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WORD ACCENT AND THE DURATION OF VOWELS IN /C1u1C2u2/ IN JAPANESE

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1. Introduction

The accent pattern of the Japanese language has been considered as consisting of high and low pitch tones. A lot of studies concerning the relations between accent and syllables or accent and the fundamental frequencies of vowels have been carried out[1-4]. It seems, however, that the studies or observations of the quantitative relation between accent and the duration of vowels for words with different accents are very few. This study discusses whether it is possible to claim some quantitative relation between accented vowels and the duration of consonants or vowels for words in accentual opposition by measuring the actual speech for minimal pairs of bisyllabic words in accentual opposition.

2. Experiments

2.1 Preparation of test words

Four pairs of words with opposite accent patterns, one with accent on the first syllable of two syllables, the other with accent on the second syllable, were used for the experiment. There were fricative consonants, /h/, /s/, the africative consonant /ʦ/, or the stop consonant /k/ in the word-initial position followed by the vowel /u/ in the first syllables and the nasal consonant /m/ in the second syllables. There was a word-final /u/ in each word. The resulting Japanese eight words were as follows:

/hū mu/ (verb or int.: hum), /humū/ (verb: step), /sū mu/ (verb: live, have done, become clear etc.), /sumū/ (nonsense word), /ʦū mu/ (verb: checkmate, adj: fine), /ʦumū/ (verb: pile, load, nip, pick etc.), /kū mu/ (verb: cross, fold, set up, be in league with etc.), /kumū/ (draw, ladle, drink (wine) etc.) (Table 1)

2.2 Procedures and method

The subject was an adult male Japanese speaker(MS) fifty nine years old. The test word inserted into two types of carrier sentence ('/ʦugiwa _____ daro:/' ('The next will be _____ ') (1) or '/ʦugiwa _____ toiu/' ('The next is said _____ ') (2)) were presented to him in list form to read individually, both at a slower and a faster tempo than his own speech, more than twenty times each. The procedure consisted of two sets: (A) inserting the test words into the carrier sentence (1) first, and then into

Table 1. Type of samples.

Subject: MS.

Number of types of rate: 2, slow, fast.

Number of carrier sentence: 2,

(1) /ʦugiwa __ daro:/
(2) /ʦugiwa __ toiu/

Number of accent types: 2, first syllable, second syllable.

Number of speech utterances for each word: 20.

Number of word types: 18,

/hu͡lmu/ /su͡lmu/ /ʦu͡lmu/ /ku͡lmu/
/humu͡l/ /sumu͡l/ /ʦumu͡l/ /kumu͡l/

the carrier sentence (2) (totally 16 words); and (B) reading (1) at a slow rate (ten times) first, (2) at a fast rate (ten times) second, (3) at a fast rate (ten times) third, (4) at a slow rate (ten times) fourth. The recording was performed in an anechoic studio. Speech signals low-pass filtered with a cut-off frequency of 4.5kHz were passed through A/D converters with a sampling frequency of 10 kHz and entered into a computer system. The results were then processed by an SPSS program using the VAX-11/780 sysem.

2.3 Duration of vowels

The onset of the wave form of each test word was at the beginning of the speech signal for the word-initial fricative /h/ or /s/, africative /t͡s/, or stop /k/. The offset of the wave form was at the end of the duration of the word-final /u/. The duration of each vowel or consonant in the test words was measured.

The onset of the first vowel u1 was defined as the beginning of the periodical wave form for /u/, which followed the fricating wave form for the preceding consonant /h/ in /hū mu/ and /humū/ or /s/ in /sū mu/ and /sumū/; or which followed the fricating wave form for the preceding /s/ of the africative consonant /t͡s/ in /t͡sū mu/ and /t͡sumū/; or which followed the closure for the preceding consonant /k/ in /kū mu/ and /kumū/. The end of the wave form for the first vowel u1 was defined as the boundary which the periodical wave form at smaller intensity for the consonant /m/ followed.

