The Interaction of Duration and Pitch in Japanese Long Vowels*

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0. Introduction

This paper investigates the relationship between two phonetic properties – duration and pitch – and two phonologically significant features – vowel length and pitch-accent. Vowel length and pitch-accent are phonologically distinctive in standard Japanese[1], and these two phonological characteristics are difficult for non-native speakers of Japanese to master. I conducted two production experiments to examine the way native speakers use phonetic signals to produce long vowels correctly in standard Japanese. The first experiment involved accented vowels and the second one involved unaccented vowels.

The results show that speakers employ duration and pitch unconsciously. When both signals are available, speakers use both of them; but when pitch is not available, they highlight the durational contrast between long and short vowels. These facts might shed some light on the phonetic reality of the Japanese mora.

1. Background

Japanese vowel length is distinctive; that is, the length of a vowel may change the meaning of a word. For example, the Japanese word *tori* with a short vowel means 'bird', but the word *toori* with a long vowel means 'street'. There are many such minimal pairs in Japanese. Likewise, pitch-accent is distinctive. The existence and location of pitch-accent may change the meaning of a word, just as the location of stress may change the meaning of a word in English; e.g., the noun *object* has stress on the first syllable and the verb *object* has stress on the second

* This study is partly supported by a scholarship from the Center for Japanese Studies and a grant from the Department of Linguistics Endowment Fund at University of Hawai'i at Mānoa. I am deeply indebted to Ben Bergen, Patricia Donegan, Yasuko Ito, Michiko Nakamura, and Amy Schafer for their suggestions and comments on the design of experiments and analyses of the data. I also want to thank Kenneth Rehg and Ryo Stanwood for their comments on previous versions of this paper. All mistakes are of course mine.

[1] The subject of this paper is "standard Japanese", the dialect of Japanese spoken in Tokyo and its environs, Japan. I refer to it simply as "Japanese". I also use the term "Japanese" to refer to the Japanese language in general.

syllable. Pitch-accent in standard Japanese is realized as a high pitch (H) and a following low pitch (L). When the pitch contour is changed, the meaning of the word may change as shown in (1); an unaccented word does not have this HL pitch sequence as in (2) below.

(1) Accented words in standard Japanese

hana-ga	'girl's name + NOM[2]'	*hana-ga*	'flower + NOM'
H L	L	L H	L

(2) Unaccented word in standard Japanese

hana-ga	'nose + NOM'
L H	H

When a long vowel is accented, only the first mora in the vowel carries a H pitch; consequently, the HL pitch contour must occur within the long vowel (McCawley 1968:133-134) as illustrated in (3). However, when a long vowel is unaccented, the pitch contour in the vowel must be either HH or LH followed by a H pitch as shown in (4).

(3) Words with an accented long vowel in standard Japanese

kooshi	'lecturer'	*rooba*	'elderly lady'
HL	L	HL	L

(4) Words with an unaccented long vowel in standard Japanese

kooshi	'Confucius'	*kooshi*	'lattice'
HH	H	LH	H[3]

Note that accented long vowels carry two distinctive phonological features (vowel length and pitch-accent), but unaccented long vowels only carry one (vowel length). The phonological vowel length distinction can be captured as the duration of an acoustic signal. The acoustic realization of pitch-accent is a relative pitch movement, and it is measured by the change in the fundamental frequency (F0) value. This paper also investigates the way in which these two acoustic signals interact with one another when speakers produce phonological vowel length distinctions and pitch-accent.

[2] NOM = nominative case marker

[3] The long vowel in the word *kooshi* 'lattice' has the pitch contour LH; however, McCawley (1968) states that in a widespread variety of standard Japanese, "an unaccented initial syllable of the form CVV or CVn is pronounced entirely on a high pitch" (p.133).

