

An acoustic study of Battambang Khmer vowels

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This study reports results of an acoustic-phonetic analysis of Battambang Khmer dialect. It was found that even though the majority of Battambang Khmer vowels are similar to those of the standard dialect, a few vowels were both phonemically and phonetically different from the standard ones.

1. Introduction

Khmer is the national language of Cambodia. It is also the common language of Khmer settlement areas. This includes the Mekong Delta region of the southern part of Vietnam and at least 12 provinces in the lower part of the Northeast and East of Thailand bordering Cambodia (Suwilai 1995). The Khmer spoken in the lower part of Northeast Thailand is referred to by Smalley as Northern Khmer and has been well studied by a few linguists (Smalley 1964, 1976; Jenner 1974; Dhanan and Chartchai 1978; Prakorb 1987; Thomas 1989; Thomas and Wanna 1990). The Khmer spoken in the East of Thailand, on the other hand, is comparatively less well-known.

While Khmer dialects in Thailand are quite well studied, relatively little is known about dialects of Khmer spoken in Cambodia and in Vietnam, especially in terms of instrumental phonetic analysis. In their investigation of Khmer vowels and consonants, most Mon-Khmerists relied on their trained ears (Martini 1942-5; Henderson 1952; Huffman 1967, 1977; Jacob 1968).¹ While this may be sufficient and accurate to carry out comparative work, discrepancies exist among their analyses.

2. Khmer Vowels

Khmer is a language with a large vowel system which can be divided into two distinct series known traditionally as 'a series vowels' and 'ò series vowels' (Maspero 1915). Those in the 'a series' are lower than their counterparts in the 'ò series'. 'a series' vowels also tend to be diphthongized. From the point of view of comparative Mon-Khmer, the existence of two series of vowels in Khmer is the

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¹Henderson (1952), however, also included palatograms, and kymograms in her study.

consequence of a historical process of devoicing of the consonants which has turned old Khmer initial voiced stops into voiceless ones. The older consonantal distinction has been transferred to the next vowel, causing the vowel system to split into two sub-systems which, following Huffman (1967, 1977) will be referred to as 'first' and 'second registers' in this study. This fact is generally known and accepted in the literature (Pinnow 1979) and conforms to parallel historical developments in other Mon-Khmer languages (Ferlus 1979; Diffloth 1984, 1980; among others).

In the modern Khmer writing system, there are two duplicate sets of consonants which are phonetically identical. Although some consonant symbols lack a counterpart in the opposite set, they can be converted by using special diacritics. The vowel symbols then represent one set of vowels when written with one set of consonants, and a different set with the other set of consonants (Huffman 1967). The match between spelling and pronunciation involves an abstract notion of 'series' for both consonants and vowels which is taught in every Khmer school. Some examples of first and second series vowels and consonants are given below:

Consonants		Vowels		
1st series	2nd series	symbols	1st series value	2nd series value
ក [k]	ក [k]	្ក	[a:]	[iə]
ក្អ [k ^h]	ក្អ [k ^h]	្ក្អ	[əy]	[i:]
ច [c]	ច [c]	្ក្អ	[ae]	[ɛ:]
ច្អ [ɲ]	ច្អ [ɲ]	្ក្អ	[aə]	[ə:]

3. Acoustic study

3.1 Speaker

One male speaker from Battambang province served as the speaker for this study. He is a Khmer refugee and has been living in the U.S. for approximately 10 years, and he is 41 years of age.

3.2 Wordlist

The following wordlist is used in the analysis. It consists of 47 meaningful Khmer words. The transcription used is that of Huffman (1977).

First register				Second register			
1.	ក	/kəy/	'a loom'	ទី	/ti:/	'place, spot'	
2.	ម៉ឺន	/məin/	'ten thousand'	ពិត	/pit:/	'try hard, speed up'	
3.	កូត	/kout/	'to play (an instrument)'	ពូ	/pu:/	'uncle'	
4.	កេង	/keŋ/	'to guess'	កេង	/ke:ŋ/	'to lie down'	
5.	កើត	/kaət/	'to be born, to happen'	ទើត	/tə:t/	'to contradict'	
6.	កោត	/kaot/	'to be amazed, fearful'	ពោត	/po:t/	'maize'	
7.	កែត	/kae/	'to correct'	កែត	/pe:ŋ/	'a cup'	
8.	កាត	/kat:/	'a card'	ទា	/tiə/	'a duck'	
9.	ខ្លាត	/k ^h to:t/	'to cackle'	ទត	/tə:t/	'to look (royal)'	
10.	ច្រៀម	/ciəm/	'a baby sheep'	ទ្រៀម	/tiəp/	'near, almost'	
11.	ច្រើក	/p ^h iək/	'albino'	ជឿ	/ciə/	'to believe'	
12.	កូត	/kuət/	'to thin bamboo'	ទូត	/tuət/	'third ascending or descending generation'	
13.	មតិ	/mate/	'opinion'	ជ័រ	/cəə/	'resin from a tree'	
14.	ចិត្ត	/cət/	'heart, mind'	លទ្ធិ	/latthi/	'precept'	
15.	តឹង	/təŋ/	'tight, stuffed'	ជិត	/cit/	'to be near, close to'	
16.	កូដ	/kot/	'monk's living quarters'	ទឹក	/tik/	'water'	
17.	កាត់	/kat/	'to cut'	ពុត	/put/	'pretension, feint'	
18.	កប់	/kɔp/	'to bury'	កាត់	/kɔət/	'he, she'	
19.	កត់	/kɔt/	'to note or jot down'	បន្ទប់	/bontup/	'a room'	
20.	តាំង	/taŋ/	'to set up, to appoint'	ពត់	/pŭət/	'to bend'	
21.	សក្កវ	/skəw/	'to be white (of hair)'	ទាំង	/təəŋ/	'all, all of it'	
22.	កែត	/kay/	'a trigger'	នូវ	/niw/	'consisting of'	
23.	កៅ	/taw/	'a kind of basket'	ទែ	/tiy/	'a cloth bag'	
				ទៅ	/tiw/	'to go'	