The onset of the second vowel u2 was defined as the beginning of the periodical wave form for /u/, which followed the wave form for the preceding consonant /m/, losing the clear wave form of /m/. The end of the wave form for the second vowel u2 was defined as the offset of the periodical wave form for /u/.

The boundary of the vowel u1 and the folowing consonant /m/, and the consonant /m/ and the following vowel u2, was determined both by observing the formants of the test words on a graphic display screen and by listening to the speech sounds which had been D/A converted.

3. Results

The total number of samples obtained from the repetitions of the test words was 640: the no. of samples at a slow rate were 320, and at a fast rate were 320. The words inserted into the carrier sentence '/t͡sugiwa _____ daro:/' (1) were 160, and 160 in the carrier sentence '/t͡sugiwa _____ toiu/' (2).

The duration of each segment of the test words was measured and analyzed as follows:

Duration of test word:	W(msec)	
Duration of the first vowel:u1	X(msec),	P=100(X/W)(%)
Duration of the second vowel:u2	Y(msec),	Q=100(Y/W)(%)
Duration of the first syllable	H(msec),	U=100(H/W)(%)
Duration of the second syllable	Z(msec),	R=100(Z/W)(%)

The difference in duration between the minimal pairs of words in accentual opposition for the values W, X, Y, H, Z, P, Q, U and R was examined for the words alone at each speech rate and for the words with each carrier sentence via t-tests. Tables 2 and 3 give the results for the above values. The values in Tables 2 and 3 with an asterisk or double asterisk were significant at the levels p=0.05 and p=0.10, respectively.

4. Discussion

4.1 Speech at the slow rate (Table 2)

The mean values of the duration of the test words in the minimal pairs of /humu/, /sumu/, /tsumu/ and /kumu/ in opposition as to accent were between about 422 msec and about 464 msec. The mean values of the duration of the first vowels u1 were between about 43 msec and about 81 msec. The normalized values of the duration of the first vowels u1 for the duration of the test words were between about 10% and about 18%. The mean values of the duration of the second vowels u2 were between about 115 msec and about 138 msec. The normalized values of the duration of the second vowels u2 for the duration of the test words were between about 27% and about 32%. The mean values of the duration of the first syllables were between about 208 msec and about 265 msec. The normalized values of the duration of the first syllables for the duration of the test words was between about 49% and about 58%. The mean values of the duration of the second syllables were between about 201 msec and about 223 msec. The normalized values of the duration of the second syllables for the duration of the test words were between about 42% and about 52%.

Regardless of the type of carrier sentence (that is to say, regardless of whether /d/ or /t/ followed the test word) the duration of the first vowel u1 of any test word accented on the first syllable was longer than that of the same test word unaccented on the first syllable both for the mean and the normalized values of the duration of the test word. The difference in duration between them was significant at the level p=0.05 (Tables 2.1 and 2.2).

For any test word accented on the second syllable and inserted into the carrier sentence '/tsugiwa _____ daro:/'(1), the mean value of the duration of the second syllable was longer than that of the same word unaccented on the second syllable. The difference in duration between them was significant at the level p=0.05 (Tables 2.1). On the other hand, for any test word accented on the first syllable and inserted into the carrier

Table 2. The duration of words, vowels u1 and u2 and the first and the second syllables at the slow rate.

2.1) Subject: MS, Carrier: /daro:/

Word	N	u1	u2	Word(msec)	u1(msec)(%)		u2(msec)(%)		syllable 1st(msec)(%)		syllable 2nd(msec)(%)	
hu͡l mu	20	V	V	427*	76	17.9	127	30.0	223	51.7	204*	48.3
humu͡l	20	V	V	433	59	13.7	132	30.5	210	48.5	223	51.5
su͡l mu	20	V	V	451	81*	17.8*	115*	25.5*	262*	58.0*	189*	42.0*
sumu͡l	20	V	V	452	55	12.3	134	29.6	234	51.7	218	48.2
t͡su͡l mu	20	V	V	439	69*	15.8*	121*	27.6**	238	54.1**	201*	45.9**
t͡sumu͡l	20	V	V	449	58	12.9	134	29.8	229	51.1	219	48.9
ku͡l mu	20	V	V	436	68*	15.6*	133	30.9	226	51.3	209*	48.7
kumu͡l	20	V	V	438	55	12.4	138	31.5	215	48.9	223	51.1