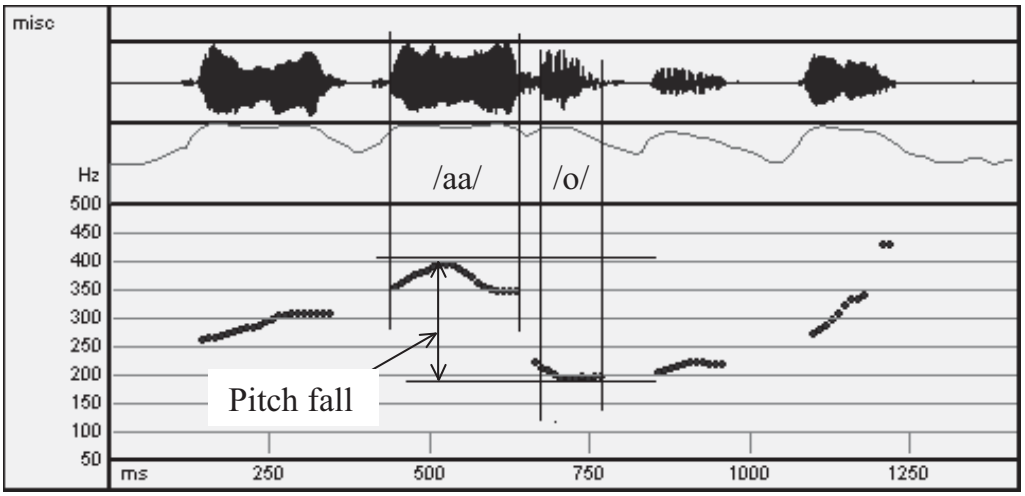
2. Configuration of Experiments

I conducted two production experiments. Experiment 1 involved accented vowels and Experiment 2 involved unaccented vowels. There were four participants (two female and two male) in each experiment, and each experiment had a different group of participants; only one male participant participated in both experiments. All were native speakers of the Tokyo dialect of Japanese, and their parents were also native speakers of the Tokyo dialect or had lived most of their lives in a community where the Tokyo dialect was spoken. Five out of a total of seven participants taught Japanese as a foreign language to adults. The age range of the participants was from the late 20s to the early 40s.

The participants were asked to read sentences written in Japanese in a sound attenuated recording studio at three different speech rates – fast, normal and slow – which were determined individually by each speaker. Since a pause would affect the duration of utterances and pitch movement, the participants were instructed not to insert any pauses into sentences. The utterances were recorded on a TANBERG TCR522 cassette-recorder through a microphone and digitized by Pitchworks at a sampling rate of 11,025 Hz. Only the data from fast and slow speech were used for the analysis.

The duration of vowels and pitch fall were measured from the digitized files. The location of the beginning and end of a vowel was determined by the presence of the second and higher formants and also by listening to the actual recordings. Pitch fall was the difference between the highest F0 value in the target vowel and the lowest F0 value in the following mora as illustrated in (5).

(5) Measurement points of pitch fall
Material sentence: *sono k<u>aa</u>do fuite* ‘please clean the card’



Because I took multiple measurements from four speakers performing the same task, I used a repeated measures two-way analysis of variance (2-way ANOVA) to analyze the duration of vowels and pitch fall. There were two

different factors used as independent variables – speech rate (fast and slow) and vowel type (long and short).

3. Experiment 1: Involving accented vowels

3.1. Materials

In this experiment, words containing an accented vowel were the target vowels for the data. Three to five minimal pair sentences contrasting vowel length for each of the five Japanese vowels were used as the materials. Examples are shown in (6) (see appendix A for the entire list).

(6)	*sono k<u>aa</u>do fuite*	vs.	*sono k<u>a</u>do fuite*
	'Please clean the card.'		'Please clean the corner.'
	sore-wa k<u>ee</u> desu	vs.	*sore-wa k<u>e</u> desu*
	'That is the letter *K*.'		'That is the letter *ke*.'
	sono ch<u>ii</u>zu-ga hoshii	vs.	*sono ch<u>i</u>zu-ga hoshii*
	'I want that cheese.'		'I want that map.'
	kawaii b<u>ee</u>ru da ne	vs.	*kawaii b<u>e</u>ru da ne*
	'What a pretty veil!'		'What a cute bell!'
	sore-ga k<u>oo</u>i-no araware desu	vs.	*sore-ga k<u>o</u>i-no araware desu*
	'That is affection.'		'That is love.'

3.2. Results

The results show that speech rate had a significant main effect on the duration of vowels ([F(1,3) = 66.729, p = .0038]); that is, the mean durations of both long and short vowels were significantly shorter in fast speech and longer in slow speech. Vowel type (long vs. short) also had a significant main effect on the duration of vowels ([F(1,3) = 1377.831, p < .0001]); that is, the mean duration of long vowels was significantly longer than that of short vowels in both fast and slow speech. The mean duration of vowels and ratios are shown in (7).

