Preboundary lengthening and boundary-related spatial expansion in Korean

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ABSTRACT

This EMA study examines kinematic characteristics of preboundary lengthening (PBL) in CV.CV and CV.CVC contexts in Korean. Almost all lip closing/opening gestures – both proximal and distal to the prosodic juncture and regardless of phonetic contents and information status of the word – showed preboundary lengthening although in a gradient fashion. The articulatory lengthening was largely accompanied by an increase in both displacement and peak velocity. There was a mutual dependence of displacement and peak velocity, but when the dependence was factored in, the boundary-related spatial expansion remained significant while the effect on peak velocity disappeared. The results thus characterize the preboundary effects in Korean as a kind of articulatory strengthening in both the spatial and temporal dimensions distributed over the entire word than being localized to the gestures near the prosodic juncture. Some implications for dynamical underpinnings of PBL will be discussed.

Keywords: prosody, speech dynamics, articulatory kinematics, preboundary lengthening, Korean

1. INTRODUCTION

Preboundary lengthening (PBL) refers to the boundary-related temporal expansion toward the end of a large prosodic unit (e.g., Intonational Phrase (IP)) compared to that of a small unit (e.g., prosodic word) [12]. While PBL is observed nearly universally, its detailed phonetic implementation differs across languages [13,16,17], suggesting that the effect should be fine-tuned in the phonetic grammar of each language possibly in conjunction with other higher-order linguistic structures in a given language.

One linguistic factor that influences PBL in a language-specific way is the prominence system of the language. Unlike early findings which showed that PBL in English is localized to the phrase-final syllable [2,18], recent studies have found that lengthening can be extended to a non-final stressed syllable within a phrase-final word [9,15,17]. Similar stress attraction effects are reported in other languages as well [13,16]. In addition, from an articulatory gestural point of view, articulatory strengthening of lip opening gesture in IP-final position may disappear under prominence — i.e., when the boundary-adjacent syllable is pitch-accented, which can be seen as a ceiling effect [15].

While acoustic and articulatory properties of PBL in head-prominence languages were widely investigated with respect to prominence marking, studies on PBL in languages without lexical-level prominence have been very limited.

The present study investigates the domain of PBL in Korean in conjunction with information structure that is known to affect PBL. Korean does not have lexical-level prominence, but it is well-known for the robust phrase-initial strengthening effect compared to other languages, showing an extension of the phrase-initial strengthening effect even to the non-initial segments [7, 10,11]. This extended domain-initial effect has been considered to be attributable at least in part to the lack of the lexical prominence system in the language [10,11]. The present study explores this possibility further by examining how the prominence that may arise with information structure ('new' vs. 'given') may influence the phonetic implementation of PBL, and the extent to which the result may be interpreted as being driven by the characteristics of the language-specific prominence system in Korean. In exploring these questions, additional questions will be considered as to how the scope of PBL may be further influenced by different vowel contexts (intrinsically long /i/ vs. short /a/) and the syllable structure at the end (closed vs. open), which have been also known to influence the scope of PBL [e.g., 16].

2. METHOD

2.1. Speech materials

There were eight test words: /mami/, /mima/, /p*ap*i/, /p*ip*a/, /mamim/, /mimam/, /p*ap*ip/, /p*ip*ap/. They were all pseudo-words, which were introduced as pet names in the mini dialogue shown in Table 1. Note that the words included two bilabial consonants (*C-type*: /m/ or /p*/) to test whether the PBL effect is generalizable across consonants. They also differed in terms of vowel sequences (*V-pattern*: /CaCi/ or /CiCa/), which was done to test whether and how PBL is affected by the intrinsic durational difference between a high and a low vowel. In addition, two different syllable structures (*WordType*: CV.CV or CV.CVC) were used in order to observe the scope of PBL in words with open vs. closed final syllables.

Test words appeared in four types of sentences which were answers to questions (A's in Table 1). The sentences were designed to induce the intended prosodic boundary (*Boundary*: IP-final vs. (IP-internal) Wd-final) and information structure (*Info*: given vs. new). By manipulating information structure, we intended to elicit two different prominence levels. In the "given" condition, the test word was expected to be weakened as it was part of the given information in the question and the narrow focus fell on a following word (e.g., *ate, rat*). In the "new" condition, all words in the answer contained new information as the question prompted broad focus whose domain was the whole sentence. In all test sentences, the test word was preceded by an /ɛ/-final word and followed by either [pinu], '*soap*', or [patʃi], '*pants*', in a way that the following word had a bilabial onset and continued the V-pattern.

Table 1: Examples of test sentences. Test words are underlined. Focused words are marked in bold.

Boundary=IP-final	
Info =given	Q: [jʌŋmaninɛ mima IP pinu ʌtʃ*ɛt*ɛ] "What did Youngman's Mima do with the soap? A: [jʌŋmaninɛ <u>mima</u> IP pinu **mʌgʌt*ɛ**] "Youngman's Mima **ate** the soap."
Info =new	Q: [musɨn il is*ʌt*ɛ] "What happened?" A: [jʌŋmaninɛ <u>mima</u> IP pinu mʌgʌt*ɛ] "Youngman's Mima ate the soap."
Boundary=Wd-final	
Info =given	Q: [jʌŋmaninɛ mima wd pinu nuga mʌgʌt*ɛ] "Who ate Youngman's Mima's soap?" A: [jʌŋmaninɛ <u>mima</u> wd pinu **tʃwiga** mʌgʌt*ɛ] "A **rat** ate Youngman's Mima's soap."
Info =new	Q: [musɨn il is*ʌt*ɛ] "What happened?" A: [jʌŋmaninɛ <u>mima</u> wd pinu tʃwiga mʌgʌt*ɛ] "A rat ate Youngman's Mima's soap."