2.2) Subject: MS, Carrier: /toiu/

Word	N	u1	u2	Word(msec)	u1(msec)(%)		u2(msec)(%)		syllable 1st(msec)(%)		syllable 2nd(msec)(%)	
hu͡l mu	20	V	V	446	77*	17.2*	128	28.8	237*	53.0*	209**	47.0*
humu͡l	20	V	V	431	60	13.8	125	28.9	213	49.3	218	50.7
su͡l mu	20	V	V	464**	80*	17.2*	124	26.7	265*	57.1*	199*	42.9*
sumu͡l	20	V	V	449	51	11.3	125	27.9	238	52.9	211	47.1
t͡su͡l mu	20	V	V	455*	67*	14.6*	126	27.7*	249*	54.5*	206	45.5*
t͡sumu͡l	20	V	V	432	43	9.9	130	30.1	218	50.4	214	49.6
ku͡l mu	20	V	V	458*	70*	15.3*	132	28.9	240*	52.4*	218	47.6*
kumu͡l	19	V	V	422	44	10.5	128	30.4	208	49.3	214	50.7

* Significance levels: (*) $p<0.05$, (**) $p<0.10$.

sentence '/tsugiwa _____ toiu/'(2), the duration of the first syllable was longer than that of the same word unaccented on the first syllable both for the mean and the normalized values of the duration of the test word. The difference in duration between them was significant at the level p=0.05 (Tables 2.2). For any test word accented on the second syllable inserted into the carrier sentence '/tsugiwa _____ toiu/'(1), the normalized value of the duration of the second syllable was longer than that of the word unaccented on the second syllable in opposition to the former. The difference in duration between them was significant at the level p=0.05 (Tables 2.2).

As a whole, the duration of the vowels and the syllables in accented syllables was longer than that in unaccented syllables both for the mean and the normalized values of the duration of the test words (Tables 2.1 and 2.2).

4.2 Speech at the fast rate (Table 3)

The mean values of the duration of the test words in the minimal pairs of /humu/, /sumu/, /tsumu/ and /kumu/ in opposition as to accent were between about 300 msec and about 339 msec. The mean values of the duration of the first vowels u1 were between about 35 msec and about 69 msec. The normalized values of the duration of the first vowels u1 for the duration of the test words were between about 11% and about 22%. The mean values of the duration of the second vowels u2 were between about 51 msec and about 95 msec. The normalized values of the duration of the second vowels u2 for the duration of the test words were between bout 17% and about 30%. The mean values of the duration of the first syllables were between about 157 msec and about 205 msec. The normalized values of the duration of the first syllables for the duration of the test words was between about 49% and about 64%. The mean values of the duration of the second syllables were between about 112 msec and about 160 msec. The normalized values of the duration of the second syllables for the duration of the test words were between about 36% and about 49%.

Regardless of the type of carrier sentence, the duration of the first vowel u1 of any test word accented on the first syllable was longer than that of the same test word unaccented on the first syllable both for the mean and the normalized values of the duration of the test word. The difference in duration between them was significant at the level p=0.05.

Regardless of the type of carrier sentence, the duration of the second vowel u2 of any test word accented on the second syllable was longer than that of the same test word unaccented on the second syllable both for the mean and the normalized values of the duration of the test word. The difference in duration between them was significant at the level p=0.05.

Regardless of the type of carrier sentence, the duration of the first syllable of any test word accented on the first

Table 3. The duration of words, vowels u1 and u2 and the first and the second syllables at the fast rate.

