



Elasticity of Prepausal Vowels in Japanese Rhythmic Structure

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Abstract

This study explores the effect of accent on duration from the viewpoint of Japanese rhythmic structure. Phonetic experiments reveal that prepausal vowel duration significantly and consistently varies by more than 40% depending on accent and position. This great degree of durational variation restricted to prepausal position suggests that the prepausal position is free from the constraints of mora timing in Japanese.

1. Introduction

Previous studies have roughly agreed that there is no marked correspondence between accent and duration in Japanese (cf. Kaiki & Takeda & Sagisaka, 1992; Sakaguchi & Yoshida, 1999). By contrast, Mori (2001; 2003) has found a consistent and significant effect of an accentual fall on the duration of prepausal vowels in isolated words and phrases. The present study extends Mori's studies through a similar analysis of prepausal vowels in a sentence-final context. It further addresses what this correlation between accent and duration suggests in relation to Japanese rhythmic structure.

2. Experiment 1

2.1. Subjects and materials

Subjects were five middle-aged females, all native speakers of Tokyo (standard) Japanese.

Test sentences used in Experiment 1 were all real Japanese declarative sentences presented in Table 1. In order to examine the effect of accent on the duration of sentence-final vowels without the effect of segmental differences, the vowel phrases (VPs) in each set were selected such that they had the same segmental make-up but different accent patterns (e.g. *hareru* vs. *hare'ru*). Also, in the *hareru*- and *hareta*-sets, the subject noun phrases (NPs) differed in whether they had an accentual fall or not (e.g. *kaoga* vs. *ka'taga*).

2.2. Procedure

Each test sentence was written in Japanese orthography (*kanji* and *kana*), one sentence per card. The 12 test sentences were then mixed with 20 other test sentences or phrases that were used for other experiments.

Each subject was presented a test sentence one at a time in a random order and asked to read the sentence naturally at a tempo comfortable to herself without placing focus or emphasis on any

particular constituent of the test sentence. Every time the subject finished reading all the sentences, the cards were randomized and presented to the subject, for a total of seven different randomizations.

2.3. Results & discussion

Table 1 presents the mean duration and mean f_0 of sentence-final vowels for each test sentence. We can see that the sentence-final vowel is longer when the verb (phrase) has no accentual fall than when it is initially- or medially-accented, that is, when it has an accentual fall. The difference in duration for each set is on average 36.1 ms. The ratio of the longer vowel duration to the shorter one is on average 1.43:1, ranging from 1.31:1 to 1.70:1.

Table 1. Duration(ms) and SD (standard deviation), and mean f_0 (Hz) and SD (in parentheses), of sentence-final vowels in each test sentence. "D" indicates the difference in duration of each sentence-final vowel from the shortest vowel for each set.

Test sentence	Duration (ms)	SD	D	Mean f_0 (SD)
kao ga hareru	129.9	22.2	34.6	203.7(28.9)
ka'ta ga hareru	124.8	27.8	29.5	175.8(25.2)
kao ga hare'ru	100.6	26.4		156.3(20.4)
so'ra ga hare'ru	95.3	26.9		147.9(27.0)
kao ga hareta	120.4	28.7	36.4	206.1(29.8)
ka'ta ga hareta	113.9	30.2	29.9	175.3(22.4)
kao ga ha'reta	84.0	26.6		148.8(14.5)
so'ra ga ha'reta	85.5	26.7		143.4(25.5)
kju'uri o tukeru	130.2	28.9	38.1	174.3(19.8)
kju'uri o tuke'ru	92.1	21.2		149.1(28.1)
kju'uri o tuketa	116.9	26.6	48.3	177.6(20.8)
kju'uri o tu'keta	68.6	19.0		141.2(22.6)

Two-way repeated measures analyses of variance (RM-ANOVAs)¹ were run on the duration of sentence-final vowels for *hareru*-set and *hareta*-set, with the presence or absence of an accentual fall in the NP and that in the VP as two fixed factors. They showed a significant effect of the presence or absence of an accentual fall in the VP [*hareru*-set: $F(1,4)=31.9$, $p<0.01$; *hareta*-set: $F(1,4)=15.2$, $p<0.05$]. There was no significant effect of the presence/absence of an accentual fall in the NP nor any significant interaction between the two factors.

In *tukeru*-set and *tuketa*-set, one-way RM-ANOVAs with the presence or absence of an accentual fall in the VP as a fixed factor showed the effect to be significant [*tukeru*-set: $F(1,4)=27.8$, $p<0.01$; *tuketa*-set: $F(1,4)=41.4$, $p<0.01$].