3.3 Recording

Three repetitions of each target word produced in isolation in randomized order were recorded in an IAC sound-proof booth, using a cardioid microphone

(Electrovoice, model RE 20) and high quality cassette recorder (Marantz, Model PMD 222). Some target words that were subsequently added to the list were recorded in a quiet room, using similar equipment. The speaker was instructed to produce the target words at a normal speaking rate.

3.4 Analysis

The recordings were digitized on a SUN-Sparc station LX computer at 11 kHz and stored as files to be processed by the commercial software package WAVES+/ESPS. This speech analysis package enabled us to simultaneously examine wave forms and (wide-band) spectrograms of each token.

3.5 Acoustic parameters measured

In each vowel, the following attributes were measured:

- a. Vowel Duration
- b. First and second formant frequency (F1, F2)
- c. Fundamental frequency (F0)

For monophthongs, the duration of the whole vowel was measured. Vowel onset was taken to be the onset of periodicity in the wave form. Vowel offset was indicated by the loss of F2 on the spectrogram. Pitch tracks (a representation of F0 over time) giving a data point every five msec were derived and the average F0 of the whole vowel was computed. Formant frequencies (F1, F2) were obtained from the steady-state region of the vowel by deriving LPC spectra using a Hamming window of 25.6 ms, with 16 poles and preemphasis of .98 (Figure 1).

Diphthongs were analyzed in two parts. The onset of the first part was taken to be the onset of periodicity in the wave form. The offset was indicated by the beginning of movement of the first and/or the second formant. This was accomplished by deriving a formant track, a representation of formant frequency values (in Hz) over time, yielding a data point every 10 msec.

The offset of the first part of the diphthong was taken to be the onset of the second part, and the offset of the second part was indicated by the loss of the F2 on the spectrogram (Figure 2). The duration of each part of the diphthongs was measured. Formant frequencies (F1, F2) were also obtained from the steady portions of both parts of the diphthongs (Figure 2) by deriving LPC spectra. For those diphthongs that consisted of only one steady state and an onglide or offglide, the vowel formants were taken from the middle regions of the onglides and offglides (Figure 3).

