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VOWEL DURATION IN JAPANESE /hū ku/ AND /hukū/ (II)

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1. Introduction

In our previous study [1] the duration of segments in a minimal pair of Japanese words, /hū ku/ and /hukū/, was examined in terms of both the occurrence of unvoicing and the duration of vowels. The test words were placed in three types of sentences.

The present study is an extension of that previous study. Here, the test words were placed in six different types of sentences.

2. Procedure and Method

The six pairs of sentences designed for comparison were as follows.

test words: /hū ku/ (blow), /hukū/ (wipe)

sentence 1:/huku/ "He blows." and "He wipes."

sentence 2:/hukuka/ "He blows or..." and "He wipes or..."

sentence 3:/hukuga/ "He blows but..." and "He wipes but..."

sentence 4:/huewohuku/ "He blows a pipe."
"He wipes a pipe."

sentence 5:/huewohukuka awawohukanaika/
"Whether he blows a pipe or does not blow bubbles."
"Whether he wipes a pipe or does not wipe bubbles."

sentence 6:/huewohukuga awawohukanai/
"He blows a pipe but does not blow bubbles."
"He wipes a pipe but does not wipe bubbles."

Sentence 1 is a kind of one-word sentence and served as a reference for the other five test sentences. Sentence 2 and sentence 3 were made by adding different words to the head or the end of sentence 1. Sentence 4 was made by adding different word groups to the head of sentence 1. Sentence 5 and sentence 6 were made by adding different word groups to both the head and the end of sentence 1.

Two subjects of Tokyo dialect, one male and the other female, read these sentences at their normal tempo more than ten times each.

The recording was performed in a anechoic recording studio and the speech sounds were analyzed by means of an LPC analysis program2). The results were then calculated and examined with the SPSS program on the VAX-11/780 system.

In the present study, the duration of a vowel was defined as the time period when a periodic (or quasi-periodic) vibration for the vowel was observable on the speech wave. The measurement unit for duration was 0.1 msec. The relative duration of each segment in a word was calculated in each case.

3. Results and Comments

3.1. Unvoicing of vowels

The wave forms of 238 sentences for subject M.S. and 208 sentences for subject F.K. were examined for the minimal pairs of /huku/ in six types of sentences. The number of samples treated here is given in Table 1.

Table 2 showes the incidences of voiced or unvoiced vowels in relation to the two words by MS. and FK., respectively. As for the results for subject MS.,the vowel of the first mora,u_1, was unvoiced and the vowel of the second mora, u_2, was voiced in every case despite the differences in accent between the two words. Concerning /hu̥ku/ produced by subject FK., the vowel u_1 was pronounced unvoiced in 84.3% (86 cases) of the total(102 cases). As for vowel u_2 in these 86 cases, 66 cases(64.7% of 102 cases) were voiced, but 20 cases (19.6% of 102 cases) were unvoiced. In relation to the rest of the cases which contained a voiced u_1(16 cases, 15.7% of 102 cases) in /hu̥ku/, 10 cases (9.8% of 102 cases) were unvoiced in the final vowel u_2, but in the other 6 cases (5.9% of 102 cases) u_2 was voiced. On the whole, the final vowel u_2 was unvoiced in 30 cases (29.4% of 102 cases) for /hu̥ku/. As for /huku̥/ produced by subject FK., however, the vowel u_1 was unvoiced and the vowel u_2 was voiced in every case, as in subject MS.

Concerning /hu̥ku/ in subject FK., the occurrence of unvoicing or voicing of the first (u_1) and the second mora (u_2) was examined as to the rate of occurrence in the total number of cases of each sentence (Table 3).

3.2. Duration

3.2.1 Duration of vowels

Table 1. Number of samples for each subject.

Subject	Word	Sentence	N	Total
1)MS.	hū ku	1	26	
		2	13	
		3	15	110
		4	16	
		5	23	
		6	14	
	hukū	1	30	
		2	21	
		3	17	128
		4	14	
		5	29	
		6	14	
2)FK.	hū ku	1	22	
		2	13	
		3	12	102
		4	16	
		5	26	
		6	12	
	hukū	1	25	
		2	12	
		3	15	106
		4	18	
		5	23	
		6	13	

Table 2. The occurrence of unvoicing or voicing in the /u/ of the first (u1) and the second mora (u2).