These results make it clear that the final vowel duration in a

sentence-final VP is significantly and consistently affected by the presence or absence of an accentual fall in the VP, but not by that of the preceding NP. In addition, it turns out that initially-accented VPs (e.g. *ha'reta*, *tu'keta*) do not differ in their effect on the duration of sentence-final vowels from medially-accented verbs (e.g. *hare'ru*, *take'ru*). This result confirms that the decisive factor involved in the phenomenon is not the actual position of an accentual nucleus, but the presence or absence of an accentual fall in the VP.

3. Experiment 2

This experiment was performed to examine whether the effect of an accentual fall on duration was specific to sentence-final position or it was applicable to any prepausal position, by using long test sentences with intervening pauses. It also attempted to clarify the factors involved in this correlation between an accentual fall and final vowel duration.

3.1. Subjects and materials

Subjects were six middle-aged females, all native speakers of Tokyo (standard) Japanese. Three of them had participated in Experiment 1.

Test sentences were seven sets of 26 real Japanese declarative sentences with intervening pauses exemplified below: (| denotes boundaries in which punctuation marks were inserted.)

[*sake*-set]

sono tugitateno sakega | totemo oisiso'oni mi'eta
 "The *sake* that has just been poured looked very delicious."
sono toretateno sa'kega | totemo oisiso'oni mi'eta
 "The salmon that has just been caught looked very delicious."
ka'rega i'ma itibaN hos'i'nowa | sono tugitateno sakeda
 "What he wants most now is the *sake* that has just been poured."
ka'rega i'ma itibaN hos'i'nowa | sono toretateno sa'keda
 "What he wants most now is the salmon that has just been caught."

In each test sentence, a pause was inserted into a major phrasal boundary, which was marked by a punctuation mark. In each set of test sentences, target words (e.g. *sake* vs. *sa'ke*, *siro* vs. *si'ro*) differing in the presence/absence of an accentual fall occurred in prepausal phrases. Thus, in phrase-final or sentence-final position, each pair of test sentences contained target nouns that were the same in segmental make-up but different in the presence or absence of an accentual fall. In addition, each set of test sentences was constructed so as to have the same or a similar segmental structure as much as possible².

The recording and analysis procedures and the measurement techniques were the same as those in Experiment 1.

3.2. Results & discussion

A two-way RM-ANOVA was run for each set on the duration of prepausal vowels with accent (the presence/absence of an

accentual fall in the prepausal NP) and position (sentence-final/non-sentence-final position) as two fixed factors. It showed significant main effects of accent and position ($p < 0.01$) in all the sets. There was a significant interaction ($p < 0.05$) between accent and position in *atusa-*, *siro-*, and *sake2-*sets. Another two-way RM-ANOVA was performed on the durations of prepausal vowels across sets. It showed highly significant effects of accent and position [Accent: $F(1,29)=115.3$, $p < 0.0001$; Position: $F(1,29)=157.8$, $p < 0.0001$] and a significant interaction between the two effects [$F(1,29)=47.0$, $p < 0.0001$].

In sentence-final position (SF), the presence or absence of an accentual fall in the prepausal NP results in a mean durational difference in prepausal vowels of 39.5ms. The ratio of the longer vowel to the shorter one for each set is on average 1.42:1, ranging from 1.36:1 to 1.57:1.

In non-sentence-final position (NonSF), however, the accent-related difference is only 18.1ms. The mean ratio between the longer and shorter vowels is as small as 1.13:1. Thus, the effect of accent is attenuated and weaker in NonSF than in SF.

Figure 1 shows the mean duration of prepausal vowel /a/, /e/, or /o/ for each condition of accent and position for all test sets. As can be seen in the figure, the order of prepausal vowel duration from the longest to the shortest is NonSF-NoA>NonSF-A>SF-NoA>SF-A in all the sets. A one-way RM-ANOVA was run on the durations of prepausal vowels in all the sets with the four conditions of accent and position as a fixed factor. It showed that the difference between every adjacent pair of durations is significant at the $p < 0.0001$ level.

