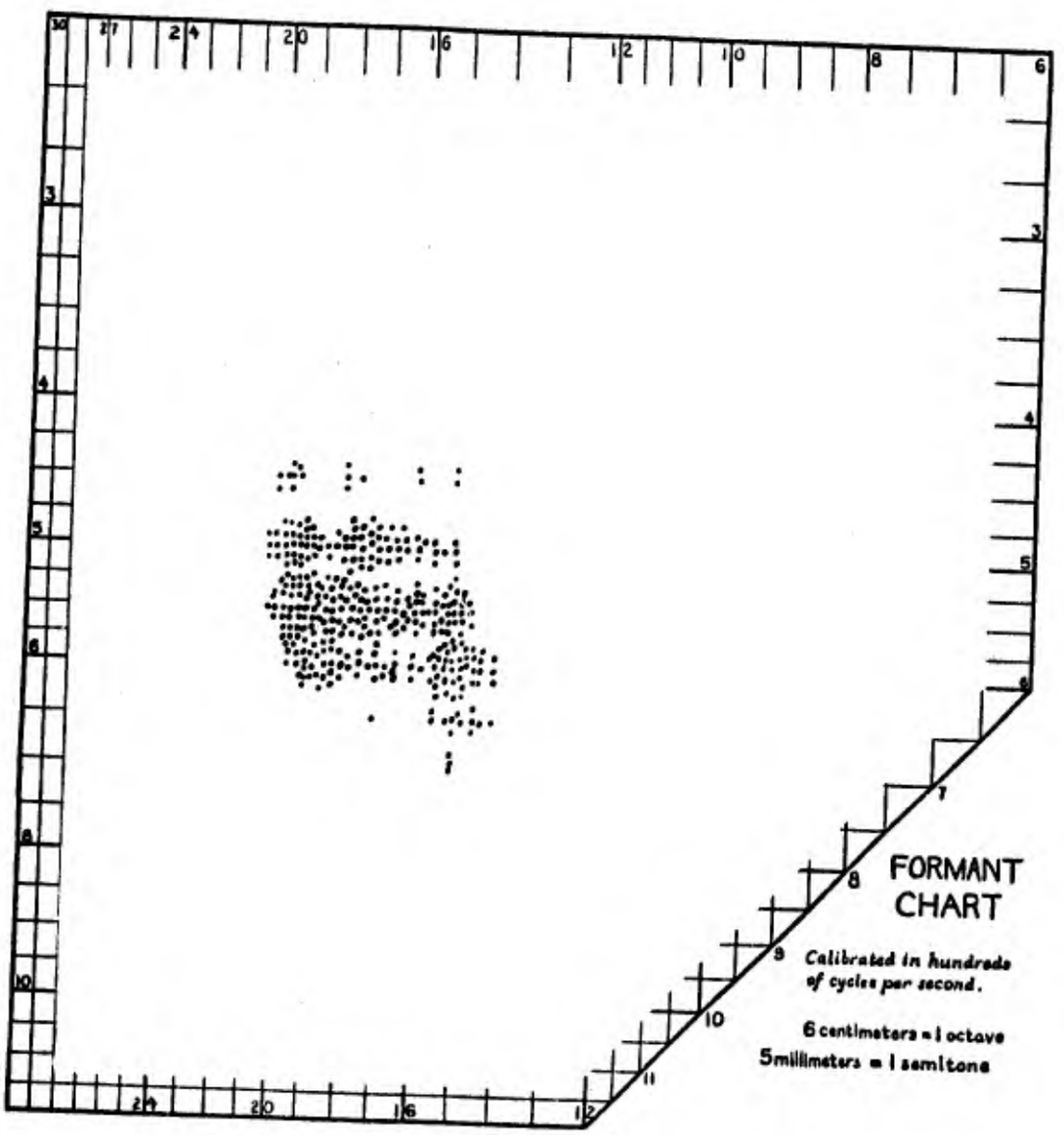


Table 14 presents the F1 and F2 measurements of the segment [ɨ] of [wɨ] in closed syllables with /-m, -n, -ŋ, -p, -t, -k/ as the final consonants. All tones are represented in these utterances by Informant 4. Figure 14 is the corresponding graphic representation of the figures presented in Table 14. It may be noted that the domain of [ɨ] in these examples of the nucleus in closed syllables is slightly larger and extends further back than does the domain of [ɨ] in open syllables.

Table 15 presents the F1 and F2 measurements of [θ] of [uθ] in closed syllables with the same final consonants, and with all tones as spoken by Informant 4. Figure 15 is the corresponding graphic representation on the formant chart. It may be noted that, here again, the domain of [θ] covers a slightly larger area and extends further back on the formant chart.

Figure 15a is a composite chart showing all three nuclei segments [ʒ], [ɨ], and [θ] in a variety of environments. Some overlap of the three is seen in this presentation; but on careful examination, it is clear that this overlap is regularly conditioned. Three different environments are included on this chart. The small dark areas indicate the domains of [ʒ], [ɨ], and [θ] in the restricted environment [t-n] with level tone. The larger striped areas indicate the domains of [ʒ], [ɨ], and [θ] in open syllables with all six tones. The very large white areas show the domains of [ʒ], [ɨ], and [θ] in closed syllable

TABLE 14

Formant measurements of complex nuclei segment [ɨ̃] Closed syllable cycles/second

All tones Informant 4

Segment [ɨ̃] with tone [-]

Word	1 F1	F2	F3	2 F1	F2	F3	3 F1	F2	F3	4 F1	F2	F3
tw̃ɨ̃m	550	1150		500	1200		550	1200		550	1200	
nw̃ɨ̃m	550	1150		550	1200		550	1200		550	1150	
gw̃ɨ̃m	500	1150		500	1200		500	1200		500	1150	
w̃ɨ̃n	600	1400		600	1400		600	1400		600	1350	
lw̃ɨ̃n	550	1450		500	1400		500	1500		550	1450	
tw̃ɨ̃ŋ	600	1200		600	1200		600	1200		550	1200	
cw̃ɨ̃ŋ	650	1200		650	1250		550	1250		650	1250	
kw̃ɨ̃ŋ	600	1150		600	1200		600	1200		600	1250	
bw̃ɨ̃ŋ	600	1250		500	1250		500	1250		500	1250	
dw̃ɨ̃ŋ	550	1200		500	1200		500	1250		500	1250	
lw̃ɨ̃ŋ	550	1200		500	1200		450	1300		500	1200	
mw̃ɨ̃ŋ	650	1200		550	1200		500	1300		550	1300	
nw̃ɨ̃ŋ	600	1200		600	1250		600	1250		600	1200	
gw̃ɨ̃ŋ	600	1200		600	1250		600	1200		550	1200	
hw̃ɨ̃ŋ	650	1150		550	1150		500	1150		550	1250	

Segment [ɨ̃] with tone [↖]

Word	1 F1	F2	F3	2 F1	F2	F3	3 F1	F2	F3	4 F1	F2	F3
cw̃ɨ̃m	550	1100		550	1100		600	1150		600	1150	
kw̃ɨ̃m	550	1100		550	1150		550	1100		550	1150	
nw̃ɨ̃m	600	1200		600	1150		600	1250		600	1250	
zw̃ɨ̃m	600	1150		550	1100		600	1250		550	1200	
cw̃ɨ̃n	600	1450		600	1400		550	1350		600	1350	
vw̃ɨ̃n	600	1450		600	1450		600	1450		550	1450	
sw̃ɨ̃n	600	1400		550	1400		550	1450		600	1450	
tw̃ɨ̃ŋ	650	1250		650	1200		600	1250		600	1250	
cw̃ɨ̃ŋ	600	1250		600	1250		600	1250		600	1250	
kw̃ɨ̃ŋ	650	1200		600	1200		650	1250		650	1250	
dw̃ɨ̃ŋ	650	1200		600	1200		600	1200		600	1200	
lw̃ɨ̃ŋ	600	1250		650	1200		600	1200		600	1250	
mw̃ɨ̃ŋ	650	1200		600	1200		600	1250		600	1250	
nw̃ɨ̃ŋ	650	1200		650	1200		650	1200		650	1250	
hw̃ɨ̃ŋ	600	1250		550	1150		600	1150		650	1200	

Segment [ɨ̃] with tone [⌣]

Word	1 F1	F2	F3	2 F1	F2	F3	3 F1	F2	F3	4 F1	F2	F3
tw̃ɨ̃ŋ	600	1200		550	1200		550	1150		550	1150	
tʰw̃ɨ̃ŋ	650	1250		600	1200		550	1150		550	1200	
cw̃ɨ̃ŋ	650	1200		600	1200		600	1250		600	1250	
sw̃ɨ̃ŋ	550	1150		500	1100		550	1150		500	1100	
hw̃ɨ̃ŋ	600	1150		600	1150		600	1150		600	1200	

Segment [ɨ̃] with tone [/]

Word	1 F1	F2	F3	2 F1	F2	F3	3 F1	F2	F3	4 F1	F2	F3
bw̃ɨ̃m	550	1100		550	1150		550	1150		550	1100	
mw̃ɨ̃n	600	1550		600	1600		600	1500		550	1450	
bw̃ɨ̃ŋ	550	1150		600	1200		600	1200		550	1150	
nw̃ɨ̃ŋ	550	1150		600	1200		600	1200		550	1150	
hw̃ɨ̃ŋ	550	1200		550	1100		550	1150		600	1200	
w̃ɨ̃p	600	1150		600	1300		500	1200		600	1300	
kw̃ɨ̃p	600	1200		550	1250		550	1200		600	1150	
mw̃ɨ̃p	550	1200		550	1150		500	1150		550	1100	
w̃ɨ̃t	550	1500		600	1400		550	1400		550	1350	
tw̃ɨ̃t	600	1450		550	1450		550	1450		550	1400	
lw̃ɨ̃t	550	1450		550	1400		550	1450		550	1500	
mw̃ɨ̃t	600	1600		550	1550		550	1500		550	1550	
w̃ɨ̃k	550	1250		600	1300		550	1250		550	1150	
tw̃ɨ̃k	600	1200		600	1250		600	1250		600	1300	
kw̃ɨ̃k	550	1250		600	1250		600	1300		550	1250	
bw̃ɨ̃k	550	1250		500	1250		550	1250		550	1250	

Segment [ɨ̃] with tone [⌢]

Word	1 F1	F2	F3	2 F1	F2	F3	3 F1	F2	F3	4 F1	F2	F3
w̃ɨ̃n	650	1500		600	1450		600	1450		600	1400	
kw̃ɨ̃ŋ	650	1200		650	1200		600	1200		600	1200	
lw̃ɨ̃ŋ	650	1300		600	1250		650	1200		600	1200	
nw̃ɨ̃ŋ	650	1200		600	1250		650	1300		650	1300	
zw̃ɨ̃ŋ	650	1250		600	1250		600	1250		600	1200	