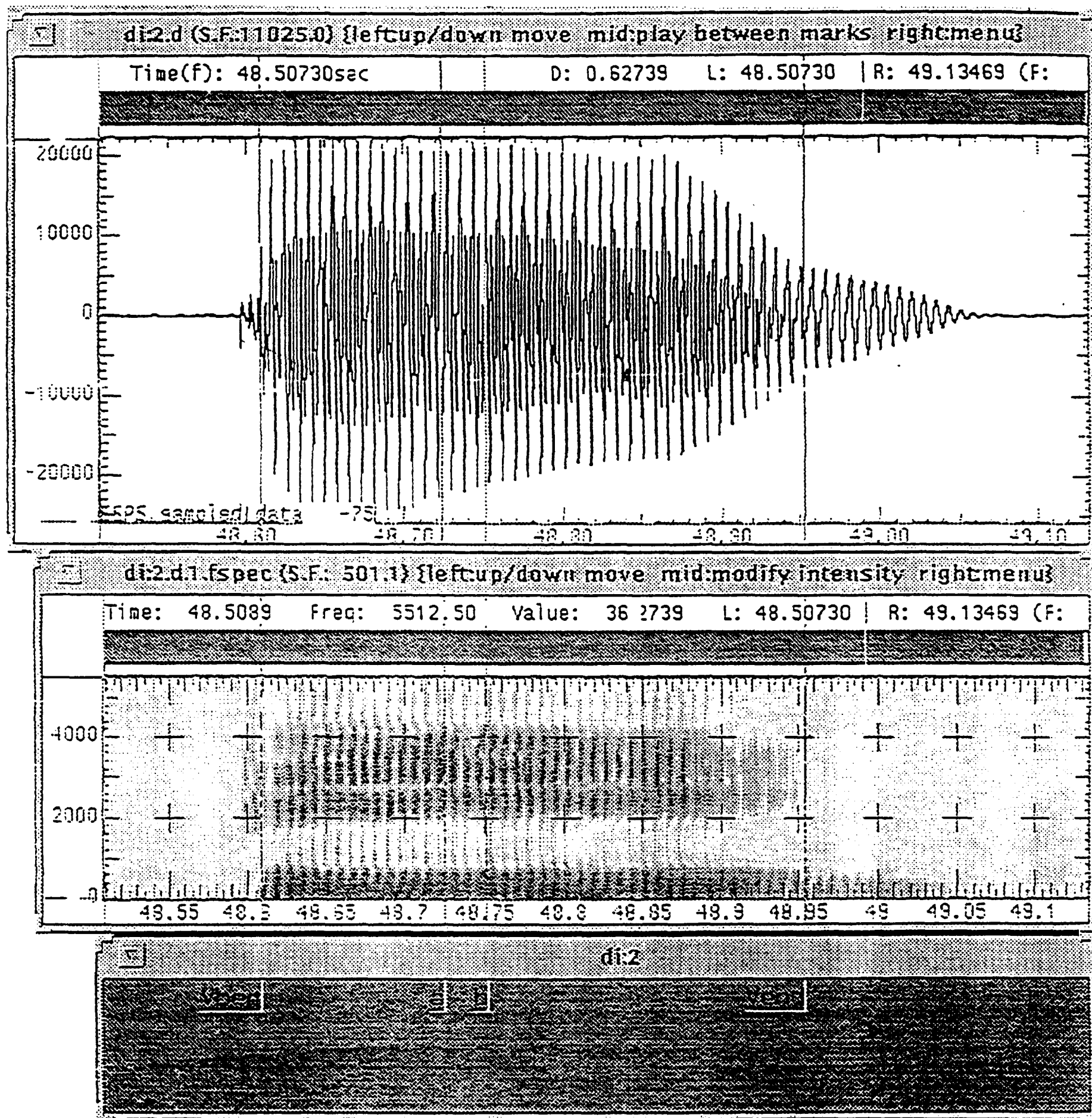


Figure 1. Wave form and spectrogram of the word ១ /ti:/ [ti:] 'place'. Vbeg marks the beginning of the vowel, Vend marks the end of the vowel and a and b mark the steady state where the 25.6 ms window was placed.

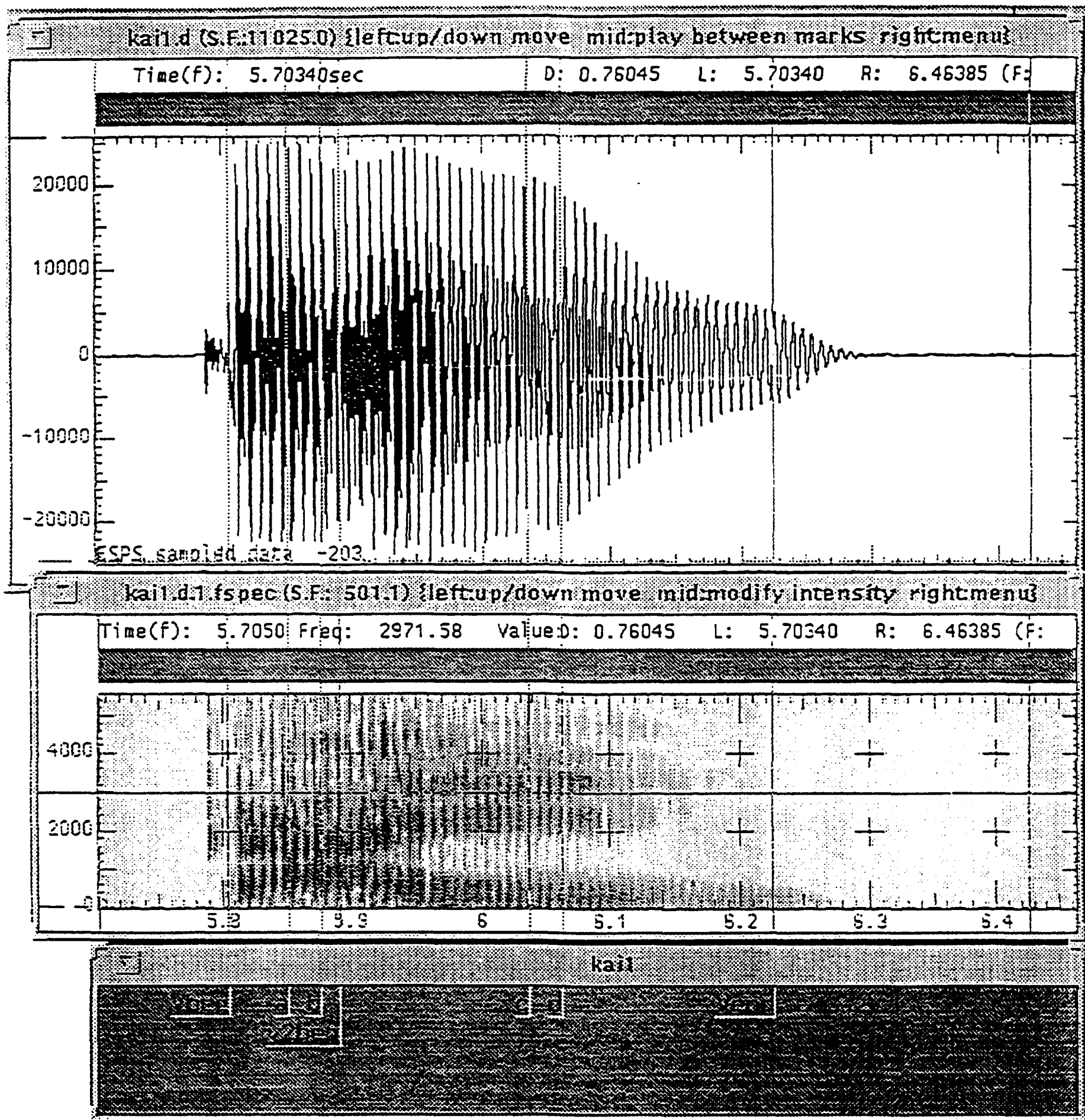


Figure 2. Wave form and spectrogram of the word ក្យ /kay/ [kai] 'a trigger'. Vbeg marks the beginning of the vowel, Vend marks the end of the vowel. V2beg marks the beginning of the second element of this diphthong. (a b and c d) mark the steady state of both elements of the diphthong where the 25.6 ms windows were placed.

