INTERACTION BETWEEN RHYTHMIC STRUCTURE AND PREBOUNDARY LENGTHENING IN JAPANESE

Jungyun Seo[1], Sahyang Kim[2], Haruo Kubozono[3], and Taehong Cho[1]

Hanyang Institute for Phonetics and Cognitive Sciences of Language (HIPCS), Hanyang University[1], Hongik University[2], National Institute for Japanese Language and Linguistics[3]
jungyunlseo@gmail.com, sahyang@hongik.ac.kr, kubozono@ninjal.ac.jp, tcho@hanyang.ac.kr

ABSTRACT

This study examines preboundary lengthening (henceforth PBL) in Japanese, focusing on how its rhythmic characteristics influence the low-level temporal realization of PBL. Disyllabic words with various moraic structures and pitch accent patterns were produced in the phrase-final vs. –medial positions. Results show a general progressive lengthening as the segments get closer to the boundary. The domain of PBL appears to be better accounted for by the syllable structure as PBL is robust at the final rhyme regardless of the moraic structure within a syllable. The moraic structure, however, does influence the distribution of PBL by showing some attraction of PBL towards the word-medial moraic consonant. In addition, the words with initial pitch accent show much less lengthening at the final rhyme than those without pitch accent. Taken together, the results suggest that Japanese PBL is not only governed by the physical temporal constraints, but further modulated by language-specific rhythmic structure.

Keywords: Preboundary lengthening, Japanese, mora, pitch accent

1. INTRODUCTION

Preboundary lengthening (PBL), also known as phrase-final lengthening, refers to a prosodically-conditioned lengthening before a prosodic boundary which serves a delimitative function of prosodic grouping [5,7,20,22]. PBL is generally assumed to be a universally applicable low-level effect, as virtually every language shows some degree of PBL [5]. The phonetic implementation of PBL, however, is known to vary across languages according to language specific linguistic structures [5,9,11,16]. The purpose of the present study is to explore the influence of the linguistic structures on PBL in Japanese by focusing on the effects of the moraic structure and the pitch accent system. Specific questions to be addressed are whether PBL in Japanese is understood as a phonetically-grounded progressive effect as has been observed in the literature; how the moraic structure influences the temporal distribution of PBL, and how PBL may be modified by the lexical pitch accent in Japanese. To answer these questions, some theoretical issues are considered as discussed below.

First, PBL has been considered to be gradient in nature. So in some languages like Hebrew and Finnish, PBL effect was strongest at the boundary and it progressively decreases as a segment gets farther away from the boundary [1,16]. This progressive process has been reported in acoustic terms, but it may be understood in gestural terms. (For example, in the π-gesture theory [2, 3,9,12], a non-tract variable 'prosodic' gesture is assumed to regulate the temporal realization of articulatory gestures at the vicinity of the prosodic juncture, with its effect being gradually attenuating as segments get farther away from the prosodic juncture.) However, the scope of PBL (i.e., how far the effect may spread to the left) may be determined in a language-specific way (e.g., [4,5,9,20]). For example, in Korean the scope of PBL may be generally limited to the last syllable [4], whereas the PBL effect in Hebrew and Finnish may spread to the penultimate syllable in a disyllabic word [1,16]. But the scope of PBL may also be influenced by the phonetic content, such that PBL may spread more to the left if the final syllable is composed of intrinsically short segments (cf. [4,9]). The present study explores to what extent Japanese follows the general progress effect, how far PBL may spread leftwards, and how the effect may be conditioned by the phonetic content, as reflected in the number of segments and moras (e.g., CVN.CVN vs. CV.CV).

Second, PBL has been discussed in terms of the phonological unit such as a rime or a syllable on which PBL operates. In English, PBL is generally assumed to operate primarily on the rime [20] (cf. [22]), although there is no clear-cut division between the rime and the onset since the onset often undergoes a small but significant PBL effect [3,10]. The issue of the relationship between PBL and phonological units leads to a question as to how PBL may be influenced by the moraic structure in Japanese as the mora is considered to be an important unit for both speech production and perception [13,14,19]. The present study therefore examines whether and how the mora may serve as a unit for PBL.