3.1) Subject: MS, Carrier: /daro:/

										syllable			
Word	N	u1	u2	Word(msec)	u1(msec)(%)		u2(msec)(%)		1st(msec)(%)		2nd(msec)(%)	
hu͡ mu	20	V	V	305**	67*	22.3*	52*	17.0*	188*	61.6*	117*	38.4*
humu͡	20	V	V	316	41	13.0	91	29.1	157	49.5	159	50.5
su͡ mu	20	V	V	321*	66*	20.8*	57*	17.8*	205*	64.1*	116*	35.9*
sumu͡	20	V	V	338	36	10.7	95	27.9	180	53.4	158	46.6
ʦu͡ mu	20	V	V	309	56*	18.1*	51*	16.6*	193*	62.4*	116*	37.6*
ʦumu͡	20	V	V	319	35	11.4	90	28.7	165	51.2	154	48.8
ku͡ mu	20	V	V	300*	66*	21.9*	53*	17.6*	188*	62.5*	112*	37.5*
kumu͡	20	V	V	316	41	13.1	90	28.5	170	53.7	146	46.3

3.2) Subject: MS, Carrier: /toiu/

										syllable			
Word	N	u1	u2	Word(msec)	u1(msec)(%)		u2(msec)(%)		1st(msec)(%)		2nd(msec)(%)	
hu͡ mu	20	V	V	325	69*	21.4*	65*	20.0*	194*	59.7*	130*	40.3*
humu͡	20	V	V	318	39	12.4	93	29.5	157	49.3	160	50.7
su͡ mu	20	V	V	329**	62*	18.8*	70*	21.4*	197*	59.9*	132*	40.1*
sumu͡	20	V	V	339	38	11.1	93	27.5	183	54.1	156	45.9
ʦu͡ mu	20	V	V	318	60*	18.7*	64*	20.2*	198*	62.2*	120*	37.8*
ʦumu͡	20	V	V	315	36	11.4	86	27.4	168	53.4	147	46.6
ku͡ mu	20	V	V	318	65*	20.3*	65*	20.6*	194*	60.9*	124*	39.1*
kumu͡	20	V	V	311	43	13.7	86	27.8	167	53.8	144	46.2

* Significance levels: (*) $p<0.05$, (**) $p<0.10$.

syllable was longer than that of the same test word unaccented on the first syllable both for the mean and the normalized values of the duration of the test word. The difference in duration between them was significant at the level p=0.05.

Regardless of the type of carrier sentence, the duration of the second syllable of any test word accented on the second syllable was longer than that of the same test word unaccented on the second syllable both for the mean and the normalized values of the duration of the test word. The difference in duration between them was significant at the level p=0.05.

Consequently, at the fast rate, the duration of the vowels and the syllables in accented syllables was longer than that in unaccented syllabls both for the mean and the normalized values of the duration of the test words (Tables 3.1 and 3.2). It seems that the shortening of the duration of the second vowel u2 may have caused the shortening of the duration of the test words in comparison with the slow speech.

5. Conclusion

A quantitative difference in the duration of vowels and syllables between accented and the unaccented vowels in minimal pairs of bisyllabic words /Clulmu2/ was clearly found. The duration of the vowels and the syllables in accented syllables was longer than that in unaccented syllabls both for the mean and the normalized values of the duration of the test words. The difference in the duration of vowels was significant in fast speech.