1) Subject:MS.

	u_1			u_2		
Word	V/UV	N	%	V/UV	N	%
hu̥ku	UV	110	100	V	110	100
huku̥	UV	128	100	V	128	100

2) Subject:FK.

	u_1			u_2					
Word	V/UV	N	%	V/UV	N	%	Sentence	N	%
hu̥ku	V	16	15.7	V	6	5.9	Sentence 1	4	3.9
							Sentence 3	2	2.0
				UV	10	9.8	Sentence 1	1	1.0
							Sentence 2	9	8.8
	UV	86	84.3	V	66	64.7	Sentence 1	15	14.7
							Sentence 2	3	2.9
							Sentence 3	11	10.8
							Sentence 4	16	15.7
							Sentence 5	9	8.8
							Sentence 6	12	11.8
				UV	20	19.6	Sentence 1	2	2.0
							Sentence 2	1	1.0
							Sentence 5	17	16.6
huku̥	UV	106	100	V	106	100			

V: voiced, UV: unvoiced, N: number of cases

Table 3. The occurrence of unvoicing or voicing in the /u/ of the first (u_1) and the second mora (u_2) of /hu⌝ku/. Subject: FK.

	u1		u2		
Sentence	N	V/UV	V/UV	N	%
1	22	UV	V	15	68.2
		V	V	4	18.2
		UV	UV	2	9.1
2	13	V	UV	9	69.2
		UV	V	3	23.1
		UV	UV	1	7.7
3	13	UV	V	11	84.6
		V	V	2	15.4
4	16	UV	V	16	100.0
5	26	UV	UV	17	65.4
		UV	V	9	34.6
6	12	UV	V	12	100.0

V: voiced, UV: unvoiced, N: number of cases

Here we report on the duration of the vowel u2. Table 4 gives the mean values of the duration of u_2 in subject MS. The data are also displayed in Fig. 1.

Concerning /hu̱ku/ in subject FK., it was necessary to separate the voiced u_2 group from the unvoiced u_2 group. Table 5 gives the mean values of the duration of voiced u_2 for subject FK. These data are also displayed in Fig. 2.

Table 6 gives the mean values of the duration of u_2 plus the release of consonant /k/, and the duration of the unvoiced u_2 plus the release of consonant /k/. These data are displayed in Fig. 3.

3.2.2 Duration of the word /huku/

The duration of the sentences were measured to compare /hu̱ku/ with /huku̱/. Table 7 gives the mean values of the duration of the words by subject MS., and the data is displayed in Fig. 4.

Concerning subject FK., the data were classified into three groups as follows:

(1) The duration of the word /huku/ in all cases for the comparison between /hu̱ku/ and /huku̱/.
(2) The duration of words with voiced u_2 for /hu̱ku/.
(3) The duration of words with unvoiced u_2 for /hu̱ku/.

Table 8 and Fig. 5 give the duration of the words in all cases in subject FK. On the other hand, the duration of the word /hu̱ku/ containing voiced u_2 or unvoiced u_2 exclusively is given in Table 9 and Fig. 6.

3.3 Comments

In subject MS., the first vowel, the /u/ following /h/, was always unvoiced. In subject FK., the unvoicing also occurred far more frequently for the first /u/ than for the second one. These results appear to be in agreement with the assumptions by M. S. Han that

> In sequences in which the voiceless consonants are stops and non-stops (that is to say, fricatives and africates) the vowels preceded by non-stops are more readily unvoiced, while the vowels preceded by stops tend to remain voiced[3,4].

In subject FK., the rate of occurrence of unvoicing for the first /u/ was 84.3% for /hu̱ku/, while it was 100% for /huku̱/. Also, the rate of occurrence of unvoicing for the second /u/ was 29.4% for /hu̱ku/, while it was 0% for /huku̱/. This result is in

Table 4. Comparison of the duration of u_2 between /hūku/ and /hukū/ for six pairs of sentences. Subject: MS.