Finally, PBL is known to interact with the prominence system of a given language. For example, PBL may be attracted to a non-final stressed syllable in English, Greek and Finnish [9,16,20]. On the other hand, a language which does not employ a lexical stress system such as Korean shows no such interaction between PBL and prominence [6]. A question then arises as to how the PBL effect may be influenced by the prominence system in Japanese which employs a lexical pitch accent [8,21]. If the attraction of PBL to the lexical-level prominence (as observed in other languages) is universally applicable, we might find a similar attraction effect in Japanese. More broadly, addressing this issue will inform how the low-level PBL interacts with the higher-order prominence system within and across languages.

2. METHOD

2.1. Participants and materials

Fourteen native speakers of Tokyo Japanese (7 females and 7 males, M_{age}= 24.2 years, range 19 – 29 years) who have lived in Korea for less than 3 years participated in the experiment. Eight disyllabic test words were used as in Table 1. Disyllabic words varied in the number of moras and the pitch accent pattern (unaccented vs. initially accented). To control for the sentence-level prominence effect, the test words were produced with and without contrastive focus. As shown in Table 2, the target words were embedded in carrier sentences, which consist of a question-answer pair: the question (prompt) sentence ('A') and a target-bearing sentence as an answer ('B'). The target word was placed in a phrase final position (IP) or in a phrase-medial position (Wd). It was either lexically focused (with lexical contrast between the target word and a word in the question sentence, TAKA vs. SAKE) or unfocused (with lexical contrast on the preceding word, SONO vs. KONO).

2.2. Procedure

In the experiment, the participants were presented with each mini dialogue on a computer screen, and heard a prompt question (pre-recorded by a female native speaker of Tokyo Japanese). Then the participants read the target-bearing sentence in response to the (auditory and visually presented) question (prompt) sentence. The data were recorded in a soundproof booth with a Tascam HP-D2 digital recorder and a SHURE KSN44 microphone at a sampling rate of 44kHz. In total, 2688 tokens were collected (4 mora structure x 2 pitch accent x 2 focus x 2 boundary x 6 repetitions x14 speakers), but 2472 tokens were used to report in this paper (excluding tokens that deviated from the intended renditions as agreed by authors).

2.3. Measurements and statistical analyses

We measured the duration of each segment in the target words by using Praat as shown in Fig. 1. The measurements were made by comparing the waveform and the spectrogram, and the end of the vowel was defined as the end of F2. VOTs for Cs were generally very short with no considerable change due to Boundary, so they were included in the vowel duration. The durational measures therefore included C (closure duration), V (VOT plus vowel duration) and N (nasal murmur). The absolute measure indicates the durational increase from IP-medial to IP-final position for each segment in the test word and it will be compared with those in relational terms (in %-increase), expressed as percent proportion of the PBL increase relative to the IP-medial condition.

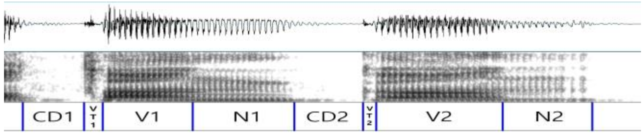
Table 1: An illustration of target words

	Structure	CV.CV (2σ,2μ)	CVN.CV (2σ,3μ)	CV.CVN (2σ,3μ)	CVN.CVN (2σ,4μ)
Pitch accent patterns	Unaccented	鷹 TAKA	炭化 TANKA	多感 TAKAN	短観 TANKAN
	Initially accented	タカ TA'KA	タンカ TA'NKA	タカン TA'KAN	タンカン TA'NKAN

Table 2: An illustration of example sentences

Boundary	Focus	Example sentences
IP – final	FOC	A. 今度もその**酒**、試しに使ってみる？ B. いいえ、今度はその**鷹**、試しに使ってみる。 A. Do you try and use that **SAKE** this time again? B. No, this time I try and use that **TAKA**.
	NoFOC	A.今度も**この**酒、試しに使ってみる？ B. いいえ、今度は**その**鷹、試しに使ってみる。 A. Do you try and use **THIS** sake this time again? B. No, this time I try and use **THAT** taka.
Wd - final (IP - medial)	FOC	A.これは、その**酒**と一緒に置きますか？ B. いいえ、今度はその**鷹**と一緒に置きます。 A. Do you put this with that **SAKE**? B. No, this time I put it with that **TAKA.**。
	NoFOC	A.これは、**この**鷹と一緒に置きますか？ B. いいえ、今度は**その**鷹と一緒に置きます。 A. Do you put this with **THIS** taka? B. No, this time I put it with **THAT** taka.