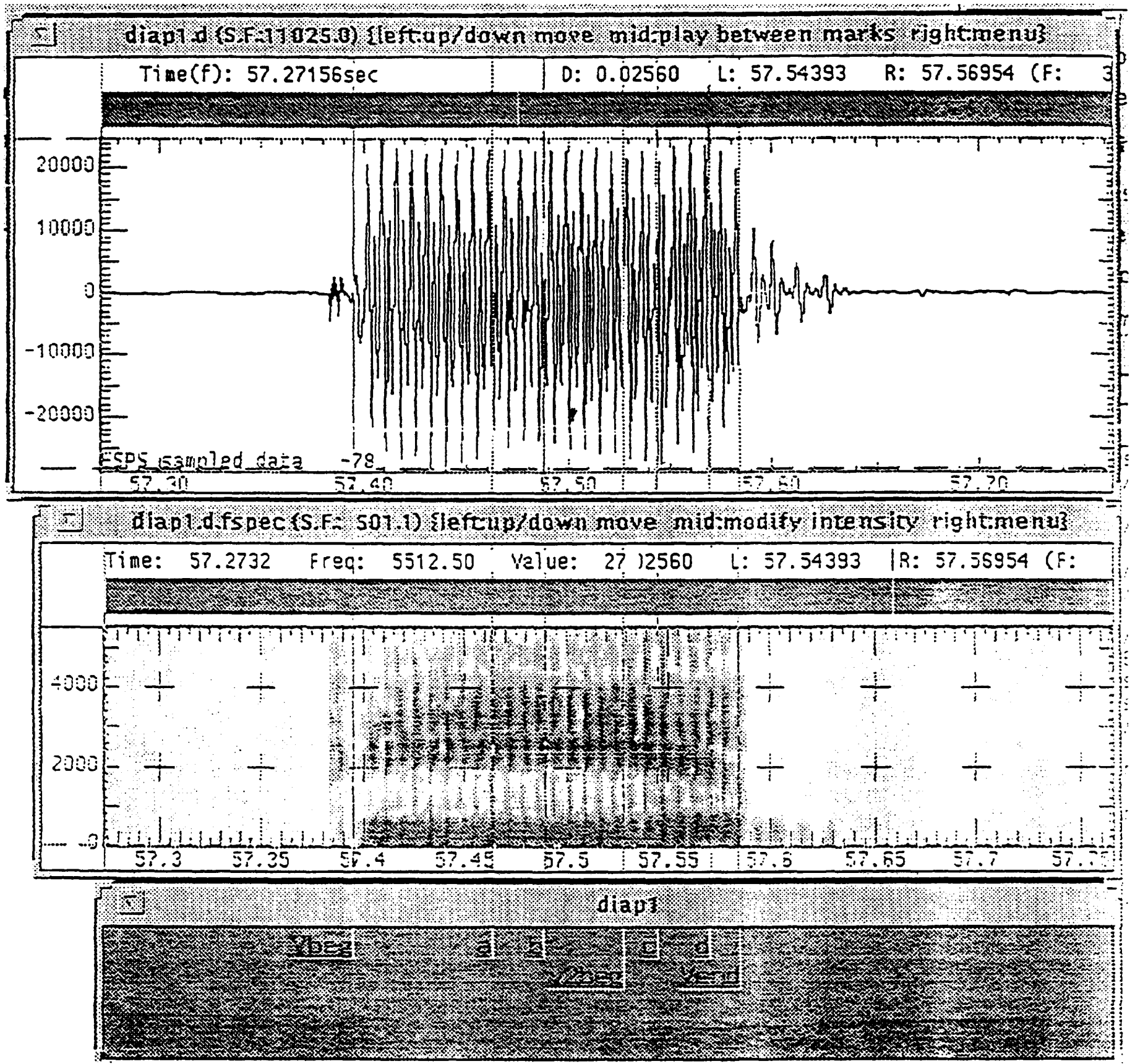


Figure 3. Wave form and spectrogram of the word ត្បាញ /teap/ [teap] 'to be close'. Vbeg marks the beginning of the vowel, Vend marks the end of the vowel, a b and c d mark the locations where the 25.6 ms windows were placed.

3.6 Results

a. Monophthongs

Table 1 shows the values of the first and second formants (F1, F2) and the duration of eight long and 10 short monophthongs of Battambang Khmer vowels. In general, with the exception of /a:, a/ it was found that F1 values of the long vowels are lower than those of the short vowels. This indicates that long vowels are higher in quality and more closed than their short counterparts. In terms of frontness and backness as indicated by the difference between F1 and F2 values, it appears that /i, u, o, a/ are more front than their long counterparts. As for duration, short vowels are approximately 60% shorter than long vowels. All monophthongs are plotted in Figure 4.

Table 1. Mean F1 and F2 values (in Hz) and duration (in ms) for Battambang Khmer monophthongs.

Words	Long Vwls	F1 (Hz)	F2 (Hz)	Duration (ms)	Words	Short Vwls	F1 (Hz)	F2 (Hz)	Duration (ms)
ឡ	i:	263	2381	437	ល្អ	i	306	2350	143
តែង	e:	460	2173	283	ឆ្ម	ɪ	372	2018	70
កាត	a:	807	1596	267	ចក	ɛ	569	1964	82
ខ្ញុំ	ɔ:	632	965	206	មក	e	548	2059	132
ពោត	o:	485	880	246	កាត	a	721	1603	128
ពូ	u:	315	680	392	កប់	ɔ	735	1209	134
ពក	ɨ:	343	1404	194	កុប	o	574	1059	95
ទេត	ə:	540	1423	194	ពុក	u	452	862	92
					ទក	ɨ	496	1633	102
					កង	ə	665	1615	103

Table 2. Mean fundamental frequency (F0, in Hz) of long and short Battambang Khmer monophthongs.