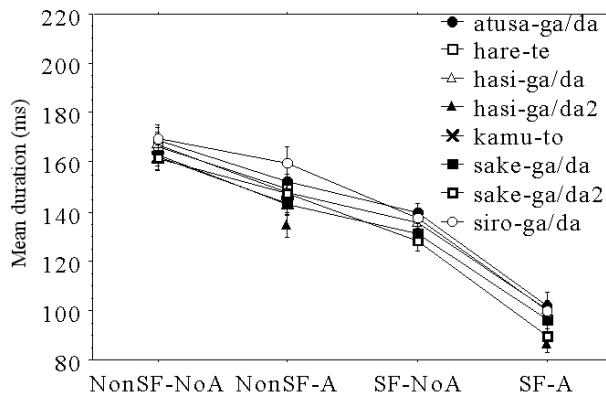


Figure 1. Mean duration (ms) of prepausal vowels for each test set in the following four conditions:

NonSF-NoA: non-sentence-final position, with no accentual fall
 NonSF-A: non-sentence-final position, with an accentual fall
 SF-NoA: sentence-final position, with no accentual fall
 SF-A: sentence-final position, with an accentual fall

The maximum ratio of durational difference resulting from the effects of accent and position is obtained for each set by dividing the longest prepausal vowel duration in NonSF-NoA by the shortest in SF-A. The average ratio is as large as 1.74:1, ranging from 1.66:1 to 1.93:1.

In sum, these results make it clear that, in long declarative

sentences with intervening pauses, whether a prepausal phrase has an accentual pitch fall or not has a significant and consistent effect on the duration of sentence-final vowels to an extent similar to that found in short declarative sentences or isolated words/phrases (Mori, 2001). In addition, it is found that the duration of prepausal vowels is affected by position (SF or NonSF), and that the accentual effect is attenuated in NonSF. Taken together, the effects of accent and position result in more than 70% durational variation in prepausal vowels.

4. General discussion

4.1. Factors involved in the durational variation

The first question we have to ask is why there is such a strong effect of an accentual pitch fall on the duration of prepausal vowels in declarative sentences as well as in isolated words and phrases. The most plausible account may be a hypothesis that there is a physiological factor that causes a low-pitched prepausal vowel to end earlier than a high-pitched one. As is obvious in Fig. 2, the f_0 of prepausal vowels is significantly lower when prepausal phrases have an accentual pitch fall than when they do not. In SF, in particular, the mean f_0 of prepausal vowels drops below around 150Hz (in female voice). The same phenomenon is observed in the mean f_0 of prepausal vowels in short declarative sentences presented in Table 1. Introspective observation suggests that, when pitch falls rather abruptly before a pause, a speaker seems to have more difficulty in drawing a prepausal vowel than s/he would when pitch does not drop. Thus, s/he tends to end up with a shorter final vowel.

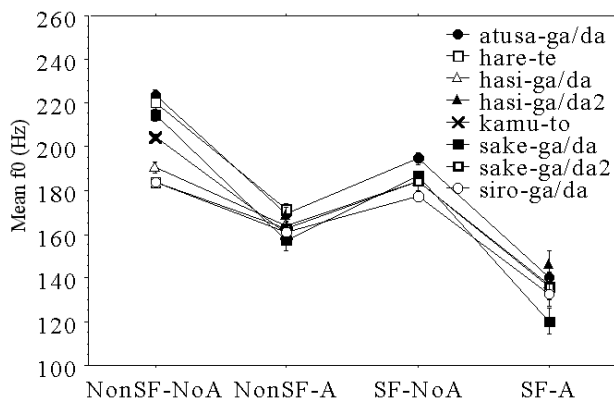


Figure 2. Mean f_0 (Hz) of prepausal vowels for each test set in four conditions of accent and position both in SF and NonSF

The next question raised from this account is why this accentual effect is attenuated in NonSF and the prepausal vowel duration is significantly longer in NonSF than in SF. It is hypothesized that there is some linguistic factor that works towards making a prepausal vowel relatively long when a sentence does not finish. Moreover, there is a possibility that the longer prepausal vowel in NonSF may have a function of signaling the incompleteness of an utterance, that is, the speaker's intention to continue his/her utterance.

By contrast, the prosodic pattern of shorter vowel duration associated with an accentual pitch fall observed in SF appears to constitute one of the typical speaking styles towards the end of an utterance in Japanese. Considering the fact that in various languages final lengthening has been more markedly observed in utterance-final position than in any other prosodic boundaries (cf. Cooper & Danly, 1981; Berkovits, 1993), it can be said that this shorter durational pattern combined with lowering pitch that occurs at the end of an utterance is characteristic of Japanese.