Segment [ɨ̃] with tone [¬]

Word	1 F1	F2	F3	2 F1	F2	F3	3 F1	F2	F3	4 F1	F2	F3
dw̃ɨ̃m	650	1100		650	1150		650	1150		650	1200	
lw̃ɨ̃m	600	1150		650	1150		600	1150		600	1150	
lw̃ɨ̃n	650	1400		650	1350		650	1400		650	1400	
mw̃ɨ̃n	650	1450		650	1450		650	1450		650	1500	
vw̃ɨ̃n	650	1400		650	1500		650	1500		600	1500	
tw̃ɨ̃ŋ	700	1250		700	1250		650	1250		650	1200	
lw̃ɨ̃ŋ	650	1250		650	1250		650	1200		650	1250	
nw̃ɨ̃ŋ	700	1250		700	1200		700	1300		700	1250	
ŋw̃ɨ̃ŋ	700	1250		700	1250		700	1250		700	1250	
cw̃ɨ̃t	600	1350		650	1350		600	1350		600	1350	
mw̃ɨ̃t	600	1500		650	1450		600	1450		600	1450	
vw̃ɨ̃t	600	1400		600	1500		600	1450		650	1500	
zw̃ɨ̃t	600	1350		550	1450		550	1500		550	1400	
dw̃ɨ̃k	650	1250		600	1250		600	1250		600	1250	
nw̃ɨ̃k	650	1250		600	1200		550	1250		600	1200	
ŋw̃ɨ̃k	700	1250		650	1250		650	1250		650	1200	

Blank spaces indicate where precise measurements were not obtainable.

FIGURE 14

[ɪ] in closed syllables

All tones Informant 4

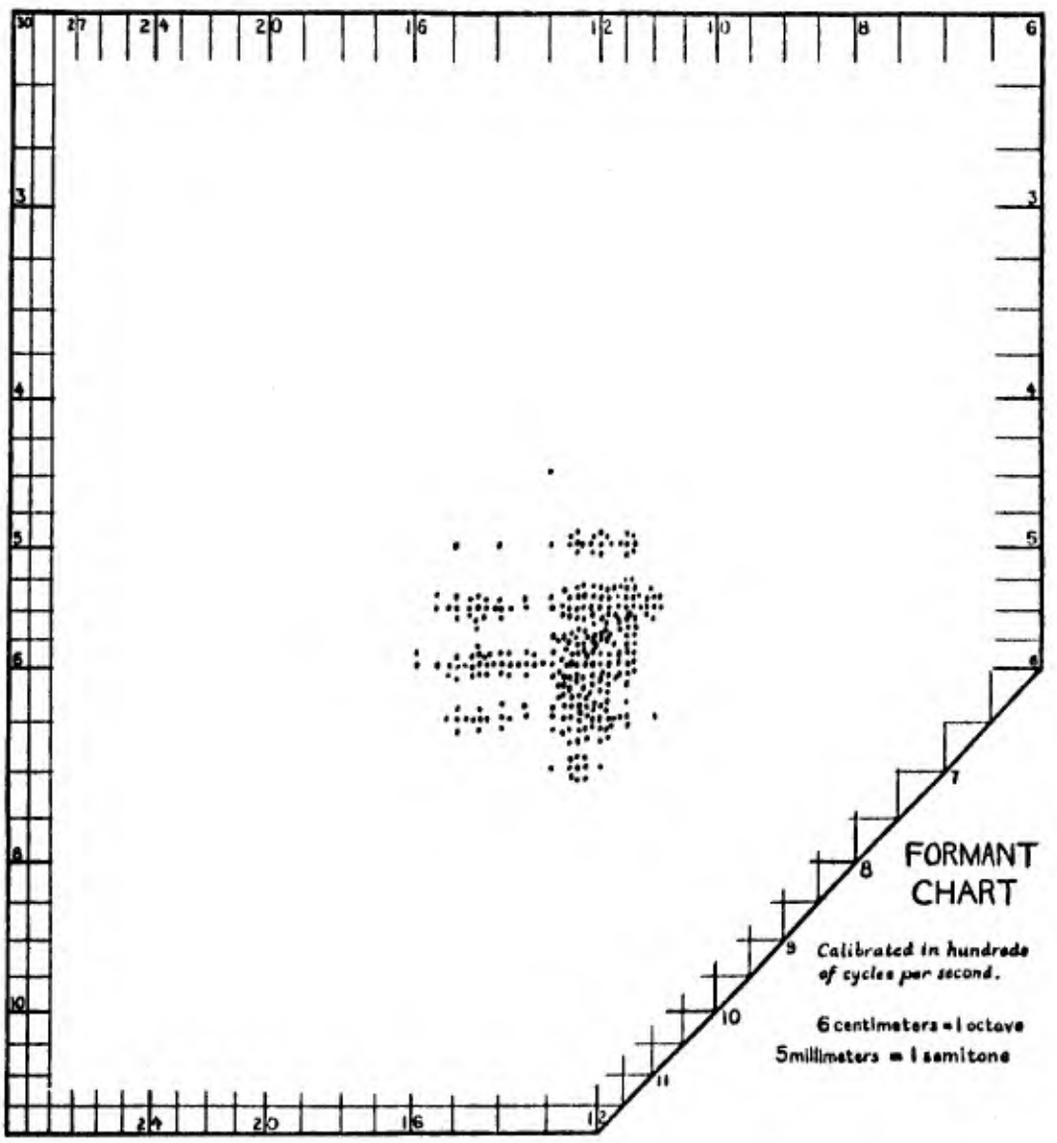


TABLE 19

Formant measurements of complex nuclei segment [ə] Closed syllable cycles/second

All tones Informant 4

Segment [ə] with tone [-]

Word	1 F1	F2	F3	2 F1	F2	F3	3 F1	F2	F3	4 F1	F2	F3
cūəm				450	850		450	1000		450	1000	
nūəm				400	1000		400	1000		450	1000	
tūən				450	1100		450	1150		450	1150	
tʰūən				450	1100		450	1150		450	1000	
būən				450	1150		450	1100		450	1100	
lūən				500	1150		450	1050		400	1000	
nūən				450	1100		400	1050		500	1050	
cūəŋ				550	1000		500	1000		500	950	
cūəŋ				500	1000		500	1000		450	950	
būəŋ				500	1100		450	1000		450	900	
lūəŋ				450	900		450	1000		450	1000	
nūəŋ				450	1000		450	1000		450	900	
nūəŋ				450	900		450	1000		450	1000	

Segment [ə] with tone [ˋ]

Word	1 F1	F2	F3	2 F1	F2	F3	3 F1	F2	F3	4 F1	F2	F3
bùəm				500	1000		500	950		450	850	
tùən				550	1200		550	1200		500	1150	
cùən				500	1150		500	1150		550	1150	
lùən				450	1100		500	1100		500	1100	
ɲùən				500	1100		500	1100		550	1050	
tùəŋ				500	1000		500	950		500	950	
kùəŋ				500	1100		500	1050		500	1050	
lùəŋ				500	900		500	950		450	1000	
bùəŋ				500	1000		550	1050		500	1050	

Segment [ə] with tone [ˇ]

Word	1 F1	F2	F3	2 F1	F2	F3	3 F1	F2	F3	4 F1	F2	F3
tʰǔəŋ				500	950		450	950		500	950	
sǔəŋ				500	900		500	950		500	1000	

Blank spaces indicate where precise measurements were not obtainable.

Segment [ə] with tone [/]

Word	1 F1	F2	F3	2 F1	F2	F3	3 F1	F2	F3	4 F1	F2	F3
núəm				400	750		350	850		350	800	
kúən				550	1050		500	1100		500	1050	
múən				450	950		450	950		550	950	
júəŋ				450	850		450	850		500	850	
kúəŋ				550	950		500	950		500	950	
múəŋ				500	950		500	900		450	800	
húəŋ				450	900		450	850		450	1000	
túət				400	1150		400	1100		500	1100	
cúət				400	1150		450	1100		450	1150	
búət				350	1050		350	1000		350	1050	
núət				450	1150		400	1050		350	1150	
tʰúək				450	900		350	850		450	900	
kúək				400	1150		400	1150		400	1100	
dúək				500	800		500	800		450	900	
gúək				450	950		450	1000		450	1050	

Segment [ə] with tone [~]

Word	1 F1	F2	F3	2 F1	F2	F3	3 F1	F2	F3	4 F1	F2	F3
kũəm				550	900		500	850		500	850	
mũəm				500	850		500	950		500	800	
mũəŋ				500	950		500	950		500	950	

Segment [ə] with tone [¯]

Word	1 F1	F2	F3	2 F1	F2	F3	3 F1	F2	F3	4 F1	F2	F3
nūəm				550	850		500	850		500	850	
kūən				550	1150		500	1150		550	1100	
mūən				500	1150		500	1100		550	1150	
gūən				500	1200		550	1200		500	1150	
kūəŋ				550	950		550	900		550	1000	
kūəŋ				550	950		500	900		550	1000	
tūət				450	1000		500	1100		450	1150	
cūət				500	1150		500	1200		500	1200	
būət				450	1100		450	1100		450	1050	
kūət				450	1150		500	1150		500	1100	
tʰūək				500	950		450	950		500	1000	
cūək				500	1000		550	1050		550	1050	
kūək				550	1100		500	1050		500	1050	
būək				500	950		450	950		450	900	
lūək				500	1050		550	1000		500	1000	