Sentence	Word	N	Duration (msec)	S.D.	Relative duration (%)	S.D.
1	hūku	28	155.8*	10.8	42.8*	2.7
1	hukū	31	187.1	16.0	45.6	2.9
2	hūku	14	105.3	5.6	36.2	1.7
2	hukū	21	106.9	6.8	37.7	2.6
3	hūku	15	99.7*	13.1	33.2*	4.3
3	hukū	17	112.5	10.5	37.6	2.6
4	hūku	16	138.6*	16.0	40.5*	3.4
4	hukū	16	189.4	13.5	45.1	1.9
5	hūku	23	77.1*	7.5	32.7*	3.7
5	hukū	29	102.3	8.6	36.3	2.4
6	hūku	14	73.1*	8.8	32.6	3.7
6	hukū	14	89.1	8.7	32.5	2.1

* Significance level was $p<0.005$.

Fig. 1-1 DURATION OF SEGMENT : U2
Subject : M S.

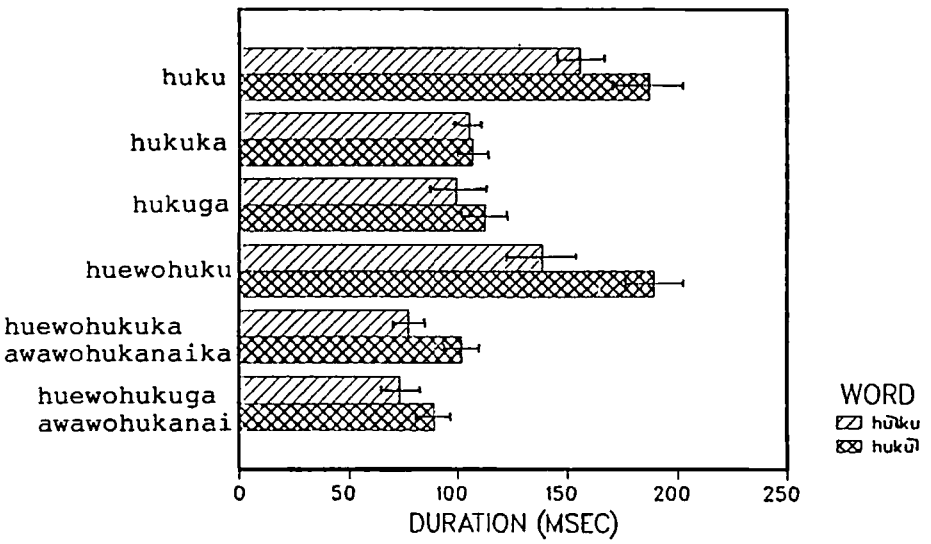


Fig. 1-2 DURATION OF SEGMENT : U2
Subject : M S.

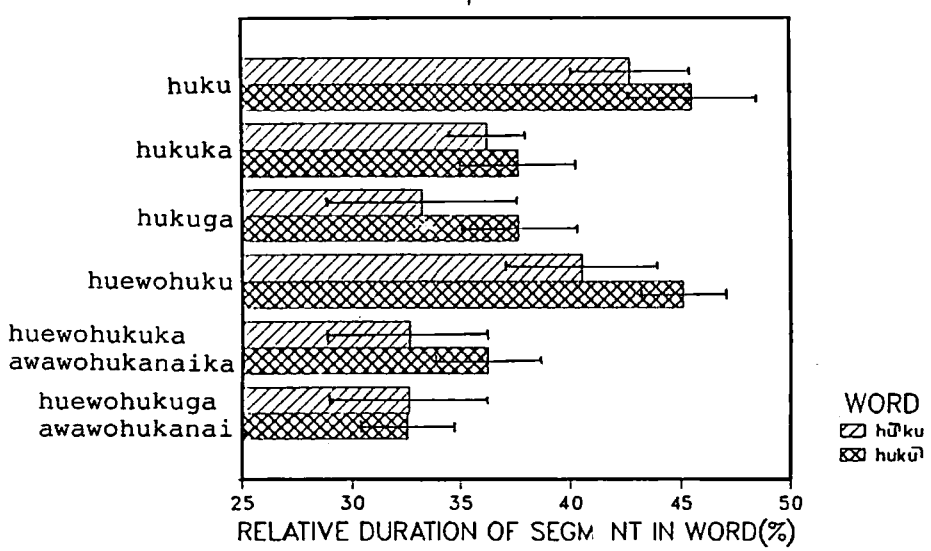


Table 5. Comparison of the duration of voiced u_2 between /hū ku/ and /hukū/ for six pairs of sentences. Subject: FK.