Words	Long Vowels	F0 (Hz)	Words	Short Vowels	F0 (Hz)
ឡ	i:	126	ឡ	i	136
ពេង	e:	124	ឡ	ɪ	144
កាត	a:	120	ឡ	ɛ	134
ខ្លាត	ɔ:	130	មត	e	137
ពោត	o:	128	កាត	a	116
ពូ	u:	129	កប់	ɔ	125
ពត	ɛ:	127	កុប	o	140
ទេត	ə:	128	ពុត	u	136
			ទក	ɪ	128
			កង	ə	129

Table 2 shows the fundamental frequency values (F0 in Hz) of long and short monophthongs. In general, it was found that long vowels have lower F0 (127 Hz) than short vowels (133 Hz). The general trend of high vowels having higher F0 than low vowels is also observed in both the short and long vowels of Battambang Khmer. The average F0 of three long high vowels /i:, ɪ:, u:/ is 127 Hz as opposed to 125 Hz of two low vowels /a:, ɔ:/ . The average F0 of high short vowels /i, ɪ, ɛ, ɪ, u/ is 135 Hz and that of low short vowels /a, ɔ/ is 121 Hz. Thus, it appears that the difference in F0 between high and low vowels is more pronounced in short vowels.

All monophthongs, short and long, are plotted in figure 4 below. With the exception of /a:, a/ and /ə:, ə/ it is rather obvious that short vowels are invariably lower and more front than their long counterparts.

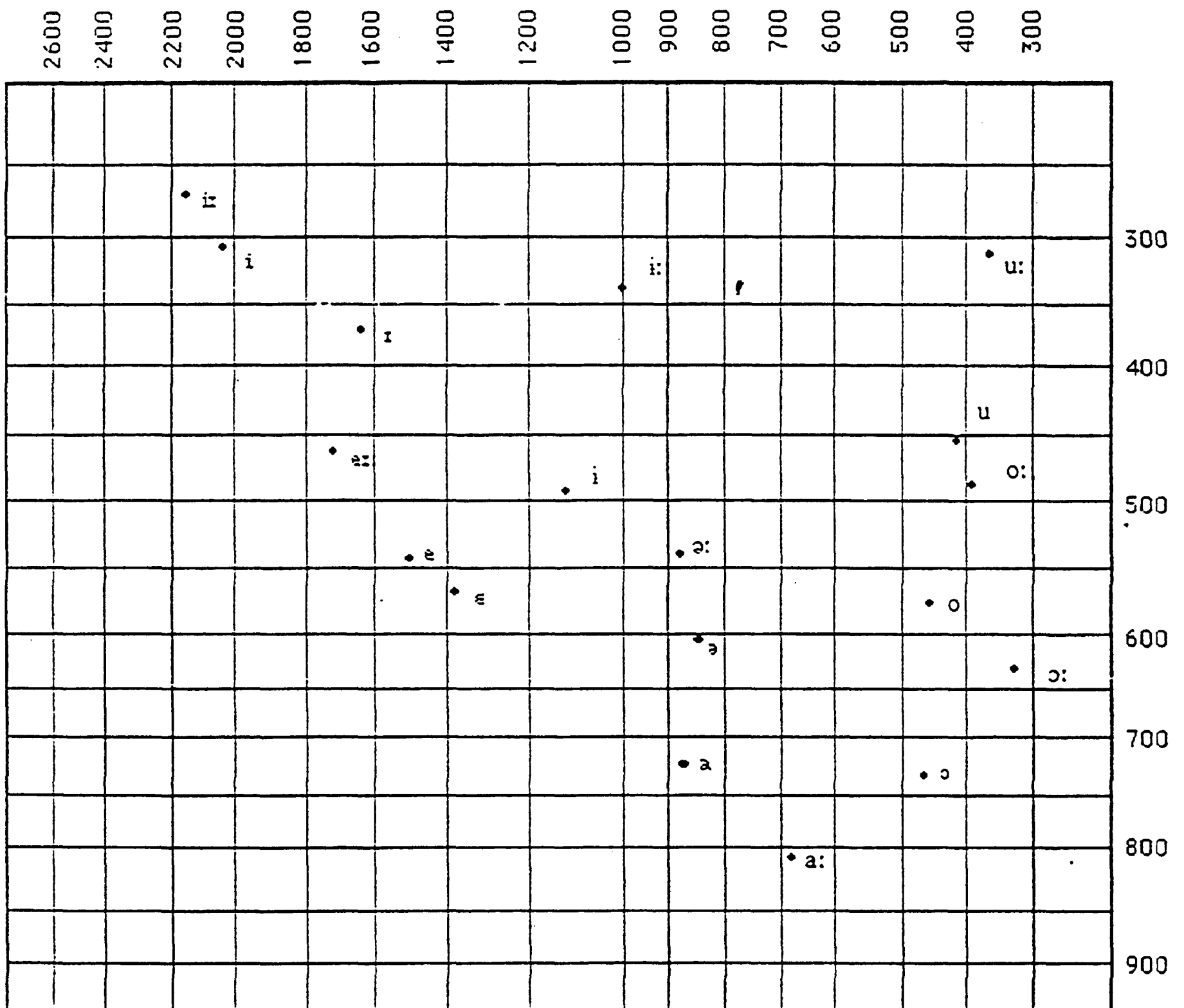


Figure 4. Long and short Battambang Khmer monophthong vowel chart as produced by a male speaker.

b. Diphthongs

Table 3. Mean F1, F2 values (in Hz) and duration (in ms) of the first and second vowels in short diphthongs and vowels occurring only in open syllables of Battambang Khmer.