(7) Mean duration and ratio of accented vowels

	Long vowel (ms)	short vowel (ms)	ratio (long : short)
fast speech	119.194	72.104	1.65 : 1.00
slow speech	176.988	100.167	1.77 : 1.00
ratio (fast : slow)	1:00 : 1.48	1.00 : 1.39	

Moreover, there was a significant interaction between speech rate (fast vs. slow) and vowel type (long vs. short) ([F(1,3) = 12.463, p = .0386]). This means that speech rate had a different effect on the mean duration of long vowels from that of the mean duration of short vowels.

Also, both speech rate and vowel type had a significant main effect on pitch fall (for speech rate [F(1,3) = 16.824, p = .0262] and (vowel type [F(1,3) = 22.058, p = .0183]).

(8) Mean pitch fall and ratio

	Long vowel (Hz)	short vowel (Hz)	ratio (long : short)
fast speech	82.433	61.573	1.34 : 1.00
slow speech	96.332	68.329	1.41 : 1.00
ratio (fast : slow)	1.00 : 1.17	1.00 : 1.11	

There was, however, no significant interaction between speech rate and vowel type ([$F(1,3) = 8.093$, $p = .0654$]). This means that the speakers tried to maintain a certain amount of pitch fall in long vowels comparable to that in short vowels.

3.3. Discussion

The results from Experiment 1 indicate that the duration of vowels is more susceptible to speech rate, whereas pitch fall is relatively stable regardless of speech rate. It is not only duration that makes accented long vowels long: F0 also plays a role. Japanese speakers use both duration and F0 to mark accented long vowels. The question, then, is how do speakers produce unaccented long vowels? They must rely solely on duration to distinguish vowel length. The way speakers use durational information in unaccented long vowels should be different from the way they use durational information in accented long vowels. This hypothesis was tested in Experiment 2.

4. Experiment 2: Involving unaccented vowels

4.1. Materials

In this experiment, words containing an unaccented vowel were used to elicit the data. Materials were 18 sets of minimal and near minimal pairs contrasting vowel length and 9 words containing an unaccented long vowel. Examples are shown in (9) (see appendix B for the entire list). They were read in the carrier sentence *ima* _____ *to iimashita* 'I said _____ now'.

(9)

kaari	vs.	*akari*
'red ants'		'light'
seekoo	vs.	*sekoo*
'success'		'construction'
shiiku	vs.	*shiku*
'to breed'		'to spread'
sookai	vs.	*sokai*
'general meeting'		'evacuation'
yuukai		
'kidnap'		

4.2. Results

The results are similar to the results from Experiment 1. Both factors, speech rate and vowel type, had a significant main effect on the mean duration of vowels (for speech rate [$F(1,3) = 33.005$, $p = .0105$], for vowel type [$F(1,3) = 928.971$,

$p < .0001$]). In addition, the interaction of these two factors was also significant ([$F(1,3) = 18.090$, $p = .0238$]). These results showed that the duration of unaccented vowels and accented vowels were equally vulnerable to speech rate. The mean duration of vowels and ratios is shown in (10).

(10) Mean duration and ratio of unaccented vowels

	long vowel (ms)	short vowel (ms)	ratio (long : short)
fast speech	117.285	60.820	1.93 : 1.00
slow speech	201.718	83.205	2.42 : 1.00
ratio (fast : slow)	1.00 : 1.72	1.00 : 1.37	

However, there was a difference in the ratio of the mean duration of long vowels to short vowels for accented vowels and unaccented vowels. I combined the results from Experiment 1 and 2 in (11) for comparison. These results indicate that speakers excessively lengthened long vowels, particularly in slow speech, to produce vowels that were unambiguously long. As I had expected, because pitch was not available in unaccented long vowels, speakers increased their use of durational information by making the ratio of long and short greater.

(11) Mean duration and ratio of vowels

		long vowel (ms)	short vowel (ms)	ratio(long : short)
fast speech	accented	119.194	72.104	1.65 : 1.00
	unaccented	117.285	60.820	1.93 : 1.00
slow speech	accented	176.988	100.167	1.77 : 1.00
	unaccented	201.718	83.205	2.42 : 1.00

5. Interaction of duration and pitch

The results from the two experiments show that the mean duration of long vowels was always longer than the mean duration of short vowels regardless of speech rate. However, the duration of vowels was susceptible to speech rate. The ratio of the duration of long vowels to short vowels varies considerably depending on presence of pitch-accent. In this section, I will examine the interaction of duration and pitch in Japanese vowels.