Sentence	Word	N	Duration (msec)	S.D.	Relative duration (%)	S.D.
1	hū ku	19	126.1*	20.1	33.7*	6.8
1	hukū	25	148.6	13.5	39.8	4.4
2	hū ku	3?	85.3*	8.5	35.7	2.9
2	hukū	12	103.8	24.3	38.9	4.6
3	hū ku	13	96.6	25.1	37.1	6.1
3	hukū	15	102.5	23.6	37.6	5.4
4	hū ku	16	105.8*	20.5	29.6	4.0
4	hukū	18	149.8	16.2	40.6*	2 9
5	hū ku	9?	76.2*	7.9	32.6	4.5
5	hukū	23	93.0	7.6	34.2	6.3
6	hū ku	12	96.4	17.2	37.0	4.3
6	hukū	13	97.1	10.7	35.8	2.5

Significance levels were as follows:

(*) $p<0.005$. (?) Inadequate for test+

+ As the vowel u_2 of /hū ku/ was often unvoiced in the case, of sentences 1.2 and 5 by subject FK., the number of cases was not sufficient to compare the mean values of the duration between /hū ku/ and /hukū/.

Fig. 2-1 DURATION OF SEGMENT : U2
Subject : F K.

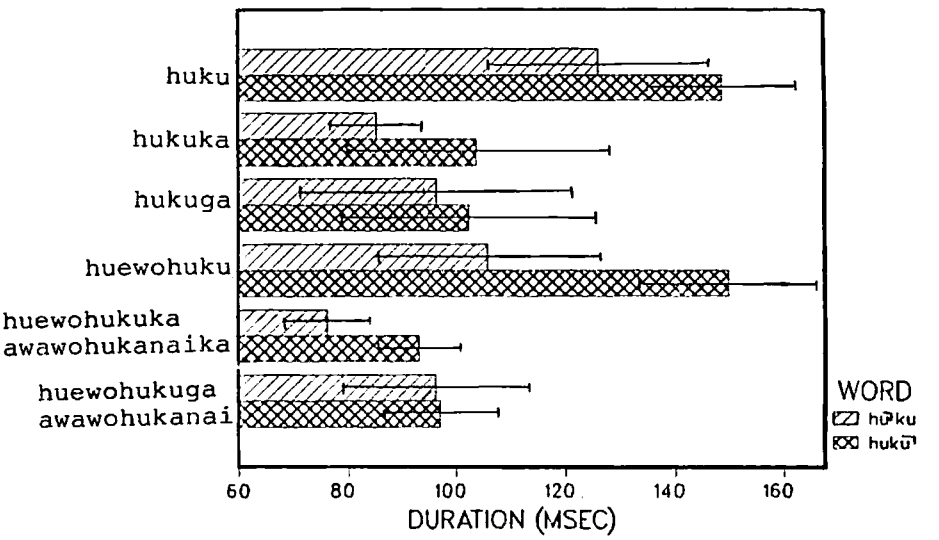


Fig. 2-2 DURATION OF SEGMENT : U2
Subject : F K.