FIGURE 15

[θ] in closed syllables

All tones Informant 4

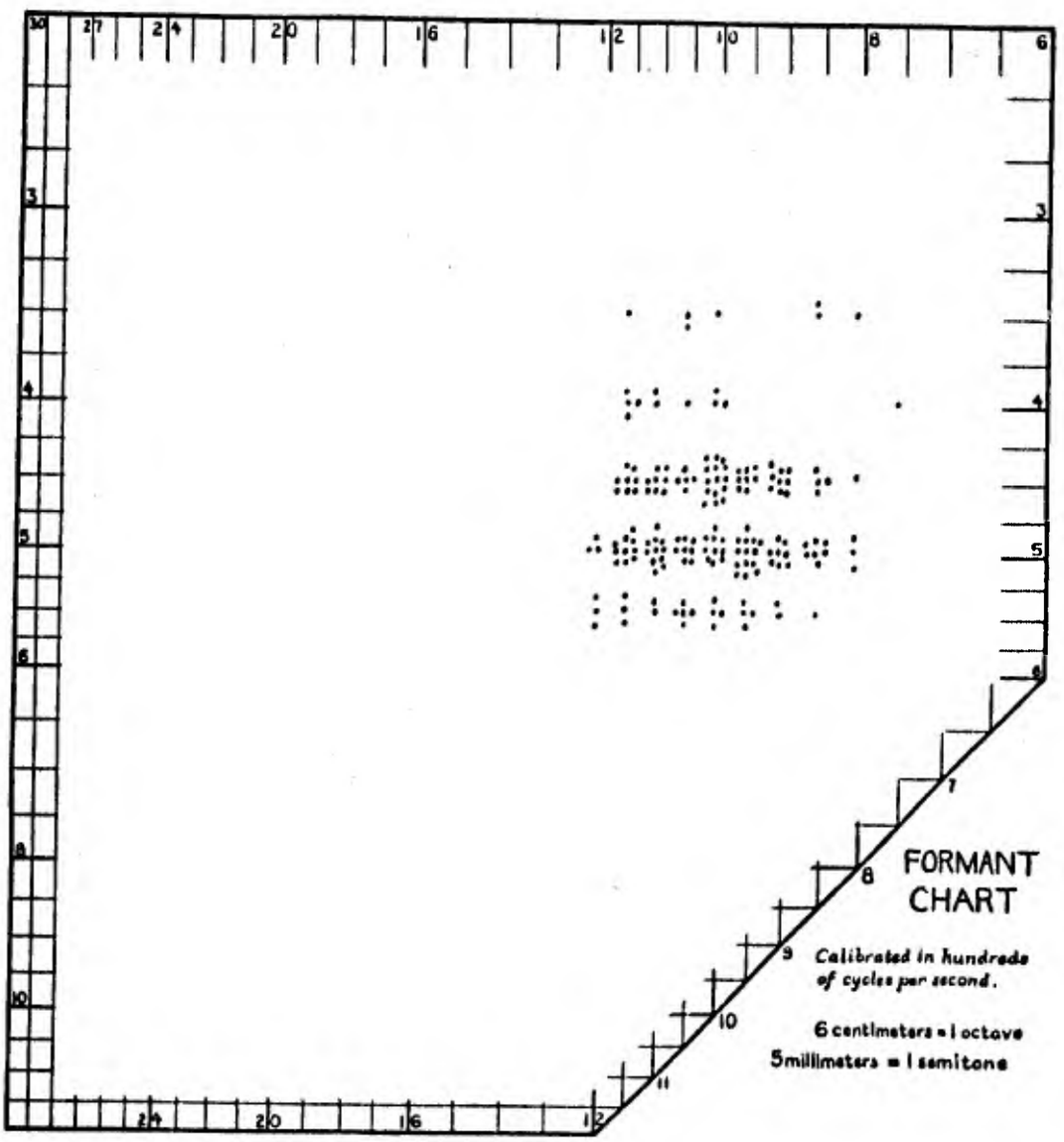
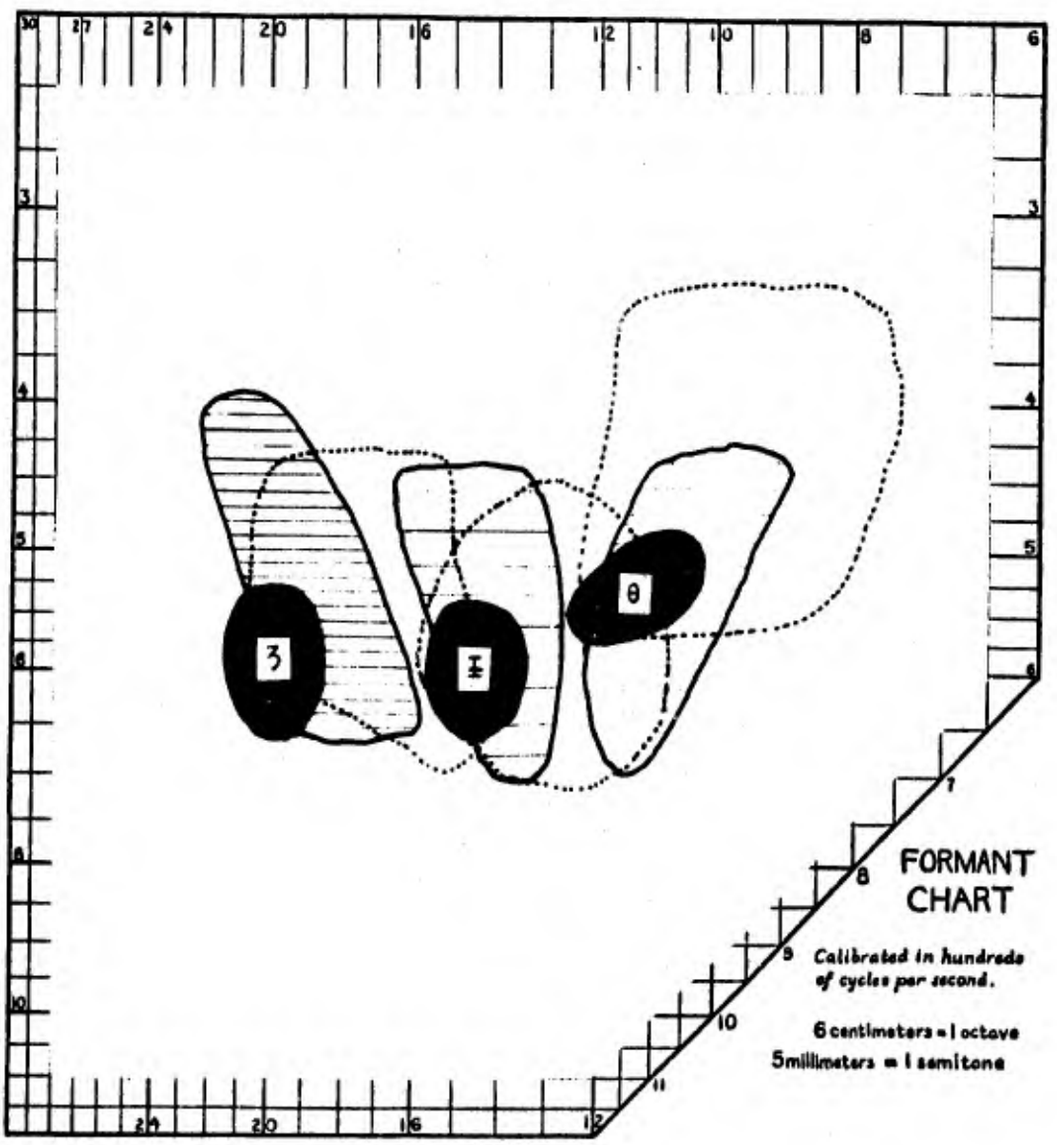


FIGURE 15a

Comparison of [ʒ] [ɪ] and [θ]

Various environments Informant 4



with /-m, -n, -ŋ, -p, -t, -k/ as final consonants, with all six tones.

As was demonstrated in the preceeding chapter and as is seen here, the domains of the nuclei segments [ɜ], [ɪ], and [ɵ] are clearly separated in a restricted environment such as [t-n] with level tone. When the environment is expanded to include all six tones, but restricted to open syllable types, the domains of [ɜ], [ɪ], and [ɵ] are still clearly distinct from one another. When the environment is expanded to include closed syllables and all tones, overlap of the three domains does occur; but, this overlap is in a regular pattern, i.e., the domains move backward on the formant chart.

To check and augment our data, we examined and analysed the recorded material of Informant 3 according to the same procedures used with that of Informant 4. Tables 16, 17, and 18 are the measurements of Informant 3's [ɜ], [ɪ], and [ɵ], respectively, in open syllables, including all tones. Figures 16, 17, and 18 are the corresponding graphic representations on formant charts.

Figure 18a presents the domains occupied by [ɜ], [ɪ], and [ɵ] in open syllables on one formant chart. Although Informant 3's [ɪ] and [ɵ] show some marginal overlap, [ɜ] is clearly separated and in general, three domains can be identified.

TABLE 16

Formant measurements of complex nuclei segment [ɔ̃] Open syllable cycles/second

All tone Informant 3

Segment [ɔ̃] with tone [-]

Word	1 F1	F2	F3	2 F1	F2	F3	3 F1	F2	F3	4 F1	F2	F3
tɔ̃	750	1800		700	1750		700	1850		700	1700	
tʰɔ̃	750	1750		700	1800		700	1700		650	1850	
cɔ̃	700	1750		650	1800		700	1800		700	1800	
kɔ̃	700	1800		700	1900		700	1900		650	1900	
bɔ̃	700	1850		700	1900		650	1850		650	1850	
lɔ̃	700	1750		700	1900		700	1900		700	1850	
nɔ̃	700	1900		650	1900		650	1850		650	1850	
ɲɔ̃	700	2000		550	2000		650	1900		550	2100	
vɔ̃	700	1950		700	1950		650	1850		650	2050	
ɣɔ̃	550	2000		700	1950		650	1950		550	2000	
hɔ̃	600	1800		550	2000		550	2000		550	1900	

Segment [ɔ̃] with tone [˥]

Word	1 F1	F2	F3	2 F1	F2	F3	3 F1	F2	F3	4 F1	F2	F3
tɔ̃					750	1950		750	1900		750	1950
mɔ̃					800	1950		750	1850		750	1850
fɔ̃					750	1800		750	1850		700	1900
xɔ̃					750	1850		750	1950		750	1950

Segment [ɔ̃] with tone [˧˥]

Word	1 F1	F2	F3	2 F1	F2	F3	3 F1	F2	F3	4 F1	F2	F3
cɔ̃		900	1750		800	1800		750	1900			
kɔ̃		800	1900		800	1900		750	1850			
cɔ̃		800	1750		850	1750		750	1800			
dɔ̃		850	1800		800	1800		800	1800			
lɔ̃		850	1850		850	1750		800	1850			

Segment [ɔ̃] with tone [˧˥]

Word	1 F1	F2	F3	2 F1	F2	F3	3 F1	F2	F3	4 F1	F2	F3
cɔ̃					900	1850		850	1950		850	1900
dɔ̃					850	1900		850	1850		800	1950
nɔ̃					850	1900		850	1850		800	1850
ŋɔ̃					850	1950		850	1850		850	1850

Segment [ɔ̃] with tone [˧˩]

Word	1 F1	F2	F3	2 F1	F2	F3	3 F1	F2	F3	4 F1	F2	F3
ɲɔ̃	850	1700		850	1700		950	1700		800	1750	
tɔ̃	900	1700		900	1700		850	1800		850	1800	
dɔ̃	900	1650		900	1750		850	1750		800	1800	
mɔ̃	850	1650		850	1700		800	1750		800	1800	

Segment [ɔ̃] with tone [˧]

Word	1 F1	F2	F3	2 F1	F2	F3	3 F1	F2	F3	4 F1	F2	F3
bɔ̃	850	1950		850	1900		850	2000		350	1900	
dɔ̃	850	1900		850	1900		800	1950		800	1950	
lɔ̃	850	1850		800	1900		850	1850		850	1950	

Blank spaces indicate where precise measurements were not obtainable.