Figure 1: An example of segmentation and labelling with a CVN.CVN word.



A series of Repeated Measured Analyses of Variance (RM ANOVA) were conducted, by using IBM SPSS Statistics 24. Statistical analyses were done separately for each target word type: CV.CV, CV.CVN, CVN.CV, CVN.CVN. Three factors (Boundary, Pitch Accent, Focus) were included in RM ANOVAs. As briefly mentioned above, we included the Focus factors, given a possibility that Pitch Accent may interact with Focus, but the result of RM ANOVA indicated that there was no interaction between Pitch Accent and Focus across all measures. We will therefore not report the results regarding the focus effect, and limit our report to the directly relevant results to the purposes of our study.

3. RESULTS AND DISCUSSOIN

3.1. Main effects of Boundary on PBL

Results of RM ANOVAs with respect to the boundary effects are summarized in Table 3 and Fig. 2.

$C_1V_1C_2V_2$ and $C_1V_1C_2V_2N_2$: All segments except C_1 showed main effects of PBL in both ms and %-increase (Fig 2a-b). The PBL effect increased as the segments became closer to the boundary, showing a generally progressive PBL effect. Even when N_2 (moraic nasal) was added at the end (Fig.2b), all segments except C1 showed main effects of PBL in both ms and %-increase. These results show that the effect spreads to the first vowel regardless of whether the moraic nasal occurs at the end, indicating the PBL effect independent of the moraic structure or the number of moras. Notice that the final N_2 in ms (the upper panel of Fig.2b) was not as lengthened as the final V_2 in $C_1V_1C_2V_2$, which is presumably because V is more subject to lengthening than N. But as shown in the lower panel in Fig. 2b, the relative measure (%-increase) revealed a consistent progressive lengthening effect. It is also noteworthy that the PBL effect on V_2 in CVCV (Fig.2a) was far greater than any single effect of either V_2 or N_2 in CVCVN (Fig.2b). It appears that the single effect on V2 in the open syllable is comparable to the combined effect of V2 and N2 in the closed syllable, indicating that PBL operates primarily on the final rime, rather than on the individual segments or moras.

$C_1V_1N_1C_2V_2$ and $C_1V_1N_1C_2V_2N_2$: Again all the segments except C_1 showed PBL in CVN.CV (Fig. 2c), but in CVN.CVN, the PBL effect spread to the first N rather than to the first V. This difference indicates that the scope of PBL is not strictly determined by the syllable count (up to the first vowel as in Fig. 2a-c), but is influenced by the phonetic content—i.e., the effect does not spread to the first vowel when there are two more segments before the boundary as in CVN.CVN. Another interesting pattern is that when there is a moraic nasal (N_1) in the middle, the PBL effect on the following C2 is boosted up. As shown in Fig.2c-d, in both CVN.CV and CVN.CVN, the PBL effect on C_2 is larger than in CV.CV and CV.CVN. The effect becomes clearer in %-increase, as highlighted in Fig. 2c-d.

Figure 2: The magnitude of increase from IP-medial to IP-final position for each segment pooled across accent types (or differences between the two position) in absolute terms (in ms, upper panels), and in relative terms (%-increase, lower panels). (*, p<.05; **, p<.01; ***, p<.001).