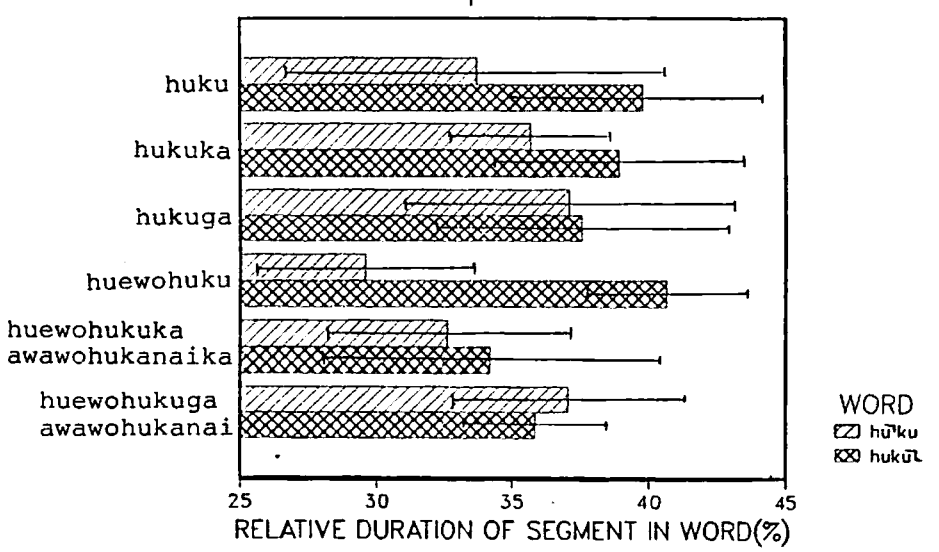


Table 6. The duration of voiced u_2 plus the aspiration of /k/ and the duration of unvoiced u_2 plus the aspiration of /k/ in /hū ku/ for six pairs of sentences. Subject: FK.

(1) The duration of voiced u2 plus the aspiration of /k/

Sentence	Word	N	u2	Duration (msec)	S.D.	Relative duration (%)	S.D.
1	hū ku	19	V	144.8*	20.3	38.8	7.9
1	hū ku	3?	UV	181.9	22.5	41.4	6.1
2	hū ku	3?	V	107.9	8.7	45.3	5.3
2	hū ku	10	UV	96.4	18.1	35.5	7.5
3	hū ku	13	V	116.9	27.6	45.1	6.9
4	hū ku	16	V	124.8	22.0	34.9	4.4
5	hū ku	9?	V	109.0	10.5	46.7	7.2
5	hū ku	17	UV	100.3	18.7	45.2	5.4
6	hū ku	12	V	117.4	14.8	45.3	3.9

Significance levels were as follows:

(*) $p<0.005$,: (?) Inadequate for test+

V: voiced, UV: unvoiced, N: number of cases

Fig. 3-1 DURATION OF SEGMENT IN /hu¯ku/
Subject : F K.

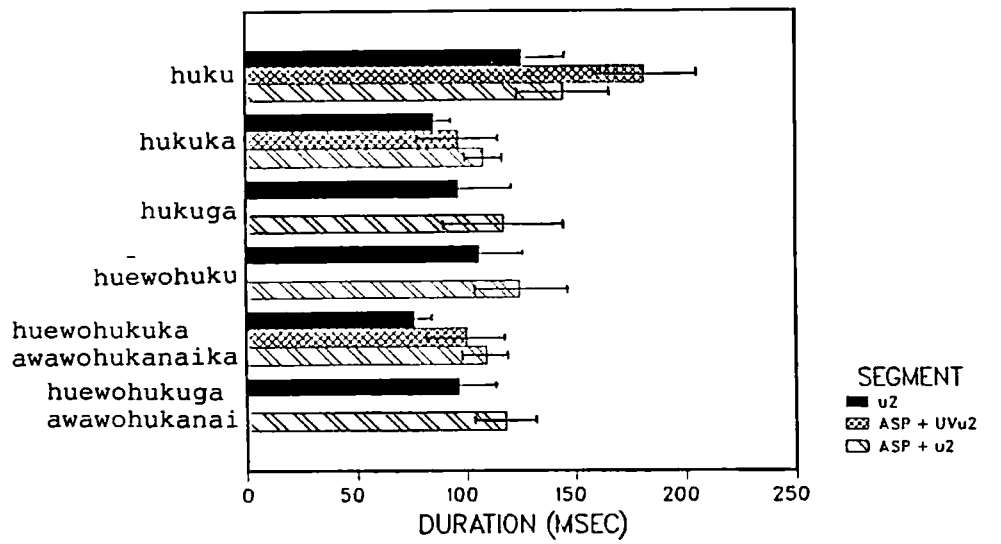


Fig. 3-2 DURATION OF SEGMENT IN /hu¯ku/
Subject : F K.