Words	Vowels	V1 (Hz)	V1 (Hz)	V1 (Hz)	V2 (Hz)	V1 (ms)	V2 (ms)
ទាំង	ěa	438	687	2094	1785	98	62
តាត់	ïə	458	615	1393	1414	59	74
ពត់	ǒa	448	607	865	1600	64	62
ក	ěy	618	324	1934	2382	97	294
កែ	ăy	777	378	1523	2263	119	301
កែ	ěy	469	322	2038	2262	138	301
លកួន	ǎw	642	343	1697	1208	128	241
នួន	ïw	547	374	1668	1116	99	243
កៅ	ăw	818	360	1518	2181	166	236
កៅ	ïw	497	355	1534	1186	125	230

First and second formant (F1, F2) values (in Hz) and duration of short and long diphthongs (in ms) are presented in Table 3. Even though vowels that occur only in open syllables are phonologically vowels + consonant, phonetically they consist of two elements: a steady state and an offglide, thus the F1 and F2 of both elements of these vowels are also included. In terms of duration, invariably the first element of these diphthongs is shorter than that of the second element. On average, duration of the first element is half that of the second element: 109 vs. 204 ms.

Table 4. Mean F1, F2 (in Hz) and duration (in ms) of the first and second vowels in long diphthongs of Battambang Khmer.

Words	Vowels	V1 (Hz)	V1 (Hz)	V1 (Hz)	V2 (Hz)	V1 (ms)	V2 (ms)
កូត	ou	484	428	949	1025	192	46
ទា	ea	350	532	2332	1929	278	175
មុន	əi	660	460	1260	1460	112	56
កេត	aə	765	578	1572	1574	133	191
កោត	ao	755	561	1370	1018	142	87
កែត	aɛ	748	609	1673	2008	157	330
ទត	oə	438	544	798	1188	161	47
ទូត	uə	318	393	776	1087	141	55
កូត	uə	306	400	715	1071	122	61
ជ័រ	iə	422	500	1420	1347	223	157
ជ្រើក	iə	310	416	1419	1322	176	95
ជ្រើ	iə	278	396	1995	1458	281	193
ទៀត	ie	264	366	2360	2124	132	53
ច្រៀម	ie	263	418	2332	1791	177	73

First and second formant (F1, F2) values (in Hz) of long diphthongs and their durations (in Hz) are presented in Table 4. With the exception of /aɛ/, these diphthongs are comprised of a relatively long steady state as the first element and a relatively short offglide as the second element. On average, the duration of the second element is approximately 57% of the duration of the first element: 175 ms vs. 99 ms. The quality of the first element is comparable to that of the same vowel in isolation, i.e. as a monophthong, but the second target generally displays undershoot. That is, it never reaches the target and merely points to its direction.

F0 values of long and short diphthongs are presented in Table 5. In general, it seems that diphthongs with higher vowels as the first element have higher F0 than those begin with lower vowels.

Table 5. Mean Fundamental Frequency (F0, in Hz) of Battambang Khmer Diphthongs.

Words	Vowels	F0 (Hz)	Words	Vowels	F0 (Hz)
កូក	ou	124	ទាំង	ěa	130
ទា	ea	125	គាត់	ǐə	128
មុន	əi	125	ពត់	ǒə	124
កើត	aə	119	ក	ěy	104
កោត	ao	121	កែ	ǎy	119
កែ	aɛ	120	កែ	ěy	127
ទក	oə	141	លក្ខន៍	ǎw	129
ទូក	uə	129	ន្ទុន	ǐw	130
កូក	uə	130	កៅ	ǎw	129
ជួន	ǐə	123	ទៅ	ǐw	120
ច្រើក	ǐə	130			
ជ្រើ	ǐə	131			
ទៀក	ie	132			
ច្រើម	ie	131			

Both short and long Battambang Khmer diphthongs are plotted in Figure 5. Horizontal axis represents the F1 value and vertical axis represents the difference between the F1 and F2 (F2-F1) value. The starting points of each diphthong were plotted based on the F1 and the difference between the F2 and F1 value of the first element of the diphthong. The angle and direction of the arrow was based on the F1 and the difference between F2 and F1 of the second element.