FIGURE 16

[ʒ] in open syllables

All tones Informant 3

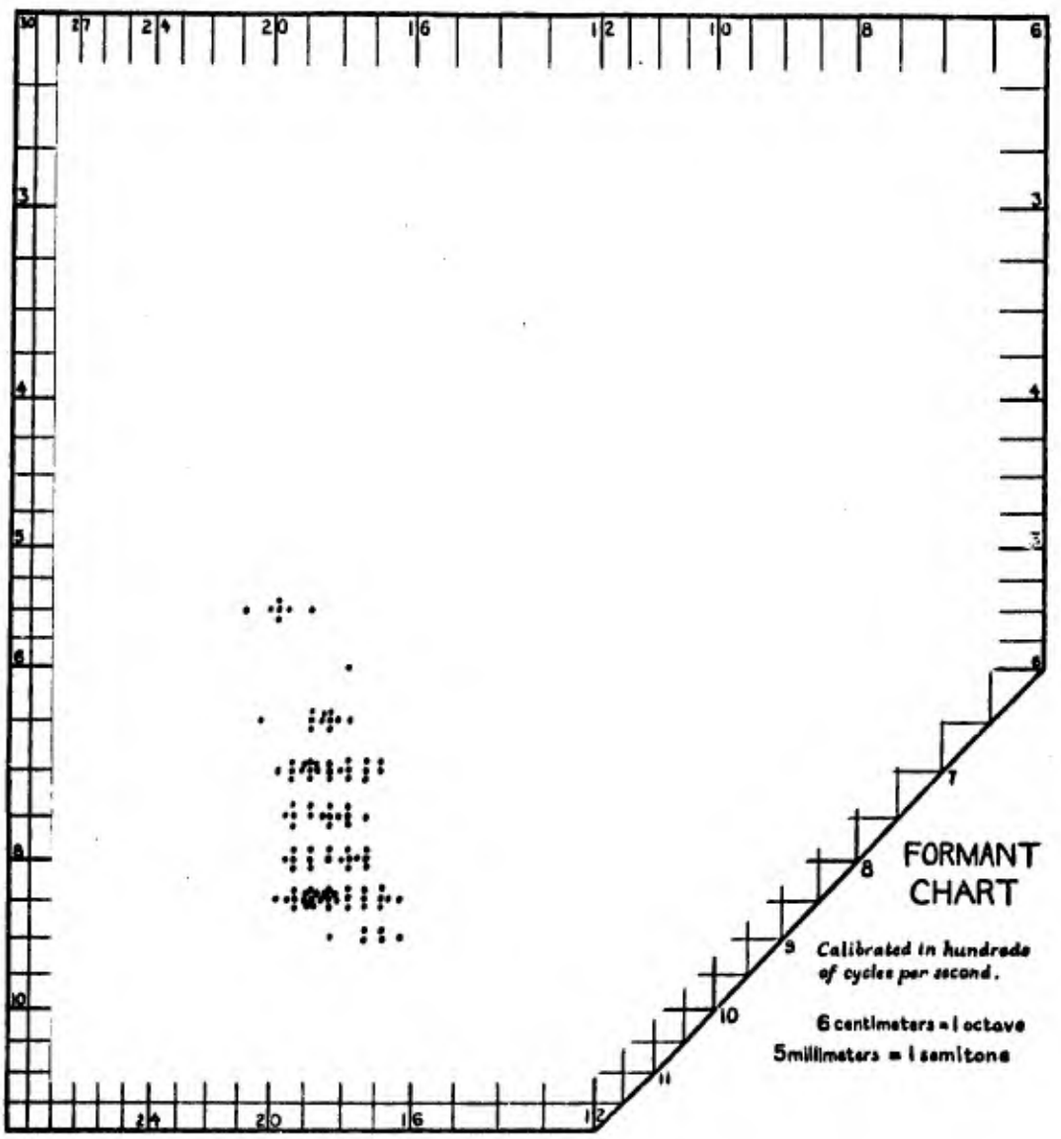


TABLE 17

Formant measurements of complex nuclei segment [ɤ̃] Open syllable cycles/second

All tones Informant 3

Segment [ɤ̃] with tone [˥]

Word	1 F1	F2	F3	2 F1	F2	F3	3 F1	F2	F3	4 F1	F2	F3
wɤ̃	500	1350		650	1300		600	1250		600	1250	
thɤ̃	650	1300		600	1250		600	1250		600	1200	
cɤ̃	700	1350		700	1350		650	1350		650	1300	
dɤ̃	650	1300		650	1250		600	1250		650	1350	
mɤ̃	550	1300		650	1250		650	1250		650	1250	
sɤ̃	650	1300		650	1250		650	1250		650	1250	
zɤ̃	650	1300		500	1300		650	1300		650	1250	

Segment [ɤ̃] with tone [˧]

Word	1 F1	F2	F3	2 F1	F2	F3	3 F1	F2	F3	4 F1	F2	F3
cɤ̃				650	1300		650	1300		650	1300	
kɤ̃				750	1300		650	1300		650	1350	
bɤ̃				700	1400		650	1350		650	1350	
dɤ̃				650	1350		650	1300		600	1350	
lɤ̃				650	1350		650	1250		600	1450	
mɤ̃				750	1250		650	1250		500	1250	
nɤ̃				650	1300		650	1400		600	1450	
ŋɤ̃				600	1350		600	1350		600	1450	
hɤ̃				650	1300		650	1300		600	1250	

Segment [ɤ̃] with tone [˨˩]

Word	1 F1	F2	F3	2 F1	F2	F3	3 F1	F2	F3	4 F1	F2	F3
cɤ̃				800	1400		750	1400		750	1350	
bɤ̃				750	1400		750	1350		750	1350	
lɤ̃				750	1450		750	1400		750	1400	
ŋɤ̃				750	1350		750	1350		750	1400	

Segment [ɤ̃] with tone [˦˧]

Word	1 F1	F2	F3	2 F1	F2	F3	3 F1	F2	F3	4 F1	F2	F3
cɤ̃				800	1500		800	1500		750	1500	
bɤ̃				800	1400		850	1450		850	1500	
nɤ̃				800	1450		800	1450		800	1450	

Segment [ɤ̃] with tone [˧˥]

Word	1 F1	F2	F3	2 F1	F2	F3	3 F1	F2	F3	4 F1	F2	F3
cɤ̃				850	1350		850	1400		800	1400	
kɤ̃				850	1400		800	1450		800	1450	
bɤ̃				850	1450		850	1400		850	1400	
mɤ̃				900	1450		900	1400		850	1400	
nɤ̃				850	1500		800	1500		800	1500	
ŋɤ̃				850	1500		850	1450		850	1500	

Segment [ɤ̃] with tone [˥˩]

Word	1 F1	F2	F3	2 F1	F2	F3	3 F1	F2	F3	4 F1	F2	F3
wɤ̃				750	1350		750	1350		750	1350	
tɤ̃				750	1400		750	1350		750	1350	
kɤ̃				750	1350		750	1350		750	1400	
bɤ̃				750	1400		750	1350		750	1350	
lɤ̃				800	1400		800	1400		750	1350	
ŋɤ̃				750	1350		750	1300		750	1350	

Blank spaces indicate where precise measurements were not obtainable.

FIGURE 17

[ɨ] in open syllables

All tones Informant 3

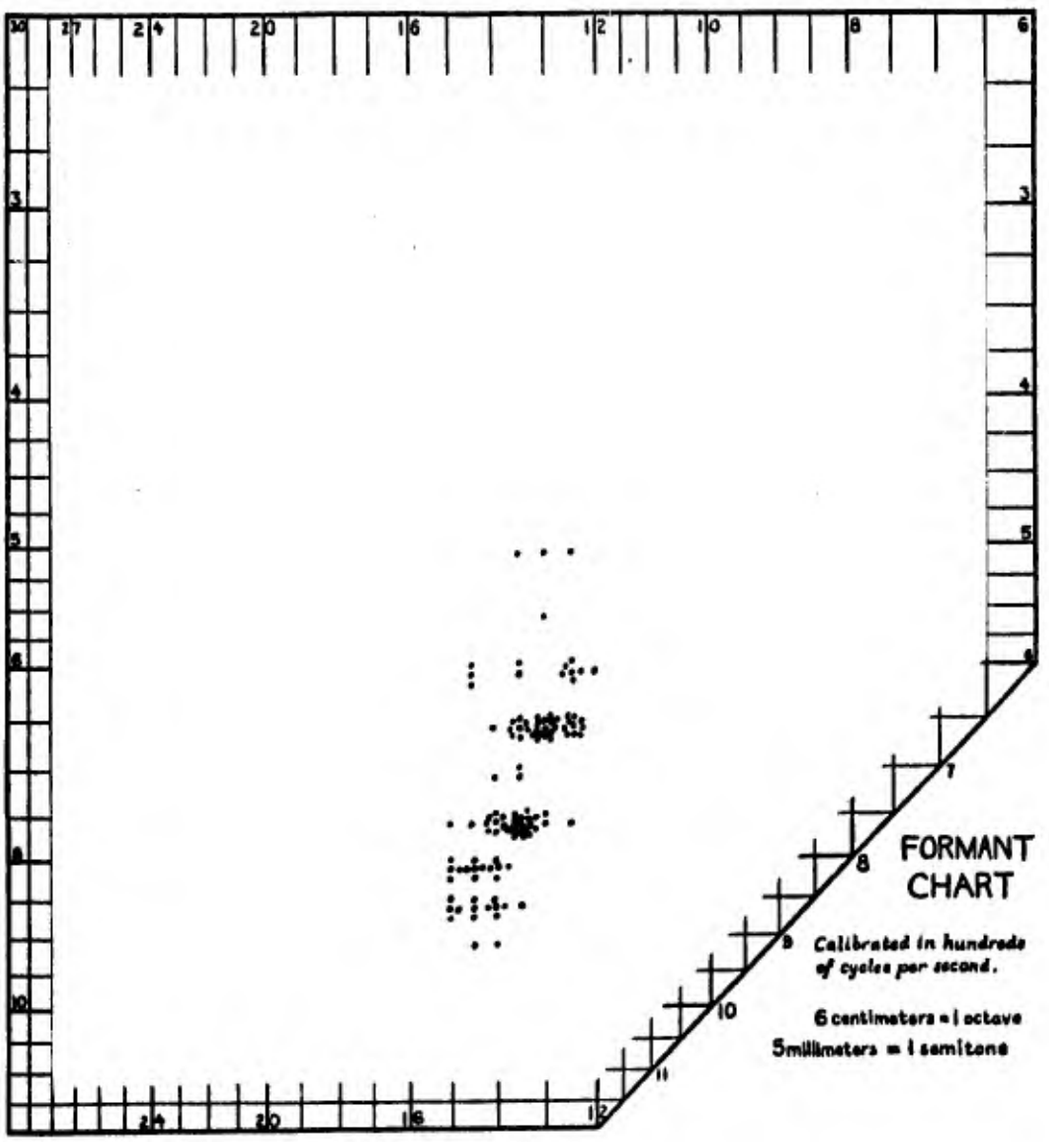


TABLE 18

Formant measurements of complex nuclei segment [ə] Open syllable cycles/second

All tones Informant 3

Segment [ə] with tone [-]