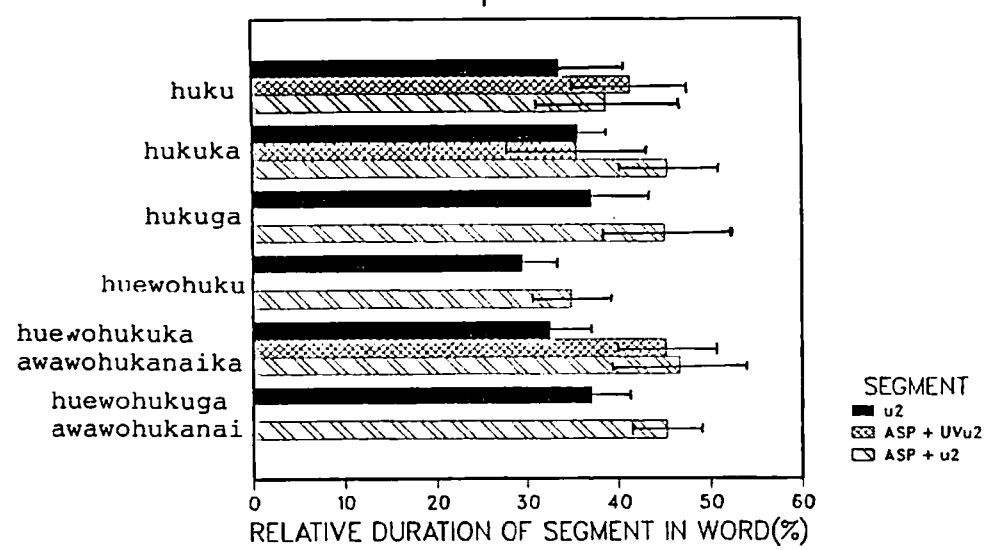


Table 7. Comparison of the duration of /hu˥ku/ and /huku˥/ for six pairs of sentences. Subject: MS.

Sentence	Word	N	Duration	S.D. (msec)
1	hu˥ku	28	364.8*	19.6
1	huku˥	31	410.5	15.8
2	hu˥ku	14	290.7	8.3
2	huku˥	21	284.2	14.3
3	hu˥ku	15	300.7	17.4
3	huku˥	17	298.8	16.1
4	hu˥ku	16	341.1*	11.9
4	huku˥	16	419.9	21.5
5	hu˥ku	23	237.3*	20.8
5	huku˥	29	282.8	22.8
6	hu˥ku	14	224.4*	11.2
6	huku˥	14	273.6	15.8

* Significance level was $p<0.005$.

Fig. 4

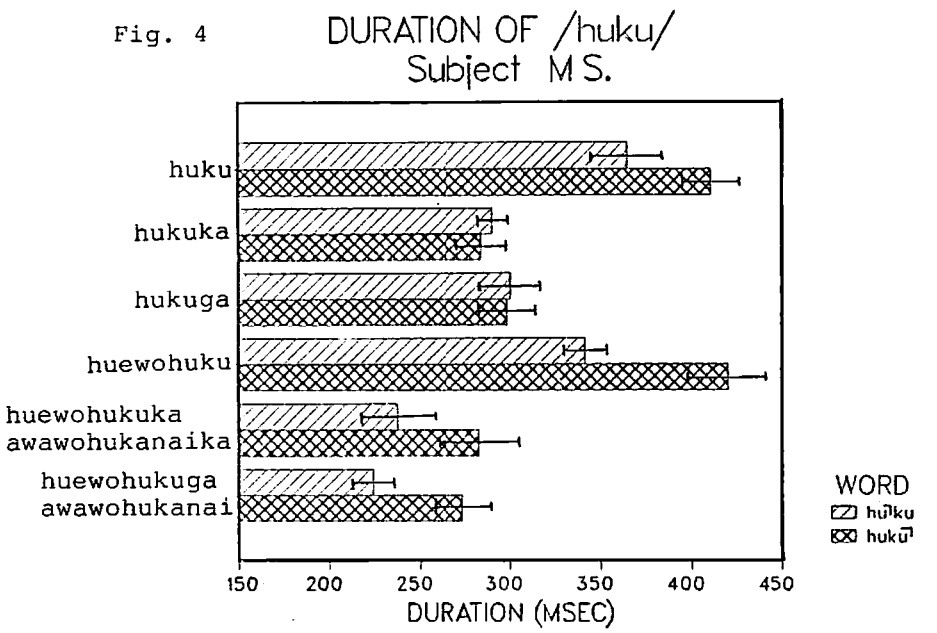


Table 8. Comparison of the duration of /hu͡ku/ and /huku͡/ for six pairs of sentences. Subject: FK.