References

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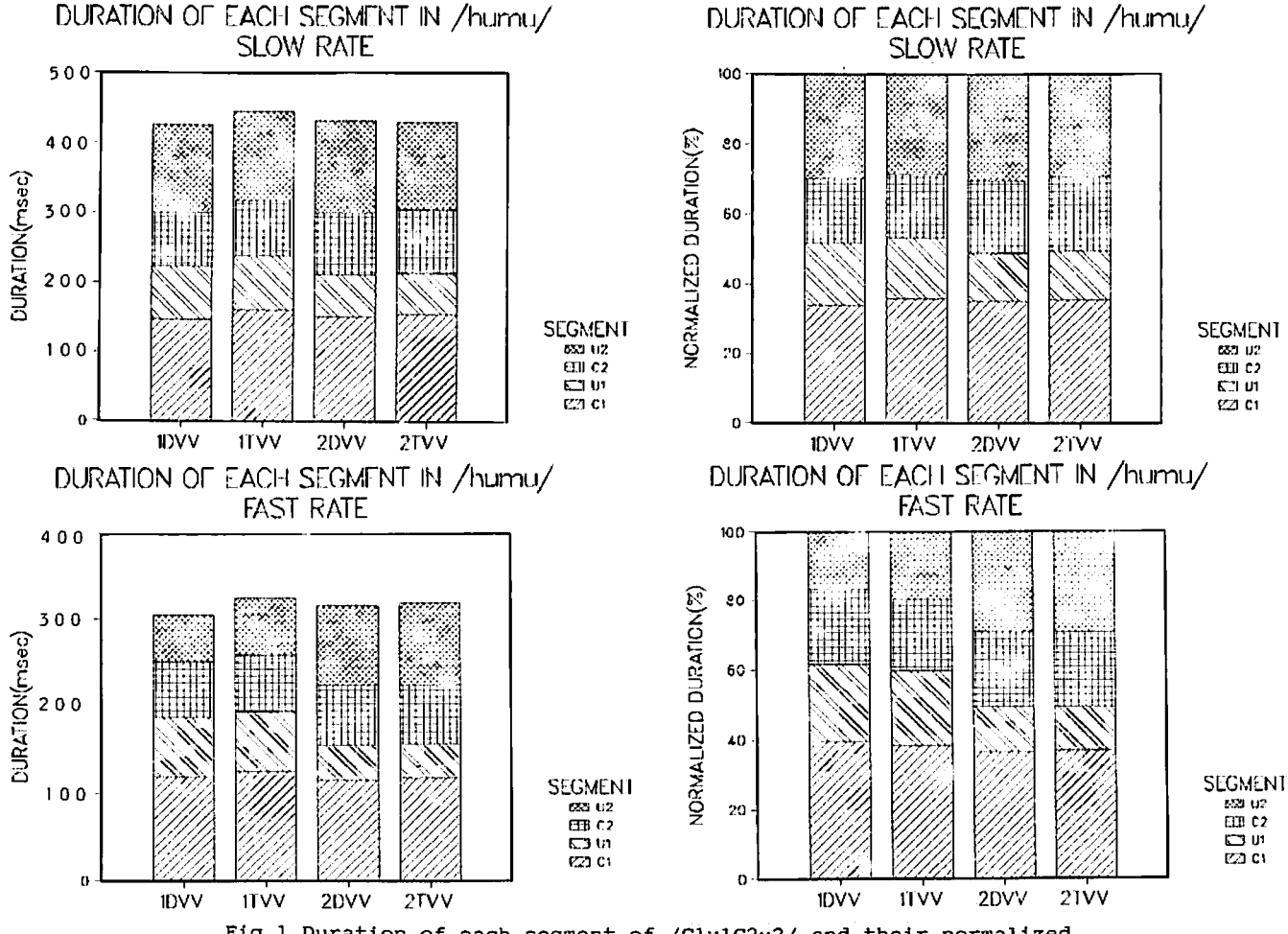

Fig.1 Duration of each segment of /C1u1C2u2/ and their normalized values to the word /hu͡mu/ or /humu͡/ at slow and fast rate. In each figure, abbreviations used are as follows.

1DVV: Fhe first syllable accented, carrier /daro:/, u1 voiced, u2 voiced.

1TVV: First syllable accented, carrier /toiu/, u1 voiced, u2 voiced.

2DVV: Second syllable accented, carrier /daro:/, u1 voiced, u2 voiced.

2TVV: Second syllable accented, carrier /toiu/, u1 voiced, u2 voiced.