Word	1 F1	F2	F3	2 F1	F2	F3	3 F1	F2	F3	4 F1	F2	F3
tʰūə̄	700	1150		700	1200		750	1250		700	1200	
tūə̄	750	1250		700	1200		700	1200		700	1200	
cūə̄	650	1250		700	1200		600	1200		600	1200	
nūə̄	650	1050		750	1250		750	1250		700	1200	
nūə̄	500	1000		600	1200		600	1200		500	1200	
ŋūə̄	500	1050		500	1000		500	1000		500	1100	
fūə̄	600	1100		600	1100		600	1200		600	1100	
vūə̄	700	1150		700	1150		700	1150		700	1150	
sūə̄	600	1100		600	1100		600	1200		500	1200	
zūə̄	500	1000		600	1100		600	1150		600	1150	
xūə̄	600	1000		600	1200		600	1150		600	1200	

Segment [ə] with tone [ˊ]

Word	1 F1	F2	F3	2 F1	F2	F3	3 F1	F2	F3	4 F1	F2	F3
ūə́				550	1050		600	1050		600	1100	
tūə́				650	1000		600	1000		600	1000	
cūə́				600	1000		600	1200		600	1200	
būə́				500	1000		600	950		450	950	
lūə́				600	1000		600	1200		550	1150	
mūə́				600	1000		600	950		600	1100	

Segment [ə] with tone [ˇ]

Word	1 F1	F2	F3	2 F1	F2	F3	3 F1	F2	F3	4 F1	F2	F3
ūə̌				650	1050		650	1100		650	1100	
cūə̌				750	1200		650	1200		650	1200	
būə̌				650	1100		650	1100		650	1100	
dūə̌				650	1150		750	1200		650	1150	
lūə̌				750	1200		700	1150		700	1200	
mūə̌				650	1100		600	1050		600	1150	

Segment [ə] with tone [~]

Word	1 F1	F2	F3	2 F1	F2	F3	3 F1	F2	F3	4 F1	F2	F3
dūə̃	700	1250		750	1200		750	1250		750	1250	
lūə̃	750	1300		750	1200		750	1250		750	1250	
sūə̃				700	1200		750	1300		750	1250	

Segment [ə] with tone [ˇ]

Word	1 F1	F2	F3	2 F1	F2	F3	3 F1	F2	F3	4 F1	F2	F3
ūə̌	850	1200		800	1250		750	1150		800	1150	
kūə̌				850	1200		750	1200		800	1150	
sūə̌				800	1200		850	1300		850	1250	

Segment [ə] with tone [—]

Word	1 F1	F2	F3	2 F1	F2	F3	3 F1	F2	F3	4 F1	F2	F3
ūə̄	750	1200		750	1250		750	1150		750	1150	
būə̄	750	1200		750	1150		700	1200		700	1150	
lūə̄	750	1200		750	1250		750	1250		700	1200	

Blank spaces indicate where precise measurements were not obtainable.

FIGURE 18

[ə] in open syllables

All tones Informant 3

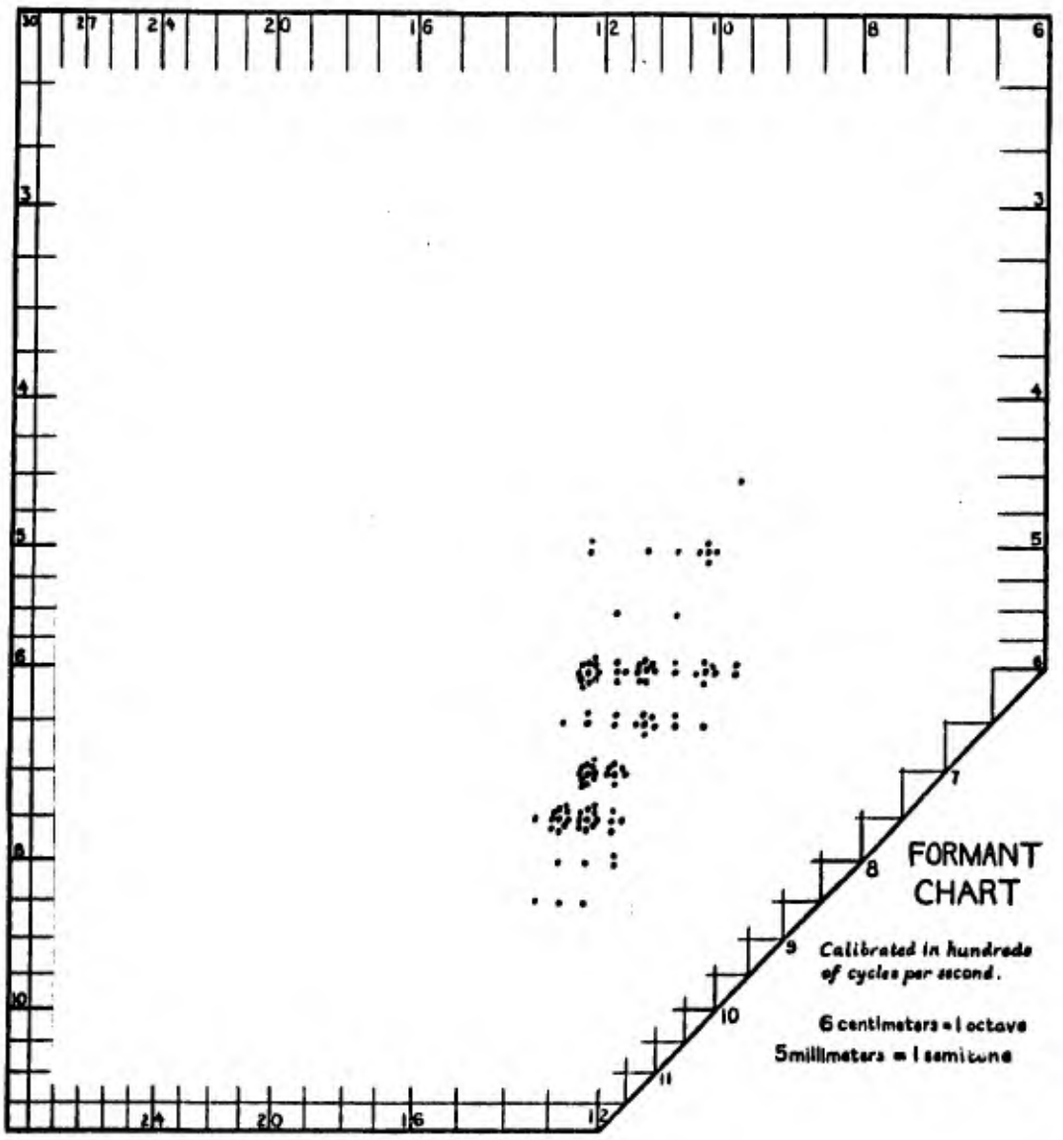
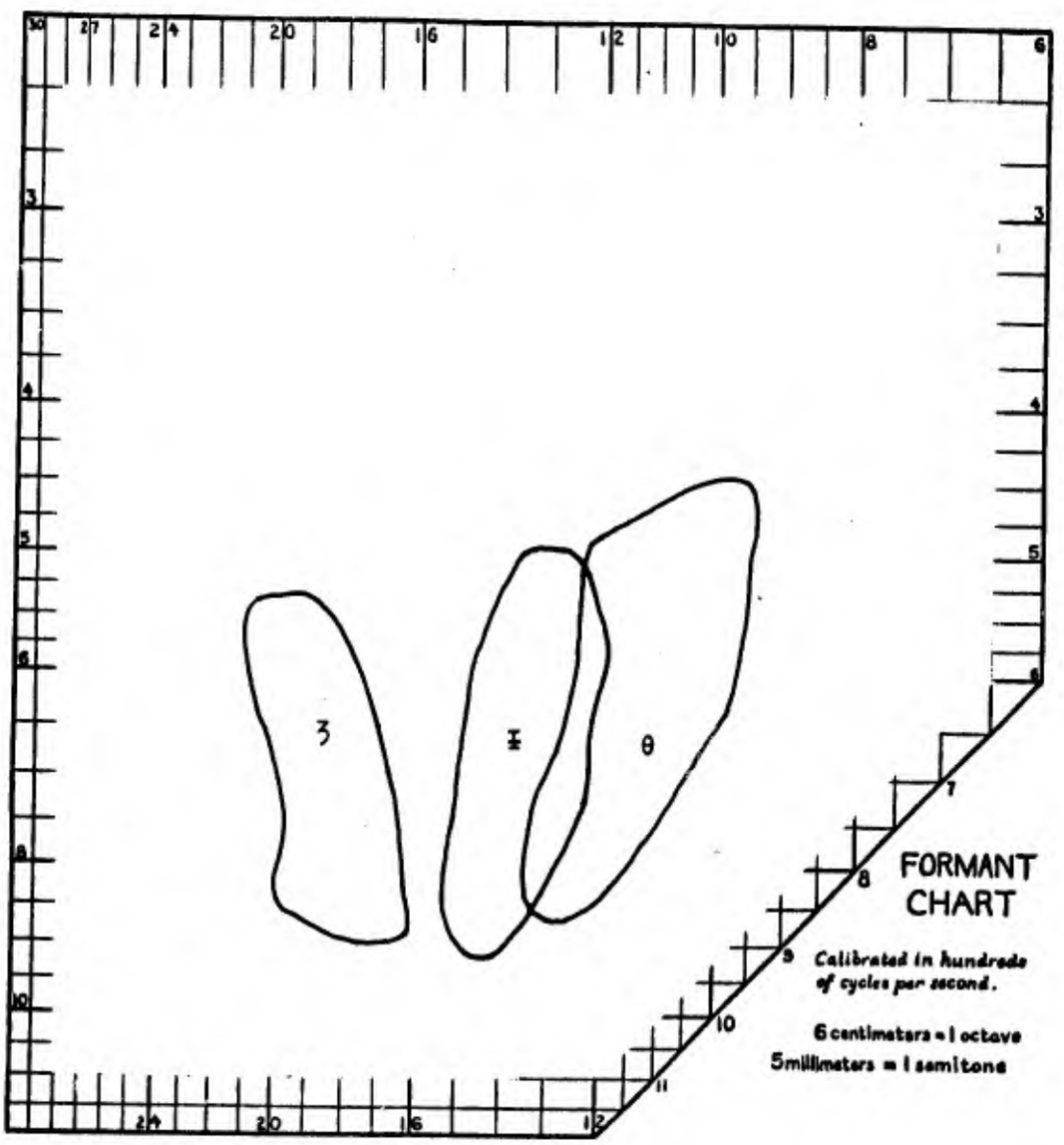


FIGURE 18a

Domains of [-ʒ] [-ɪ] [-θ] in open syllables

All tones Informant 3



Tables 19, 20, and 21 are the measurements of the three segments [ʒ], [ɪ], and [ə] of Informant 3 in closed syllables with the final consonants /-m, -n, -ŋ, -p, -t, -k/, including all six tones. Figures 19, 20, and 21 are the corresponding charts.