Sentence	Word	N	Duration	S.D. (msec)
1	hu͡ku	22	365.6	44.9
1	huku͡	25	365.5	21.2
2	hu͡ku	13	266.5	36.7
2	huku͡	12	264.5	31.5
3	hu͡ku	13	258.2	34.8
3	huku͡	15	270.1	24.1
4	hu͡ku	16	355.7	23.3
4	huku͡	18	367.8	14.9
5	hu͡ku	26	226.1*	21.4
5	huku͡	23	261.7	18.1
6	hu͡ku	12	259.7	30.0
6	huku͡	13	271.3	27.8

* Significance level was $p<0.005$.

Fig. 5

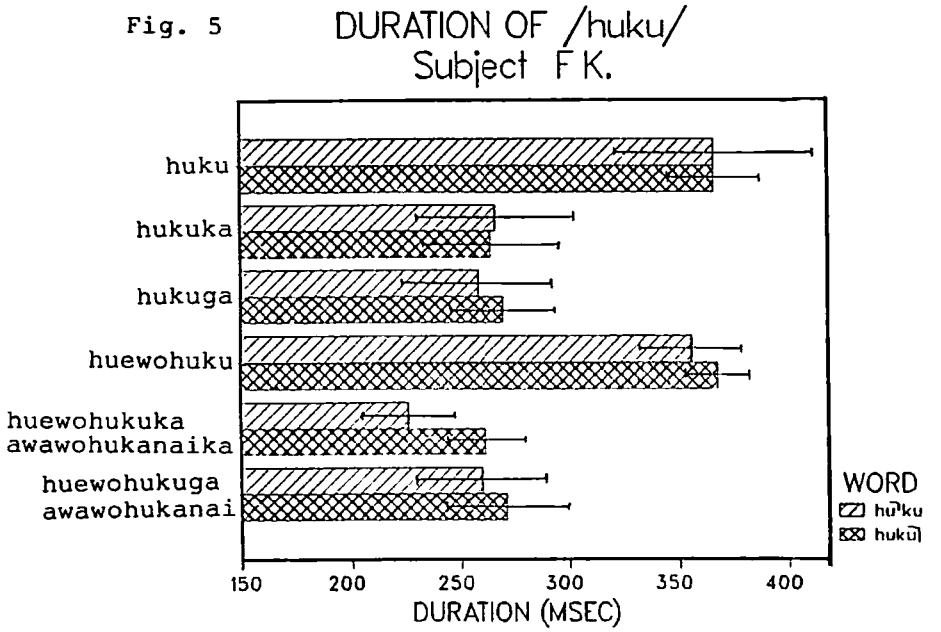
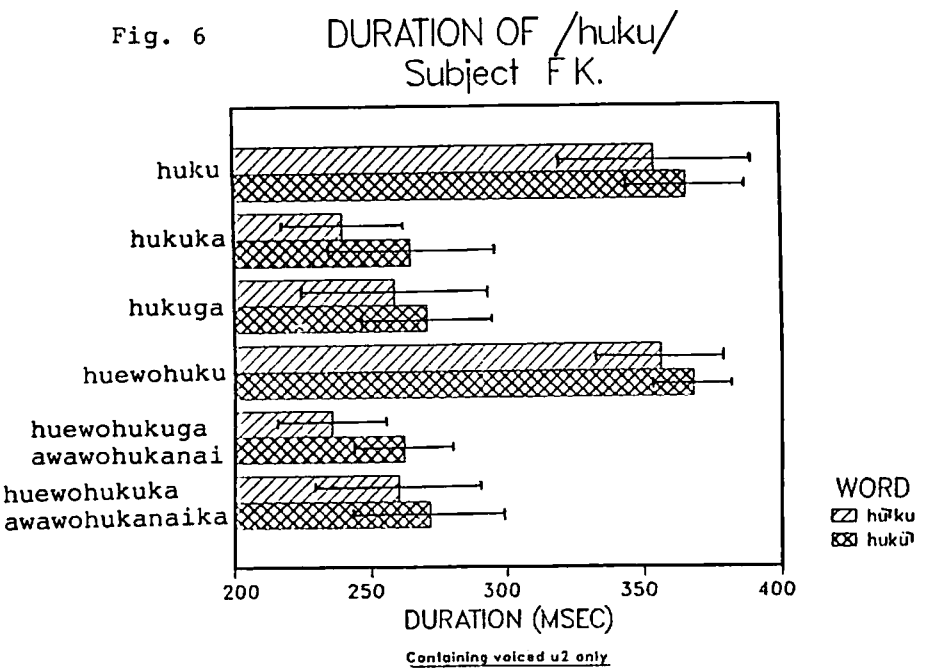