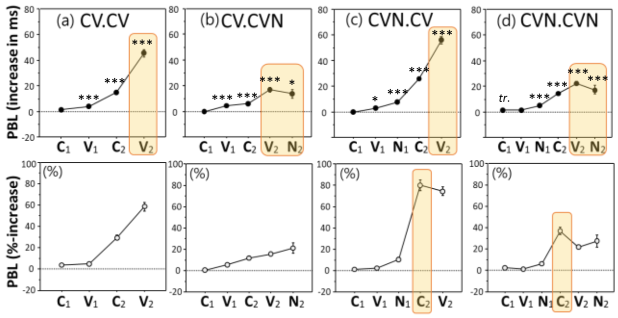


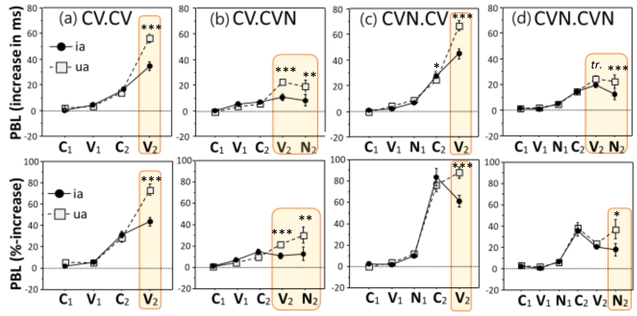
Table 3: A summary of the results of RM ANOVA with regard to the main effect of Boundary (B) and the interaction between Boundary and Pitch Accent (B x PA). ('*' refers to p<.05; '**', p<.01; '***', p<.001; '*tr*', p<0.06).

	C1	V1	C2	V2		
B		F=52.82***	F=64.73***	F=104.31***		
B x PA				F=38.91***		
	C1	V1	C2	V2	N2	
B		F=58.04***	F=28.66***	F=28.89***	F=6.35*	
B x PA				F=49.25***	F=14.22**	
	C1	V1	N1	C2	V2	
B		F=11.76**	F=26.25***	F=286.1***	F=117.66***	
B x PA				F=5.2*	F=61.41***	
	C1	V1	N1	C2	V2	N2
B			F=22.19***	F=74.66***	F=64.15***	F=8.19*
B x PA	F=7.81*				F=4.08 tr.	F=4.76*

3.2. Interaction between Boundary and Pitch accent

The results of RM ANOVAs with respect to Boundary x Pitch Accent are summarized in Fig. 3 and Table 3. All four word types showed an interaction between Boundary and Pitch Accent on the segments that form the final rime: V_2 in [...V_2]; V_2 and N_2 in [...V_2N_2]. As shown in Fig.3, the general pattern is that the lengthening effect on final rime is suppressed in the initially pitch-accented word. Notice that the suppression effect was found on the final segment V_2 in the open syllable, and on both V_2 and N_2 in the closed syllable, although the effect on V_2 was not significant in CVN.CVN.

Figure 3: The magnitude of increase from IP-medial to IP-final position as a function of accent type in absolute terms (in ms, upper panels) and relative terms (%-increase, lower panels). Solid lines with filled circles refer to initially accented words ('ia'), and dotted lines with empty squares unaccented words ('ua'). (*, p<.05; **, p<.01; ***, p<.001).



4. SUMMARY AND GENERAL DISCUSSION

A basic finding of the present study is that Japanese shows a progressive PBL effect in a gradient fashion—i.e., the PBL effect increases gradually as the segment becomes closer to the boundary. The progressive PBL effect was found across all four disyllabic words with a different number of moras: CV.CV, CV.CVN, CVN.CV and CVN.CVN (where 'V' and 'N' are moras). Considering the first three types of words (except for CVN.CVN), PBL effects spreads leftwards up to the first vowel in the disyllabic word, regardless of the number of segments or the number of moras. But the distribution of PBL in the last word CVN.CVN indicates that the scope is not entirely fixed to the first vowel, but is constrained by the phonetic content: When there are too many segments as in CVN.CVN, the PBL effect is confined to the first N, not reaching the first vowel.

The results also showed some evidence about the phonological unit on which PBL operates in Japanese. Recall that the PBL effect on V_2 in the open syllable (CV.C<u>V</u> or CVN.C<u>V</u>) was far greater than that of either V_2 or N_2 in the closed syllable (CV.C<u>VN</u> or CVNC<u>VN</u>), and the effect on V_2 in the open syllable was comparable to a combined effect of V_2 and N_2 in the closed syllable. This suggests that the final moraic N does not serve as an independent PBL-bearing unit, but that PBL operates primarily on the rime, despite the fact that moras in Japanese have been considered as the basic units for speech production and perception [13,14,19]. In other words, as far as the final syllable is concerned, the distribution of PBL appears to be better accounted for by the syllable structure rather than the moraic structure, which is consistent with the view that the syllable also plays a phonological role in Japanese (e.g., the syllable serves as a pitch accent bearing unit) [15].