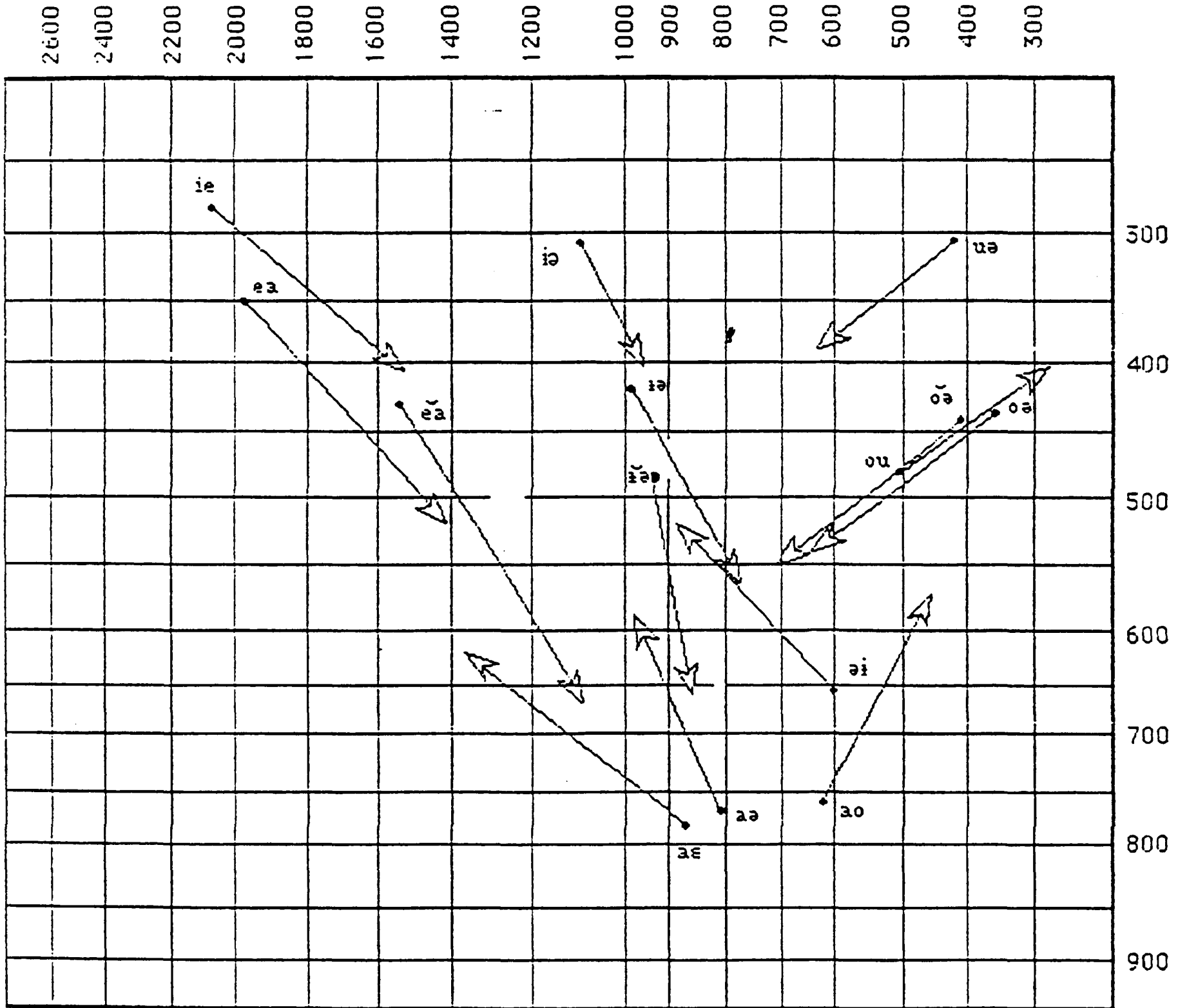


Figure 5. Long and short diphthongs of Battambang Khmer dialect as produced by one male speaker.

4. Phonetic transcription

Table 6 shows the phonetic realization of Battambang Khmer vowels, their transcription and examples of words in which these vowels were examined. The transcription chosen for each vowel approximates as closely as possible its phonetic realization. This table is adapted from Huffman (1978), however certain adjustments were made: vowels occurring only in open syllables were added and since the long vowel (i in 1) of first register never occurs with a final consonant, it is included in this category.

Table 6. Battambang phonetic realization and transcription of the Khmer orthographic vowel symbols.






































1st and 2nd Series Realization of Battambang Khmer Orthographic Vowels Symbols							
Symbols	Transliteration	Phonetic Realization		Transcription		Examples	
Long Vowels		1st	2nd	1st	2nd	1st	2nd
1. 	i		i:		i:		
2. 	i	ə:i	i:	əi	i:		
3. 	u	oʊ	u:	ou	u:		
4. 	e	e:	e:	e:	e:		
5. 	ə	a:ə	ə:	aə	ə:		
6. 	o	a:ɔ	o:	ao	o:		
7. 	ɛ	a:ɛ	e:	aɛ	e:		
8. 	a	a:	e:ɛ	a:	ea		
9. 	ɔ	ɔ:	o:ə	ɔ:	oə		
10. 	iə	i:e	i:e	ie	ie		
11. 	iə	i:ə	i:ə	iə	iə		
12. 	uə	u:ə	u:ə	uə	uə		
13. 	ǎr		i:ə		iə		

Table 6. Cont.

Symbols	Transliteration	Phonetic Realization		Transcription		Examples	
		1st	2nd	1st	2nd	1st	2nd
1. ័	ĩ	ɛʔ	iʔ	e	i	មក	លទ្ធិ
័ F	ĩ+final	ɛ	ɪ	ɛ	ɪ	ចក្ក	ជិត
2. ័	ĩ	ə	i	ə	i	កង	ទក
3. ័	ũ	a _o	u	o	u	កុប	ពុក
4. ័ V	a' +Velar	a	e ^a	a	ěa	កាំង	ទាំង
័ F	a' +non-Velar	a	iə	a	ĩa	កាត់	តាត់
5. - L'	ɔ' + Labial	ɔ	u	ɔ	u	កប់	បន្ទប់
- F'	ɔ' +non-labial	ɔ	oə	ɔ	ðə	កត់	ពត់
Vowels Occurring only in Open Syllables							
1. ័	i	ɛ ⁱ		ɛy		ក	
2. ័	uw	ə ^u	i ^u	əw	ĩw	លក្ខន៍	ន្ទន៍
3. ័	ai	ai	ei	ăy	ěy	កែ	ទែ
4. ័	aw	a ⁱ	i ^u	ăw	ĩw	កៅ	ទៅ