Figure 21a is the composite chart showing all three nuclei segments in the three environments examined: [t-n] with level tone; open syllable with all tones; and closed syllables with all tones. As with Informant 4, the overlap which is apparent is regularly conditioned with the domains becoming larger and moving further back on the formant chart.

TABLE 19

Formant measurements of complex nuclei segment [ɨ] Closed syllable cycles/second

All tones Informant 3

Segment [ɨ] with tone [-]

Word	1 F1 F2 F3	2 F1 F2 F3	3 F1 F2 F3	4 F1 F2 F3
lɨ̄m		550 1900	550 1850	550 1900
tɨ̄m		550 1950	550 1950	550 1850
kɨ̄m		550 1900	550 2150	550 2000
ɬɨ̄m		550 1900	550 1850	550 2100
ɾɨ̄m		550 1950	550 1950	550 2050
ŋɨ̄m		550 1900	550 1850	550 1850
lɨ̄n		550 2250	550 2150	550 2150
tɨ̄n		550 2050	550 1900	550 1950
kɨ̄n		550 2200	550 2100	550 2150
bɨ̄n		550 2150	550 2100	550 2100
ɑɨ̄n		550 2150	550 2150	550 2150
mɨ̄n		550 2250	550 2150	550 2250
nɨ̄n		550 2150	500 2250	500 2150
ɲɨ̄n		550 2200	500 2100	500 2050
ŋɨ̄n		500 2250	500 2100	500 2100
ɬɨ̄ŋ		500 1950	500 1950	500 1900
kɨ̄ŋ		550 1900	550 1850	550 2000
ŋɨ̄ŋ		550 1850	550 1900	550 1900
tɨ̄p		800 1750	800 1750	800 1750
ŋɨ̄p		800 1850	800 1850	800 1800
tɨ̄t		750 1950	750 2000	750 1900
tʰɨ̄t		800 1900	750 1900	750 2000
nɨ̄t		750 1950	750 1950	750 2000
ŋɨ̄t		750 2050	800 2100	750 2000
tɨ̄k		750 1750	800 1750	900 1750
vɨ̄k		800 1750	800 1800	800 1750

Segment [ɨ] with tone [˨]

Word	1 F1 F2 F3	2 F1 F2 F3	3 F1 F2 F3	4 F1 F2 F3
tɨ̀m		800 1850	800 1800	800 1850
kɨ̀m		800 1850	800 1850	750 1800
lɨ̀m		800 1750	750 1800	800 1800
nɨ̀m		800 1800	750 1750	750 1750
tɨ̀n		800 2000	800 1950	800 2000
lɨ̀n		800 2000	750 1950	750 1900
nɨ̀n		800 2150	800 2000	750 2100

Segment [ɨ] with tone [˩˨]

Word	1 F1 F2 F3	2 F1 F2 F3	3 F1 F2 F3	4 F1 F2 F3
ɾɨ̀m		850 1850	800 1700	850 1800
tʰɾɨ̀m		850 1750	850 1700	800 1800
kɨ̀m		800 1800	850 1700	750 1950
tʰɾɨ̀n		850 1950	750 1900	700 2000
ɨ̀n		900 1800	850 1700	850 1650

Segment [ɨ] with tone [˩]

Word	1 F1 F2 F3	2 F1 F2 F3	3 F1 F2 F3	4 F1 F2 F3
ɾɨ̀m		650 2100	650 2050	650 2050
tɾɨ̀m		650 2100	600 2000	600 2100
kɾɨ̀m		600 1950	650 2050	600 2000
ɨ̀n		700 2150	700 2100	700 2100
tɾɨ̀n		750 2200	750 2000	750 2150
tɾɨ̀ŋ		500 2050	500 2000	600 1950
bɾɨ̀ŋ		600 1950	600 1950	600 2150
dɾɨ̀ŋ		500 1950	500 1900	500 1950
tɾɨ̀p		650 1850	600 1900	600 1800
kɾɨ̀p		650 2000	650 1800	700 1900
ɾɨ̀t		650	650 2050	650 2200
tɾɨ̀t		700 1950	650 1950	650 1950
kɾɨ̀t		650 1950	650 2000	650 2000
tɾɨ̀k		700 1750	700 1750	650 1800
pɾɨ̀k		700 1850	700 1800	650 1800
dɾɨ̀k		750 1850	700 1750	650 1800

Segment [ɨ] with tone [˥˩]

Word	1 F1 F2 F3	2 F1 F2 F3	3 F1 F2 F3	4 F1 F2 F3
lɨ̂m		850 1850	850 1800	800 1950
nɨ̂m		800 1900	750 1750	750 1850
tɨ̂n		850 2050	800 2050	800 2000
lɨ̂n		800 2100	850 2000	800 2100
nɨ̂n		800 2100	800 2100	750 2200
nɨ̂ŋ		750 1900	750 1900	750 1950

Segment [ɨ] with tone [˥˧]

Word	1 F1 F2 F3	2 F1 F2 F3	3 F1 F2 F3	4 F1 F2 F3
tɨ̂m		800 1800	800 1900	800 1900
nɨ̂m		800 1900	800 1950	800 1900
ŋɨ̂m		750 1900	800 1950	750 1950
tɨ̂n		800 1950	800 1950	800 1900
tʰɾɨ̂n		850 1950	850 1900	850 1950
lɨ̂ŋ		800 1850	800 1900	800 1900

Blank spaces indicate where precise measurements were not obtainable.

FIGURE 19

[ɔ] in closed syllables

All tones Informant 3

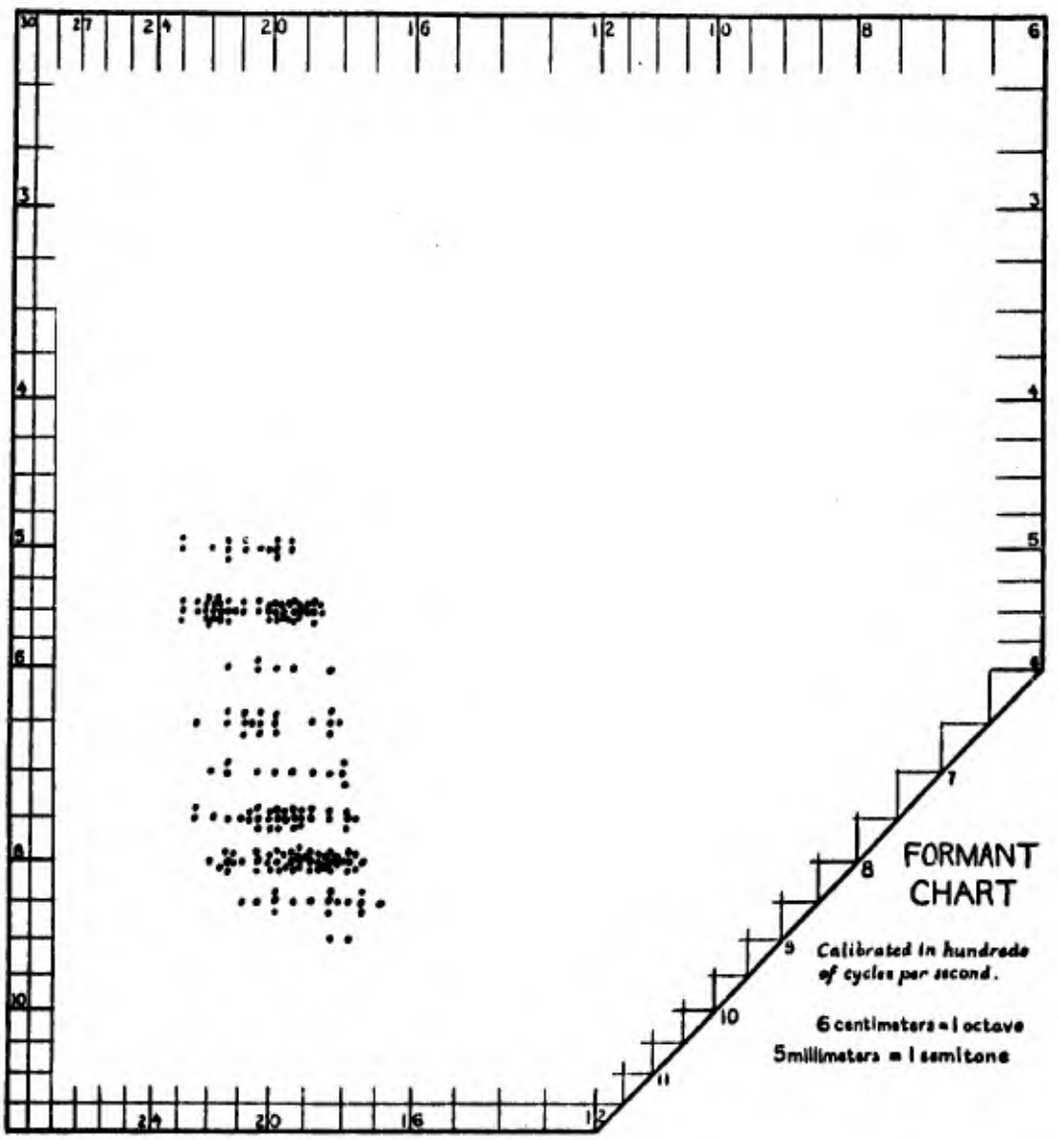


TABLE 2/

Formant measurements of complex nuclei segment [ə] Closed syllable cycles/second

All tones Informant 3

Segment [ə] with tone [-]

Word	F1	F2	F3
tuən	600 1200	600 1200	600 1200
nuən	550 1350	550 1350	550 1350
cuən	600 1200	590 1250	550 1250
ʔən	500 1300	500 1400	500 1400
lʔən	500 1400	500 1450	550 1350
tuəŋ	550 1450	550 1400	550 1350
cuəŋ	550 1350	550 1350	550 1350
tuəŋ	550 1400	550 1400	550 1400
duəŋ	550 1400	550 1350	500 1350
luəŋ	550 1350	500 1300	500 1300
nuəŋ	550 1400	550 1400	550 1350
huəŋ	550 1350	550 1350	550 1350