The results, however, suggest that the distribution of PBL is not entirely independent from the moraic structure. We observed some evidence for interactions between PBL and the moraic structure, especially when a moraic nasal (N) occurs in the middle of the word, forming a consonant cluster as in CV<u>N.C</u>V and CV<u>N.C</u>VN. When there was a moraic nasal in the middle, the PBL effect on the following consonant (C_2) was far greater that the effect on C_2 with no preceding N as in CV.<u>C</u>V or CV.<u>C</u>VN. The robust boosting-up effect of the moraic N_2 on C_2 adds some discontinuity to the gradual progressive PBL effect which is clearly shown in the relative (%-increase) measure (see Fig. 2c-d). This therefore demonstrates that the moraic N in the consonant cluster does influence the distribution of PBL in some significant ways, but it is not entirely clear why the augmented PBL effect was not found on the moraic nasal itself but on the following oral consonant. While this issue remains to be further elucidated, we can offer one possible explanation in connection with the phonetic nature of the NC cluster in Japanese.

In Japanese, a nasal consonant N in the NC cluster becomes homorganic with the following C (cf. [4,9]). Given that C in NC is [k] in this study, the actual phonetic form of N would be [ŋ]. Crucially, the nasal [ŋ] in the homorganic [ŋk] cluster may be at least partially devoiced due to a possible coarticulatory devoicing effect coming from the voiceless [k] [21]. Thus, the measured duration of the voiceless closure for C may contain the devoiced nasal component. It is therefore possible that the lengthened C-duration reflects the PBL effect on both the devoiced [ŋ] and [k]. It is possible that the attraction of PBL to the nasal is reflected on C duration, which may enhance the moraic representation to be distinct from the following moraic vowel that also undergoes a substantial PBL effect. This is somewhat reminiscent of the case of Finnish in which vowel quantity interacts with PBL constrained by the maintenance of paradigmatic contrast in the distribution of long *vs.* short vowels [16].

Finally, the findings with respect to the interaction between PBL and Pitch Accent illuminates the nature of how PBL may be constrained by the prominence system in Japanese. We observed that when the initial syllable was pitch-accented, the PBL effect on the *final* rhyme was suppressed in all four disyllabic words. This appears to run counter to what was found in English in which the non-initial stressed syllable is directly affected by the boundary strength, undergoing PBL. The restriction on PBL in the final rime in Japanese is presumably due to the possibility that too much of lengthening on the final syllable would make the final syllable too salient, as compared with the pitch-accented initial syllable. An unrestricted PBL in the final syllable would therefore have blurred the syntagmatic relationship in the prominence distribution between the accented initial syllable and the final syllable. Seen from a different angle, the suppression of PBL in the final rime in the initially-accented condition can be considered as an indirect way of enhancing the prominence of the pitch accented syllable: the shortening of the final rime would result in the percept of relatively lengthened initial syllable, making the pitch accented syllable salient. It is then reasonable to assume that the cross-linguistic difference (i.e., the suppression of PBL in the final rime in Japanese and the expansion of PBL in the stressed non-final syllable) can be taken to be driven by the same principle - i.e., the maintenance of some kind of syntagmatic contrast in the prominence distribution in conjunction with the distribution of boundary-related PBL.

In conclusion, Japanese shows a general progressive PBL effect in line with cross-linguistic patterns, and the PBL effect spreads up to the first rime in disyllable words largely independently of the mora count, although the phonetic content (e.g., the number of segments) appears how far within the first rime the PBL effect may spread. The results however imply that the exact way that PBL is distributed over the disyllable words is systematically fine-tuned in a language-specific way - i.e., in reference to the language's higher-order rhythmic structure that involves the moraic structure and the lexical pitch accent in the case of Japanese. It remains to be seen how the current findings may generalize to other words in Japanese and how they are exploited in speech comprehension.

5. ACKNOWLEDGEMENT

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