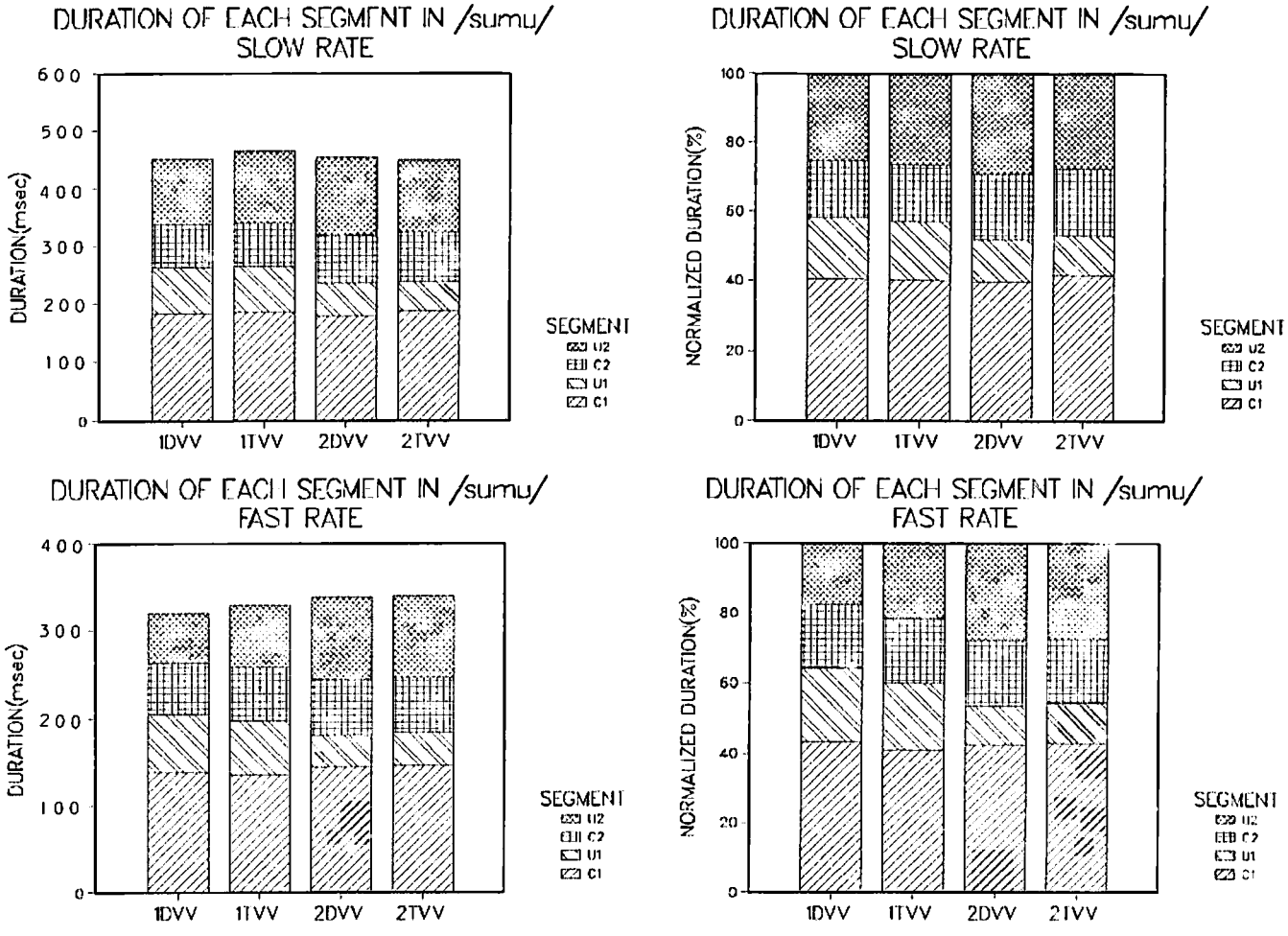

Fig.2 Duration of each segment of /C1u1C2u2/ and their normalized values to the word /s$\overline{u}$1 mu/ or /sumu$\overline{1}$/ at slow and fast rates.