Table 9. The duration of /hu̥ku/ containing voiced u2 and unvoiced u_2 for six pairs of sentences. Subject: FK.

Sentence	Word	N	u2	Duration	S.D. (msec)
1	hu̥ku	19	V	353.8	34.7
1	hu̥ku	3?	UV	440.2	24.7
2	hu̥ku	3?	V	239.4	22.1
2	hu̥ku	10	UV	274.7	37.0
3	hu̥ku	13	V	258.2	34.8
4	hu̥ku	16	V	355.7	23.3
5	hu̥ku	9?	V	235.4	20.0
5	hu̥ku	17	UV	221.1	21.1
6	hu̥ku	12	V	259.7	30.0

V: voiced, UV: unvoiced, N: number of cases

Fig. 6



agreement with the assumption by M. S. Han that

> When /i/ or /u/ occurs in a 'virtual' accented syllable, unvoicing is not common, though otherwise they are in the environment typical of the unvoicing phenomenon5,6).

But this does not apply for the result by MS., where all of the first /u/s were unvoiced, and all of the second /u/s were voiced in both accent types. Concerning the unvoicing of u_2 for /hu⌝ku/ in subject FK., it occurred in sentences 1,2 and 5, that is to say, in a single word or in the cases where the vowel u_2 was preceded by the voiceless stop /k/, but not in the cases where u was preceded by the voiced stop /g/ (sentence 3.6) or in the cases where the word group /huewo/ preceded /hu⌝ku/ and at the same time u_2 was sentence final (sentence 4). The duration of u_2 for /hu⌝ku/ was constantly shorter than that for /huku⌝/. The duration of unvoiced u_2 plus the aspiration of /k/ was shorter than the duration of voiced u_2 plus the aspiration of /k/ in the cases where a group of words followed u_2, but it was longer than the voiced u_2 for /hu⌝ku/ in subject FK. (Fig. 3).

A shorter duration of u_2 for the sentences 2,3,5 and 6 compared with sentences 1 and 4 can be explained by the difference in the context. It became clear that the duration of u in the sentence final position was much longer than the other cases where word groups followed u_2.

The duration of /hu⌝ku/ in the test sentences was influenced by the difference in the context. It became much longer when the test words were of sentence final, while it became shorter when the test words were followed by words or word groups in the case of both /hu⌝ku/ and /huku⌝/. As to the difference of duration between /hu⌝ku/ and /huku⌝/, the duration of /huku⌝/ was longer in sentences 1,4,5 and 6 in subject MS.(fig. 4), and in sentences 1,3,4,5 and 6 in subject FK.(Fig. 5). In the cases of sentences containing voiced u_2 exclusively in subject FK., the duration /huku⌝/was constantly longer than that of /hu⌝ku/ (Fig. 6).

4. Summary

The duration of segments in a pair of Japanese words consisting of the same sequence of phonemes, /hu⌝ku/ and /huku⌝/, was examined in wave forms in terms of both the occurrence of unvoicing and the duration of vowels.

1) The unvoicing of vowels occurs mostly in the case where the vowel follows the voiceless fricative consonant, regardless of which mora the accent is on.
2) The unvoicing of word final u_2 occurs mostly in the case where the vowel u_2 is preceded by the voiceless stop /k/.
3) The difference between the duration of the final vowel of /hu⌝ku/ and that of /huku⌝/ was significant with the latter

being longer.

4) The duration of u_2 is influenced by the context. When it is sentence final, it becomes longer, while it is much shorter when a word group follows the vowel.
5) The duration of word/huku/ is longer when the word is in the sentence final, while it becomes shorter when the word groups follows it.
6) It is concluded that Japanese word accent is characterized not only by the fundamental frequency, but also by the duration of the vowels.

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