4.2. Durational control of prepausal vowels

It should be noted here that prepausal vowels do not vary irregularly (Fig. 1). Instead, they show a similar temporal behavior across both sentences and speakers depending on accentual and positional conditions, suggesting some systematic durational patterns. ANOVAs were performed on the duration of prepausal vowels with test set as a fixed factor for each condition of NonSF-NoA, NonSF-A, SF-NoA, and SF-A. They showed no significant effect in any condition. The test sets differ not only in segmental structure but also in the presence or absence of an accentual fall in the preceding non-prepausal phrase. Thus, the statistical results have demonstrated that prepausal vowel duration is not significantly affected by the segmental structure of test sentences or by the presence or absence of an accentual fall in the preceding non-prepausal phrase. The crucial factors involved in the durational variation are the presence/ absence of an accentual fall in the prepausal phrase and sentence-final/non-sentence-final position. In addition, the prepausal vowel durations across sets were statistically different from one another; the order of the vowel duration from the longest to the shortest is NonSF-NoA > NonSF-A > SF-NoA > SF-A.

From all the above findings, a proposal is made that the prepausal vowel duration is differentiated into four relative levels: "Extra-long" for NonSF-NoA, "Long" for NonSF-A, "Medium" for SF-NoA, and "Short" for SF-A. These distinctions of prepausal vowel duration lead to Table 2 that predicts the duration of a prepausal vowel in a declarative sentence presumably without any intentional focus or emphasis by speakers.

Table 2. Duration control of prepausal vowels in declarative sentences "A.F." denotes an accentual fall.

A.F. in the preceding phrase	A.F. in the prepausal phrase	Duration of prepausal vowel in NonSF	Duration of prepausal vowel in SF
absent	absent	Extra-long	Medium
present	absent	Extra-long	Medium
absent	present	Long	Short
present	present	Long	Short

It should be recalled that what this control model predicts is a relative level of duration of prepausal vowels under a certain condition of accent and position. Needless to say, there is a

great interspeaker variation in the realization of duration of any segment that constitutes their speech. Thus, the relative levels presented in Table 2 are valid within the utterances produced by a single speaker, or the mean durations of utterances produced by a certain group of people.

4.3. Elastic prepausal vowels in Japanese rhythmic structure

All the experimental data reveal that Japanese speakers are able to considerably lengthen or shorten vowels immediately before pauses depending on the accentual and positional status of prepausal phrases, even though the segmental structures of the prepausal phrases are the same or almost the same. This finding indicates that final vowels do not attempt to durationally compensate for the preceding consonant to keep moras roughly equal in duration. Thus, it can be said that prepausal vowels are not subject to temporal compensation within or across moras or in larger units of production such as words claimed by the weaker version of mora-timing hypothesis (cf. Sagisaka et al, 1984; Campbell, 1999; Port, Dalby & O'Dell, 1987; Han, 1994).

It is also quite clear from the current study that the presence or absence of an accentual fall leads to a large durational difference in prepausal vowels, while it has no equivalent effect on the duration of the other non-prepausal constituents. This indicates that claims that deny any large durational difference related to accent (cf. 1) are not true for prepausal vowels.

Thus, it seems reasonable to conclude that prepausal vowels are free from the mora-timing constraints and that they are outside the domain of mora timing, which makes this great elasticity of prepausal vowels possible.

Another aspect suggested from the elasticity of prepausal vowels is that the phonological constraint on vowel length weakens in the prepausal position. In Japanese the length of a vowel is a distinctive feature that is recognized by Japanese speakers as 'making different words'. Despite this constraint, durational variation of over 50% is observed among vowels in similar segmental contexts in the present study. This great degree of durational variability suggests that the phonological contrast between short and long vowels is weakened in prepausal position.

Finally, the durational variability of prepausal vowels can successfully account for why in daily Japanese conversation, substantial shortening and lengthening of final vowels are frequently observed in prepausal position (e.g. /sa'a iko'o/ → /sa'a iko/ "OK, let's go" ; /jorosiku/ → /jorosikuu/ "I am glad to make your acquaintance").

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¹ In order to factor out interspeaker variation, a repeated measures analysis of variance (RM-ANOVA) was used throughout this paper whenever tokens were repeatedly obtained from more than one speaker under varying conditions. Segmental durations were first averaged over repeated productions of the same sentence by the same speaker. Then, with RM-ANOVAs, these durations under different conditions were compared within each speaker to examine if the varying conditions resulted in any significant difference.

² This experiment has made a comparison between the duration of prepausal vowels in SF and NonSF. Although the difference was statistically significant, there was a possibility that the change of the preceding vowel from /g/ to /d/ may have contributed to the difference in duration. However, the mean duration of prepausal vowels in nonsense word utterances composed of the last two syllables before a pause for each set showed no significant difference in the duration of the prepausal /a/ except for *siro*-set ($p < 0.05$). In addition, the absolute durational difference for each set ranged only from 1ms to 7ms.