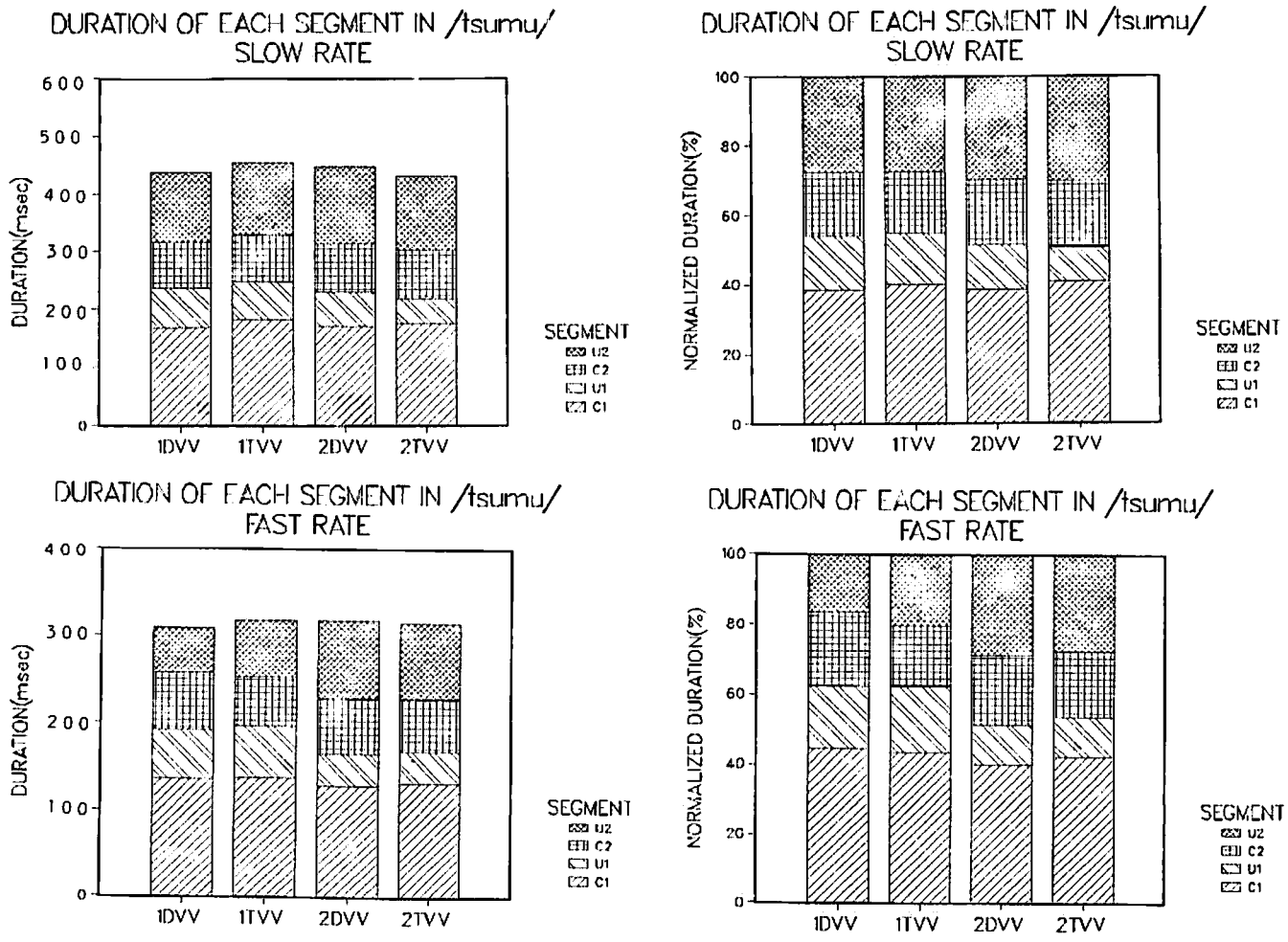

Fig.3 Duration of each segment of /C1u1C2u2/ and their normalized values to the word /tsu̱mu/ or /tsumu̱/ at slow and fast rates.