A comparison of Standard Khmer (Huffman 1978) and Battambang Khmer is presented in Table 7. In general, the Battambang Khmer vowel system is similar to that of the Standard dialect; a few differences, however, can be observed. For example, for long vowels, in 9 the second register value of the orthographic <ɔ> is realized as /ɔə/ in Standard Khmer and as /oə/ in Battambang Khmer. In 13, the orthographic <ăr> is realized as /ɔa/ in the standard dialect, but as /iə/ in Battambang. For short vowels, in Standard Khmer the orthographic <ĩ> with a final consonant and the orthographic <ĩ> are both realized as /ə/ in first register and as /i/ in second register. In Battambang Khmer, on the other hand, the orthographic <ĩ> with a final consonant is realized as /ɛ/ in first register and as /ɪ/ in second register, while the orthographic <ĩ> is realized as /ə/ and /i/ in first and second register respectively. Moreover, the second register vowel <ɔ'+ non-labial> in 5 is realized as standard /ʊə/, but as Battambang /ðə/.

Table 7. Comparison of Standard Khmer and Battambang Khmer transcription.


























Symbols	Transliteration	Standard Khmer (Huffman 1978)		BT Khmer	
		1st	2nd	1st	2nd
1. 	<u>i</u>		ii		i:
2. 	<u>i</u>	əi	ii	əi	i:
3. 	<u>u</u>	ou	uu	ou	u:
4. 	<u>e</u>	εe	ee	e:	e:
5. 	<u>ə</u>	aə	əə	aə	ə:
6. 	<u>o</u>	ao	oo	ao	o:
7. 	<u>ε</u>	aε	εε	aε	e:
8. 	<u>a</u>	aa	ia	a:	ea
9. 	<u>ɔ</u>	ɔɔ	ɔə	ɔ:	oə
10. 	<u>iə</u>	ia	ia	ie	ie
11. 	<u>iə</u>	ia	ia	iə	iə
12. 	<u>uə</u>	ua	ua	uə	uə
13. 	<u>ǎr</u>		ɔa		iə

Table 7. Cont.

Symbols	Transliteration	Standard Khmer (Huffman 1978)		BT Khmer	
Short Vowels		1st	2nd	1st	2nd
1. 	<u>i</u>	e	i	e	i
 F	<u>i</u> +final	ə	i	ɛ	ɪ
2. 	<u>i</u>	ə	i	ə	i
3. 	<u>u</u>	o	u	o	u
4.  V	<u>a</u> ' +Velar	a	ěa	a	ěa
 F	<u>a</u> ' + non-Velar	a	ǎa	a	ǎə
5.  L'	<u>ɔ</u> ' + Labial	ɔ	u	ɔ	u
 F'	<u>ɔ</u> ' + non-labial	ɔ	ǎə	ɔ	ǎə
Vowels Occurring only in Open Syllables					
1. 					
2. 	<u>uw</u>	ǎw	ǎw	ǎw	ǎw
3. 	ai	ǎy	ǎy	ǎy	ǎy
4. 	aw	ǎw	ǎw	ǎw	ǎw

5. Conclusion

Like other dialects of Khmer, Battambang Khmer has a rather large vowel system. Phonemically, there are eight long monophthongs, 8-10 short monophthongs, 10 long diphthongs and three short diphthongs. It was found that the difference between long and short monophthongs is not only in terms of their height; short monophthongs, with the exception of /a:, a/ and /ə:, ə/ are lower and more front than their long counterparts. In terms of duration, long vowels are approximately twice as long as short vowels.

Diphthongs generally consisted of one steady state and an offglide. The first element of these diphthongs has the same quality as the monophthongs, but their second element merely points to the direction of the targets. In long diphthongs, the first element is approximately twice as long as the second element. The opposite,

however, is true in short diphthongs; the first element is shorter than the second element or the offglide.

Khmer vowels are traditionally divided into two series: first and second. In Battambang Khmer long vowels, with the exception of /e:/, /a:/ and /ɔ:/, the first register vowels are lower and thus more open than the second register vowels. Moreover, the first register vowels are also diphthongized. In short vowels, for some vowels the first register ones are lower than the second register. On the contrary, for some vowels, it is the second register vowels that are diphthongized.

Even though in general the Battambang vowel system is similar to the Standard Khmer vowel system, some differences exist both phonetically and phonemically. For example, Standard /ia/ is Battambang /ie, ea/, S /əɔ/ is B /oə/, S /ia/ is B /iə/, S /ua/ is B /uə/, S /ɔə/ is B /iə/, S /i/ is B /ɪ/, S /ǝa/ is B /iə/ and S /ǝə/ is B /ǝə/.

6. Further Research

An instrumental phonetic analysis of another Khmer dialect spoken in the East of Thailand, bordering Cambodia is underway by the present author. A preliminary analysis suggests that the tense versus lax contrast in the original Mon-Khmer initial stops has been transferred to the following vowels, causing the vowels to be diphthongized and have a clear versus breathy quality. The diphthongization, however, does not affect the original short low vowel /a/. In this vowel, the differentiation between first and second register is in the voice quality: clear and breathy. Pitch level differences between the two registers are also attested. This Khmer dialect, thus appears to reflect the fourth pattern of vowel change resulting from the consonantal devoicing process.

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