Segment [ə] with tone [\]

Word	F1	F2	F3
cuən	750 1350	750 1450	700 1400
kuən	700 1350	700 1400	750 1400
nuən	800 1450	750 1350	750 1350
ruən	700 1400	700 1350	750 1300
cuən	650 1300	700 1500	700 1500
vuən	750 1350	750 1500	750 1400
suən	750 1550	750 1550	750 1550
tuəʔ	700 1400	650 1300	650 1350
cuəʔ	700 1400	650 1350	750 1300
luəʔ	650 1350	650 1350	750 1350
huəʔ	650 1350	700 1400	700 1350

Segment [ə] with tone [V]

Word	F1	F2	F3
cuəʔ	700 1250	700 1250	700 1300
cuəʔ	700 1250	750 1250	750 1250
huəʔ	800 1250	750 1300	750 1300

Segment [ə] with tone [ˊ]

Word	F1	F2	F3
buən	500 1250	500 1250	500 1250
nuən	500 1400	600 1500	600 1500
buəʔ	450 1200	450 1200	450 1200
nuəʔ	500 1250	500 1250	450 1200
huəʔ	500 1300	500 1300	500 1250
cəp	700 1350	650 1350	650 1350
kəp	700 1350	700 1400	650 1350
cət	650 1400	650 1450	650 1450
tət	650 1350	650 1300	650 1350
lət	650 1400	600 1500	600 1500
cək	700 1300	700 1300	700 1350
tək	650 1300	650 1300	650 1300
tʰək	650 1300	650 1300	650 1350
kək	650 1250	650 1250	650 1250
bək	650 1250	650 1250	650 1250

Segment [ə] with tone [~]

Word	F1	F2	F3
ʔən	700 1650	700 1650	700 1600
lʔəŋ	750 1350	750 1350	750 1300
kʔəŋ	750 1300	750 1300	700 1350
nʔəŋ	750 1350	750 1300	700 1350

Segment [ə] with tone [—]

Word	F1	F2	F3
cuən	700 1450	750 1400	750 1350
luən	750 1400	750 1400	750 1350
luən	700 1350	750 1400	800 1400
nuən	800 1450	800 1450	800 1450
cuən	750 1400	750 1350	750 1400
tuəŋ	750 1350	700 1350	750 1350
luəŋ	700 1300	700 1300	700 1350
nuəŋ	700 1400	750 1350	700 1400
cuət	800 1400	750 1350	700 1400
nuət	700 1400	700 1450	700 1400
vuət	750 1350	750 1350	750 1350
suət	750 1400	750 1400	750 1350
cuək	700 1250	700 1200	700 1200
nuək	700 1400	700 1400	700 1400
suək	700 1200	700 1200	650 1150

Blank spaces indicate where precise measurements were not obtainable.

FIGURE 20

[ɨ] in closed syllables

All tones Informant 3

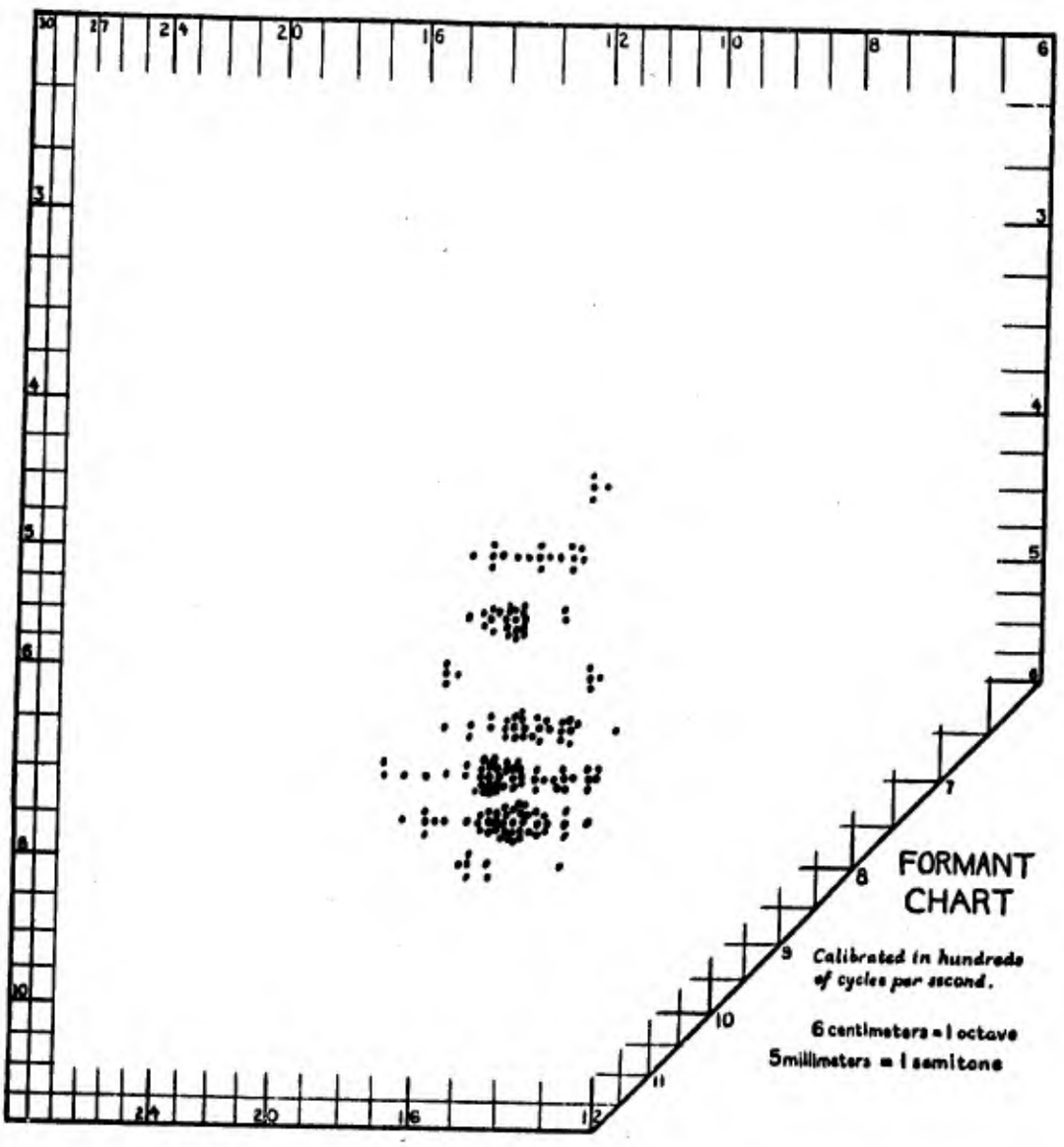


TABLE 21

Formant measurements of complex nuclei segment [ə] Closed syllable cycles/second

All tones Informant 3

Segment [ə] with tone [-]

Word	1 F1 F2 F3	2 F1 F2 F3	3 F1 F2 F3	4 F1 F2 F3
əuən		500 1100	500 1050	500 1050
iuən		550 1050	500 1050	500 1050
uən		500 1300	500 1300	500 1250
tʰuən		500 1300	500 1300	500 1300
puən		500 1300	500 1300	500 1300
luən		500 1300	500 1300	500 1300
muən		500 1350	500 1350	500 1300
uəŋ		500 1050	500 1000	500 1000
əuəŋ		500 1050	500 1000	500 1000
puəŋ		450 950	500 1000	500 1050
kuəŋ		500 1050	500 1000	500 1050
nuəŋ		500 1050	500 1000	500 1000

Segment [ə] with tone [ˇ]

Word	1 F1 F2 F3	2 F1 F2 F3	3 F1 F2 F3	4 F1 F2 F3
puən		600 1000	600 1000	550 1050
kuən		600 1300	600 1300	600 1350
əuən		650 1500	650 1350	650 1300
luən		600 1350	650 1300	650 1350
tuəŋ		600 1000	650 950	650 1000
puəŋ		600 1000	650 1000	650 1050
luəŋ		600 1000	650 1000	650 1050

Segment [ə] with tone [ˇ]

Word	1 F1 F2 F3	2 F1 F2 F3	3 F1 F2 F3	4 F1 F2 F3
tʰuəŋ		700 1100	700 1150	700 1100
suəŋ		700 1050	700 1050	650 1050

Segment [ə] with tone [ˊ]

Word	1 F1 F2 F3	2 F1 F2 F3	3 F1 F2 F3	4 F1 F2 F3
nuəm		450 950	450 950	450 950
kuən		450 1250	450 1250	450 1250
muən		500 1250	500 1200	450 1200
uəŋ		450 950	450 950	450 950
cuəŋ		450 1000	450 1000	500 1000
muəŋ		450 950	450 950	450 1000
huəŋ		450 950	450 950	450 950
tuət		600 1250	600 1250	600 1250
cuət		650 1300	650 1250	600 1200
puət		600 1250	600 1200	600 1250
nuət		600 1250	550 1250	600 1250
tʰuək		600 1000	650 950	700 1050
kuək		650 1050	650 1000	650 1000
cuək		650 1000	650 950	650 950
suək		700 1000	700 1050	650 1000

Segment [ə] with tone [~]

Word	1 F1 F2 F3	2 F1 F2 F3	3 F1 F2 F3	4 F1 F2 F3
kuən		650 1200	650 1150	650 1200
nuən		700 1300	700 1250	700 1250
muəŋ		650 1000	650 1050	700 1100

Segment [ə] with tone [-]

Word	1 F1 F2 F3	2 F1 F2 F3	3 F1 F2 F3	4 F1 F2 F3
puən		700 1250	750 1250	700 1200
kuən		700 1350	700 1350	700 1350
muən		750 1350	750 1300	750 1300
suən		650 1300	700 1400	700 1400
kuəŋ		700 1300	650 1150	600 1100
suəŋ		700 1200	700 1250	700 1200
tuət		700 1300	700 1300	700 1350
cuət		700 1300	750 1350	750 1350
puət		600 1250	700 1300	700 1250
suət		650 1300	650 1250	600 1250
tʰuək		700 1000	650 1050	650 1100
cuək		700 1100	750 1150	650 1050
kuək		650 1050	700 1100	700 1200
puək		700 1100	700 1100	650 1050
luək		700 1100	650 1150	700 1150

Blank spaces indicate where precise measurements were not obtainable.