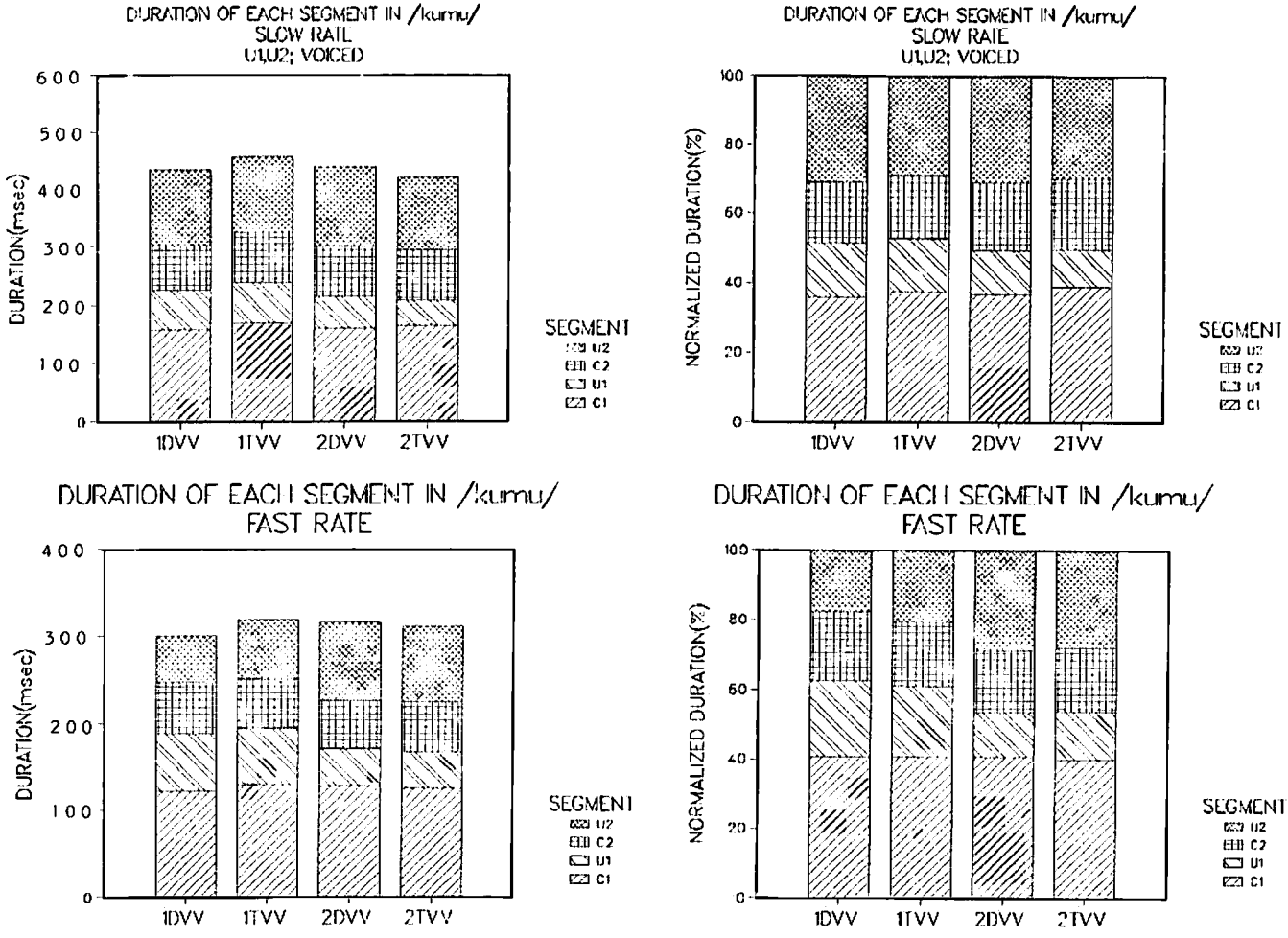

Fig.4 Duration of each segment of /C1u1C2u2/ and their normalized value to the word /kū mu/ or /kumū / at slow and fast rates.