Note that although the ratio of the mean duration of long vowels to short vowels is greater in unaccented vowels, the actual duration of accented vowels was longer than the duration of unaccented vowels (see (11) in Section 4.2). It is widely accepted that stress affects the duration, intensity, and quality of vowels in English. There are, however, two opposing views on Japanese pitch-accent. These two contradicting positions are due to differences in the methodology used by the researchers.

On one hand, McCawley (1968) states, “The accented mora is characterized solely by its high pitch relative to the following mora; it does not differ in length or intensity from the other moras” (p.135); however, he does not provide any

acoustic evidence for his statement. Homma (1973, 1981) and Beckman (1982a, 1982b) also assert that pitch-accent does not have a significant effect on the duration of vowels. In addition, Larish's (1989) findings from a production experiment support Homma and Beckman's claim.

Homma's (1973, 1981) conclusion is based on measurements done in a single production experiment. The data were collected from a single participant who was a native speaker of the Kyoto dialect (which has pitch patterns distinct from the Tokyo dialect). The durations of accented and unaccented vowels within a bimoraic word were compared with one another; that is, the durations of V_1 and V_2 in CV_1CV_2, such as the words *hana* (HL) 'flower,' *hana* (HH) 'nose,' *kaki* (HL) 'fence,' *kaki* (HH) 'persimmon,' *kaki* (LH) 'vase,' and *kaki* (LHL[4]). Since the environments of the two vowels, V_1 and V_2, were different, the differences in the duration of vowels could have been affected by other factors as well as by pitch-accent. Moreover, material words were uttered in isolation. Therefore, as she admitted in her paper, phrase final lengthening might also have affected the duration of V_2.

The measurements made by Beckman (1982b) were similar to Homma's, although she used several native speakers of standard (Tokyo) Japanese. Beckman, too, compared the duration of CV_1 and CV_2 within two-syllable CV_1CV_2 words. While one could argue that it might be sufficient to simply compare the duration of moras, this would not allow us to accurately investigate the effect of pitch-accent on the duration of vowels. First, the locations of V_1 and V_2 within a word were different, which might have affected the duration of vowels. Second, the duration she measured included the preceding consonants, which, incidentally, were not all identical.

Larish (1989) also rejects the position that pitch-accent affects the duration of vowels. The experiments he conducted were well designed. However, the materials used to examine the effect of pitch-accent on duration were only two minimal pairs *k<u>o</u>ko* (HL) 'houses' vs. *k<u>o</u>ko* (LH) 'here' and *k<u>oo</u>koo* (HL) 'filial piety' vs. *k<u>oo</u>koo* (LH) 'high school.' These words were read in the carrier sentence *sono* ____ *desu* 'It's that _____' at a normal speech rate by six native speakers of the Tokyo dialect (three female and three male). Notice that each set of accented and unaccented vowels consists of a long and a short vowel. Larish's problem is that he combined the mean durations of both long and short vowels to compute the ratio of the duration of accented to unaccented vowels. Recall that speech rate influences the duration of long vowels. Larish observed that some participants were reading material sentences so slowly that he had to coach them to speed up their speech (pp.108-109). It is thus entirely possible that the duration of unaccented vowels was exaggerated. Therefore, combining the duration of long and short vowels could have cancelled out the effect of accent on the duration of vowels, and might cast serious doubt on his conclusions. Because he does not

[4] This HL sequence realized in the final vowel is considered a contour tone. The number of moras that this tone bears is still an unresolved issue.

provide us with the raw numbers used in his calculations, it is difficult to assess the accuracy of his findings.

On the other hand, several studies investigating the relationship between the pitch and duration of vowels have suggested that pitch-accent increases the duration of the vowel (Han 1962, Hoequist 1983, Kuriyagawa & Sawashima 1987).

Han (1962) compared the duration of accented vowels with the duration of unaccented vowels from sets of minimal pair words uttered "in various ways and by a number of native speakers" (p.104). That is, she compared the duration of vowels with contrasting accent, such as /a/ in *hashi* (HL) 'chopsticks' with /a/ in *hashi* (LH) 'bridge.' She found that higher pitch slightly increases intensity and duration.