FIGURE 21

[ɜ] in closed syllables

All tones Informant 3

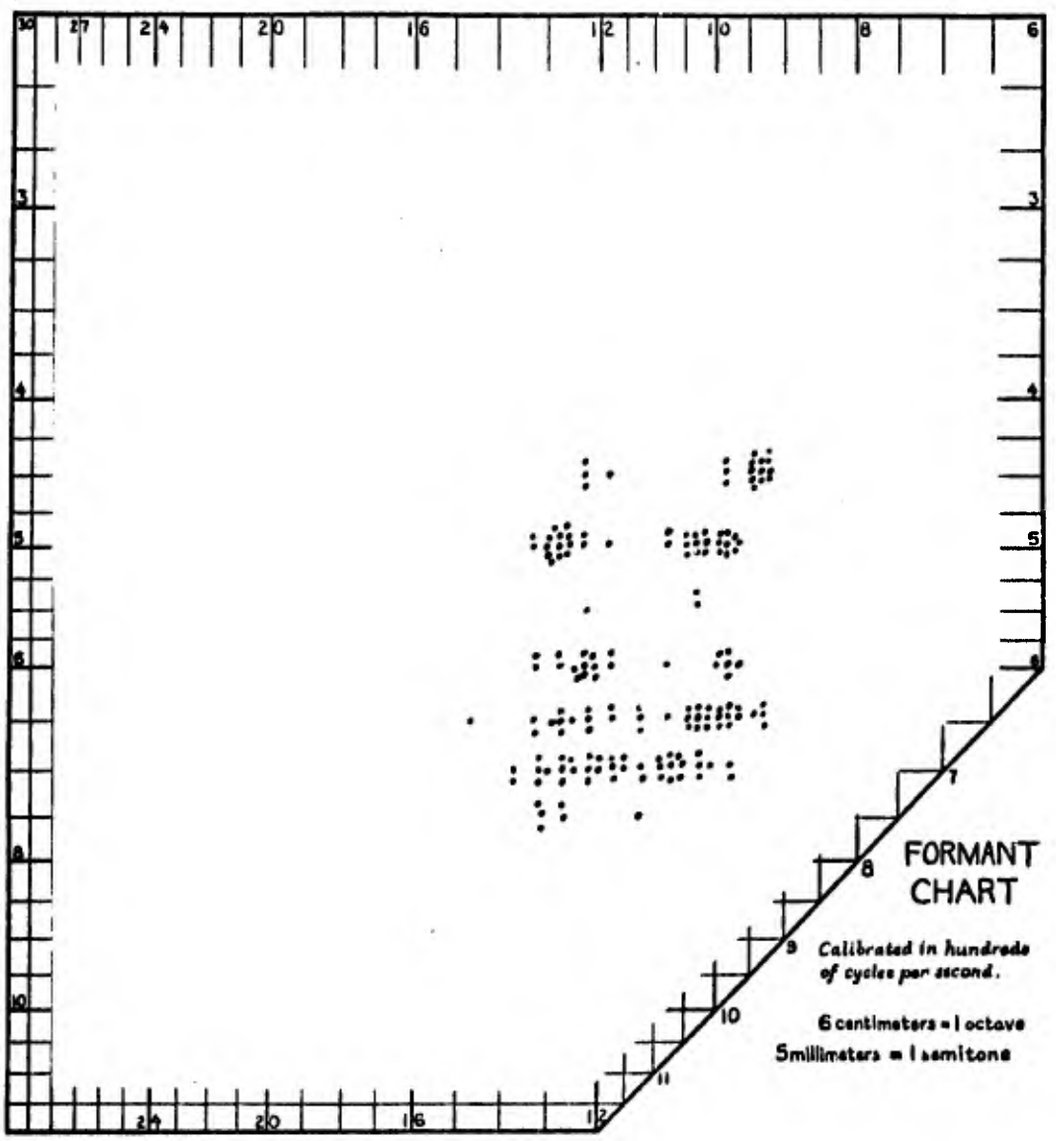
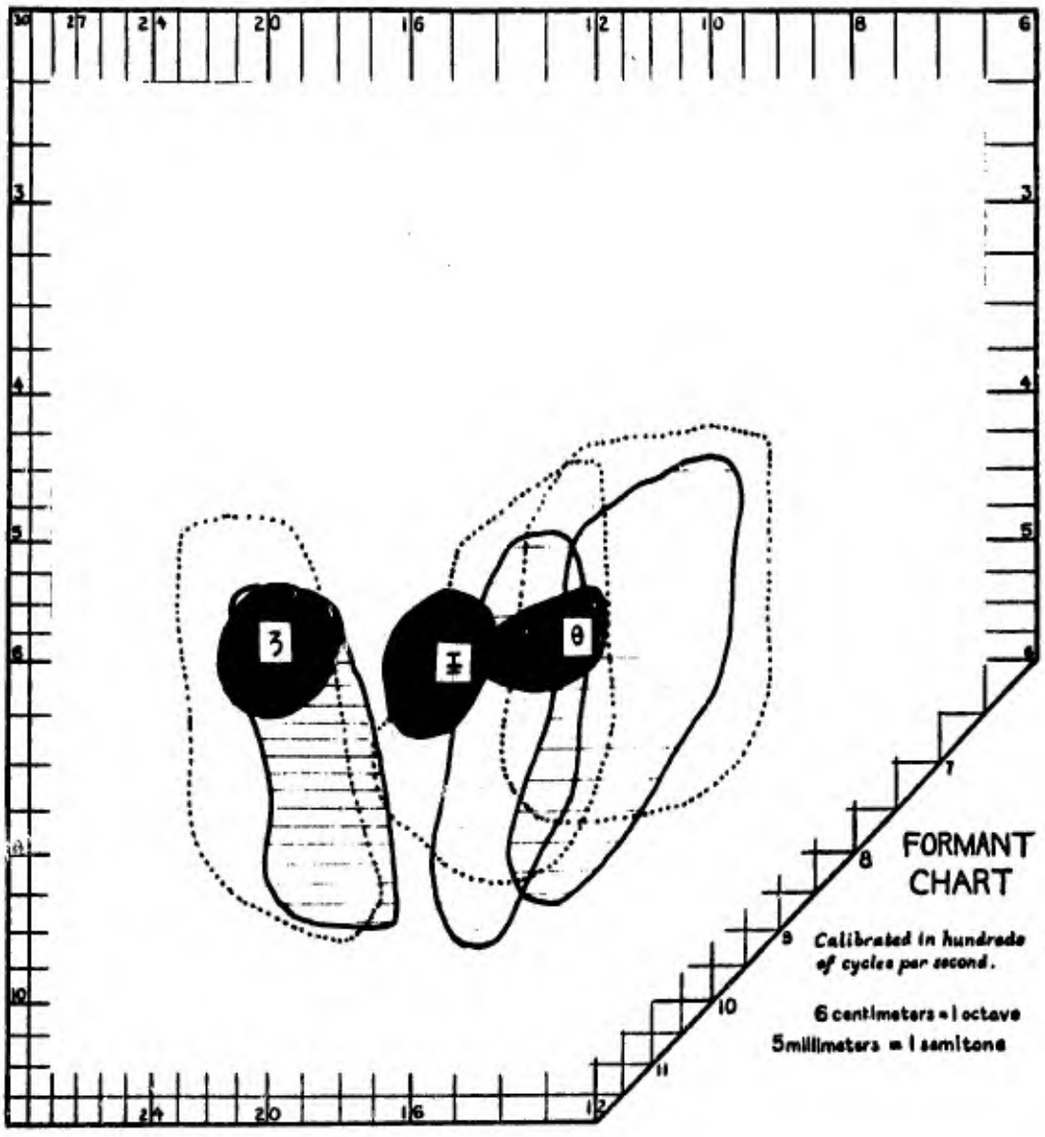


FIGURE 21a

Comparison of [ʒ] [ɪ̈] and [θ]

Various environments Informant 3



CONCLUSIONS

After carefully considering all the data presented, we came to several conclusions regarding Vietnamese complex nuclei.

1) In Chapter 3, it was established that the first segments of the complex nuclei [Iɜ], [ɯɪ], and [Uθ] could be clearly assigned to the phonemes /i/, /ɯ/, and /u/. It was then demonstrated that the analysis of [ɜ], [ɪ], and [θ] as the three separate phonemes /e/, /ə/, and /o/ was that most consistent with the phonetic phenomena. Experiments with the complex nuclei in more varied environments as delineated in Chapter 4 support this analysis as a valid one.

2) With regard to the question of whether the difference between the sequences spelled "-ia", "-uả", "-ua" in final position and "-iê-", "-uở-", "-uô-" in medial position are so great that they should be considered as two different phonemes, we can say that our preliminary phonetic transcription of [Iɜ], [ɯɪ], and [Uθ] for both sequences is supported. Although the location of the domains are shifted slightly backward in closed syllables, they maintain a relative distinctiveness, and the differences among the domains in closed syllables are comparable to those in open syllables. If [ɜ], [ɪ], and [θ] are demonstrated as being three different vocalic qualities in

open syllables, they should be so analysed in closed syllables. In closed syllables or open, spelled "-ia", "-uə", "-ua", or "-iê-", "-uɔ̂-", "-uô-", our phonetic interpretation of these complex nuclei as [iɜ], [ɯɪ], [uθ] is adequately supported by the acoustic data.

3) We also noted that tone and consonant influence on the complex nuclei is very similar to that observed on the simple vowels /e/, /ə/, and /o/. As was mentioned earlier, there are also distributional characteristics associated with /y/ and /w/ that make [ɜ] similar to /e/, [θ] similar to /o/, and [ɪ] different from /e/ and /o/ and more similar to /ə/.

Therefore, it is our conclusion that the complex syllable nuclei are best analysed with [ɜ] as an allophone of /e/, [ɪ] as an allophone of /ə/, and [θ] as an allophone of /o/, making the complex nuclei phonemically /ie/, /ɯə/, and /uo/.

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13. ABSTRACT

A phonetic and phonemic analysis of the three complex nuclei of Vietnamese (Hanoi dialect) spelled (1) yê-, -iê-, -ia, (2) -ươ-, -ưa, (3) -uô-, -ua, was carried out, using the sound spectrograph. The relative domains of the target qualities of the complex nuclei were established and then compared with those of the eleven simple vowels. The first segments of the complex nuclei were easily established as being the same as /i/, /ɯ/, and /u/. The second segments, which have been variously analysed, were found to occupy three distinct domains which led to our analysis of them as phonemically /e/, /ə/, and /o/. Further analysis was done, varying the environment with regard to type of syllable, tone, initial and final consonants. Regardless of environment, a relative distinctiveness of domain seems to be maintained and this, together with distributional characteristics, supports our final phonemic analysis of the complex nuclei as /ie/, /ɯə/, and /uo/.

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14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Acoustic Phonetics						
Vietnamese						
Syllable Nucleus						
Sound Spectrograph						

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