Hoequist (1983) also suggested that pitch-accent has a significant effect on the duration of syllables. The materials used in Hoequist's study were words of various lengths. They were read in the carrier sentence *kinoo* _____ *ga kita* 'yesterday _____ arrived' at a speech rate that was comfortable for the participants. There were five participants who were native speakers of the Tokyo dialect.

Kuriyagawa and Sawashima (1987) also suggested that the duration of vowels increases significantly when they carry pitch-accent. They conducted a production experiment specifically designed to investigate the effect of pitch-accent on the duration of vowels. There was a single male participant who read material words in the two different carrier sentences, *tsugi-wa* _____ *daroo* 'the next will be _____' and *tsugi-wa* _____ *toiu* 'the next is said _____', at two different speech rates, fast and slow. They used four sets of minimal pairs contrasting pitch patterns but used only the high-back short vowel /u/ for analyses. They found that "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" (p.46).

After comparing the methodologies of previous studies, I have come to the conclusion that the latter group of studies more accurately investigated the effect of pitch-accent on the duration of Japanese vowels. The results from the present study also clearly show that pitch-accent affects the duration of vowels. Needless to say, the present experiments covered all five Japanese vowels and compared the duration of accented and unaccented vowels in identical environments for both long and short vowels. The data was collected from four native speakers of the Tokyo dialect.

I performed a repeated measures 2-way ANOVA to analyze the effect of pitch-accent on the duration of vowels. There was a significant interaction between vowel type and the factor 'experiment' ([$F(1,6) = 59.127$, $p = .0003$]). The conditions in the factor 'experiment' were 'accented vowel' and 'unaccented vowel'. Therefore, the significant interaction between vowel type (long vs. short) and experiment (accented vs. unaccented) indicates that pitch-accent affected the mean duration of long vowels and the mean duration of short vowels differently.

The measurements show that the existence of pitch-accent made the duration of vowels longer, and the absence of pitch-accent made the duration of long vowels excessively long in slow speech.

6. Conclusion

I have conducted two production experiments to investigate the phonetic properties of long vowels in standard Japanese. There are two types of long vowels in standard Japanese: accented and unaccented. I have examined each type of long vowels separately in different experiments and compared the results. There were three major findings from these experiments. First, when speakers produce accented long vowels, they employ both duration and F0; when they produce unaccented long vowels in which F0 is not available, they increase durational contrast between long and short vowels. The second finding is that pitch-accent affects the duration of vowels. It increases the duration of vowels. Lastly, we found that long vowels are more susceptible to speech rate. The duration of long vowels increases in slow speech, especially when they are unaccented. Minagawa et al. (2003) examines a spontaneous speech corpus and reports that the ratio of the duration of long vowels to short vowels increases in slow speech, which supports the present study.

In summary, native speakers of standard Japanese employ both duration and pitch unconsciously when they produce Japanese long vowels. How does this relate to the perception of the mora? Japanese vowels are often used to explain the notion of the mora as a timing unit. Vowel length is vulnerable to speech rate and to pitch-accent, and yet Japanese speakers perceive two moras in a long vowel. A couple of studies suggest (Nagano-Madsen 1990, Kozasa 2002) that F0 cues are more robust for the perception of the mora count in a vowel. Nagano-Madsen moved the pitch peak within a vowel, and then had listeners judge vowel length. She found that listeners had a tendency to perceive the vowel as a long vowel, although it had the same duration as a short vowel. However, when the pitch peak was at the end of the vowel, the vowel was perceived as short, even though the duration was the same as a long vowel. Kozasa manipulated the duration of vowels while maintaining the pitch contour, and then had Japanese speakers judge vowel length. In other words, the vowels Kozasa used had the duration of long vowels and the pitch contour of short vowels. The participants were not able to judge vowel length consistently. Responses were distributed evenly between long and short vowels.

The evidence is mounting, from the present study and others (such as Nagano-Madsen and Kozasa), that pitch-accent is a vital key to unlocking the mystery of the phonetic reality of the mora in Japanese vowels.

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Appendix A: Materials used for Experiment 1

Long vowel	**Short vowel**
/aa/	/a/
*sakki **aaru** to iimashita*	*sakki **aru** to iimashita*
'I said *aaru* while ago.'	'I said *aru* while ago.'
*watashi-wa **naasu** ga suki desu*	*watashi-wa **nasu** ga suki desu*
'I like nurses.'	'I like egg-plants.'
*sono **kaado** fuite*	*sono **kado** fuite*
'Please clean that card.'	'Please clean that corner.'
/ee/	/e/
*kore-wa **kee** desu*	*kore-wa **ke** desu*
'This is a *K*.'	'This is a letter *ke.*'
*kawaii **beeru** da ne*	*kawaii **beru** da ne*
'What a pretty veil!'	'What a cute bell!'
*watashi-ga **reeji**-ni iku*	*watashi-ga **reji**-ni iku*
'I will go there at midnight.'	'I will go to the cash register.'
*kyonen-mo **seeto**-wo tazuneta*	*kyonen-mo **Seto**-wo tazuneta*
'I visited a student last year, too.'	'I went to *Seto* last year, too.'
/ii/	/i/
*kono **biiru**-ga takai*	*kono **biru**-ga takai*
'This beer is expensive.'	'This building is high.'
*ano **chiizu**-ga hoshii*	*ano **chizu**-ga hoshii*
'I want that cheese.'	'I want that map.'
*kinou **niisan**-ga roku-to kotaeta*	*kinou **nisan**-ga roku-to kotaeta*
'My brother said six yesterday.'	'I said 2 times 3 was 6 yesterday.'
/oo/	/o/
*yamamichi-o **rooba**-ga oruiteiru*	*yamamichi-o **roba**-ga oruiteiru*
'An elderly lady is walking on the mountain path.'	'A donkey is walking on the mountain path.'
*kore-ga **dooki**-no sakura desu*	*kore-ga **doki**-no sakura desu*
'This is my former schoolmate.'	'This is earthen cherry blossoms.'
*sore-ga **kooi**-no araware desu*	*sore-ga **koi**-no araware desu*
'That is the affection.'	'That is the love.'
/uu/	/u/
*ima **kuuru** to iimashita*	*ima **kuru** to iimashita*
'I said *cool* now.'	'I said *to come* now.'
*kimi-o **Yuuki** to yoboo*	*kimi-o **Yuki** to yoboo*
'I will call you *Yuuki.*'	'I will call you *Yuki.*'
*ano hito-ga **Yuuka** san desu*	*ano hito-ga **Yuka** san desu*
'That is *Yuuka.*'	'That is *Yuka.*'
*Jyon-ga **suuri** ni yarareta*	*Jyon-ga **suri** ni yarareta*
'John failed in Math theory.'	'John got hit by a pickpocket.'

Appendix B: Materials used for Experiment 2

Long vowel		**Short vowel**	
/aa/		/a/	
akaari	'red ants'	*akari*	'light'
haaku	'to grasp'	*haku*	'to put on (shoes)'
jaaku	'evil'	*shaku*	'a unit of length'
kaaki-iro	'khaki'	*kaki-iro*	'color of persimmon'
suupaamaaketto	'supermarket'		
/ee/		/e/	
kareeraisu	'rice curry'	*kareru*	'to wither'
seekoo	'success'	*sekoo*	'construction'
keekoo	'tendency'		
meekyappu	'makeup'		
toreenaa	'sweatshirt'		
/ii/		/i/	
hiikime	'with favor'	*hikime*	'time to withdraw'
keshiin	'post mark'	*keshin*	'to transform'
niigata	'*Niigata* prefecture'	*nigata*	'the type 2'
shiiku	'to breed'	*shiku*	'to spread'
okiishi	'mile stone'		
sukiijoo	'ski slope'		
/oo/			
hoosoo	'broadcast'	*hosoo*	'pavement'
kooritsu	'efficiency'	*koritsu*	'isolation'
kooshi	'Confucius'	*koshi*	'waist'
moomoku	'blind'	*momokuri*	'chestnut & peach'
sookai	'general meeting'	*sokai*	'evacuation'
tookai	'a district name'	*tokai*	'big city'
/uu/		/u/	
fuuchoo	'trend'	*fuchoo*	'bad condition'
kuuchi	'empty lot'	*kuchi*	'mouth'
suushiki	'math formula'		
tsuushinhanbai	'mail order'		
yuukai	'kidnap'		