2.2. Procedure

Articulatory data were collected from ten native speakers of Seoul Korean (5 male and 5 female college students) using a 2D Electromagnetic Midsagittal Articulography (Carstens AG200). Sensors were attached on various articulators including the upper/lower lips.

In each trial, participants heard a pre-recorded prompt question and read the corresponding answer presented on a computer screen. Note that orthographic schemes were used to induce the intended sentences. IP-final position was marked by a comma, and Wd-final without a space between the test word and the following noun. Words receiving focus were written in red. In the "new" condition, all words were written in red because the sentence was an answer to a broad focus question. Each participant had a practice session on a different day prior to the experiment.

Items were blocked by C-type and V-pattern to help participants recognize the test words. Prosodic renditions were later cross-checked by three trained phoneticians, which confirmed that all tokens were produced with intended prosodic structure. In total, 1280 tokens were collected (8 words x 2 boundary x 2 information x 4 repetition x 10 speakers).

2.3. Measurement

Lip closing/opening gestures were obtained from the Euclidean distance of the sensors on the upper and lower lips (i.e., Lip Aperture). Peak velocity (PKVEL), displacement (DISP), and duration values were obtained using the standard EMA measurement processes [11]. First, PKVEL (in mm/s) was the maximum velocity value during the movement phase. The onset and target were defined as the time points when the velocity during the acceleration or deceleration reached 20% of its maximum velocity, respectively. DISP (in mm x 100) represents the distance between the onset and target. Duration (in ms) was taken from the movement onset to the onset of the following movement (thus including the plateau).

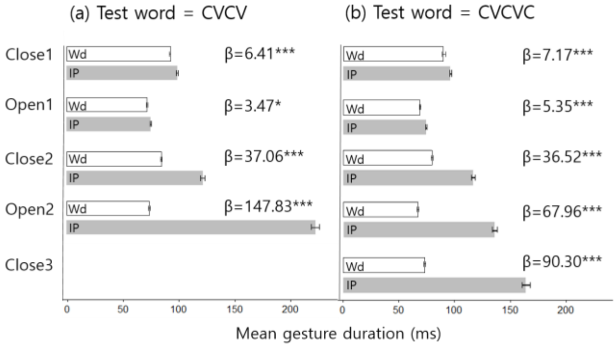
3. RESULTS

Note that five tokens were removed from both the duration (Section 3.1) and the DISP/PKVEL analyses (Sections 3.2 and 3.3) due to missing PKVEL values. Additionally, data from 1 female participant (N=128) were excluded in the DISP/PKVEL analysis due to measurement errors in DISP. Thus, 1,275 tokens were submitted to the duration analysis and 1,147 tokens to the DISP/PKVEL analysis.

3.1. Gesture duration

A series of linear mixed effects model were fit separately to duration of each gesture in CVCV and CVCVC words (thus 9 models in total). Fixed effects were Boundary (<u>Wd</u> vs. IP), V-pattern (<u>AI</u> vs. IA), Info (<u>given</u> vs. new), and all their 2-way and 3-way interactions. In addition, C-type (<u>M</u> vs. P) was included as a control variable. The underlined categories above were the reference level, and all factors were deviation-coded. The maximal random effects structure justified by the design [1] was employed as long as the model converged (i.e., by-subject intercept and slopes for all test variables). In case of non-convergence, slope for Info was removed, which had the smallest variance. All significant effects of the test variables are summarized below. A full presentation of the structure and output of all models can be found at http://tcho.hanyang.ac.kr/kim-baek-cho-kim-2019_supplementary.

Figure 1: Mean gesture durations. Close/Open represent the lip movement direction, and numbers the order of occurrence (e.g., Close1 refers to the first lip-closing gesture). Error bars represent standard errors. Coefficients of the boundary effect estimated from mixed modelling are given for each gesture.



The positive coefficients for a main effect of boundary in Figure 1 indicate that all gestures in both word types were lengthened IP-finally (p=.011 for Open1 in CVCV, p<.001 elsewhere). The relatively small effect in Open1 of both word types was presumably due to word-internal truncation of Open1.

There were some indications of an effect of vowel content. First, when producing the phonetically-short first vowel /i/ (i.e., IA type), its opening gesture was not shortened (also possibly due to the truncation) but its consonantal Close1 gesture showed a preparatory shortening (β=-6.589, p<.001 in CVCV; β=-4.578, p=.027 in CVCVC). Second, Boundary:V-pattern interaction in Open1 indicated a decreased boundary effect for the short first vowel /i/ than long /a/ (β=-3.31, p=.038 in CVCV; β=-3.45, p=.011 in CVCVC). Similarly, the interaction in Open2 of CVCVC (but not CVCV) showed a greater boundary effect for the long second vowel /a/ (β=18.71, p=.004).

As for the Info, lengthening occurred when the test word provided new information in the final closing gesture of both word types: Close2 of CVCV (β=2.99, p=.007) and Close3 of CVCVC (β=11.43, p=.003). Boundary:Info interaction was found at Close3 of CVCVC: the magnitude of IP-final lengthening increased when the test word was new information (β=17.32, p=.034).

In further analysis, significant boundary effects were found in all gestures even when all subsets of the data were tested separately, except for Open1 for IA in CVCV words. This is also indicated by the above-mentioned Boundary:V-pattern interaction, which is attributable to the word-internal truncation. Thus, PBL seems to be generalizable across all conditions tested in this experiment.

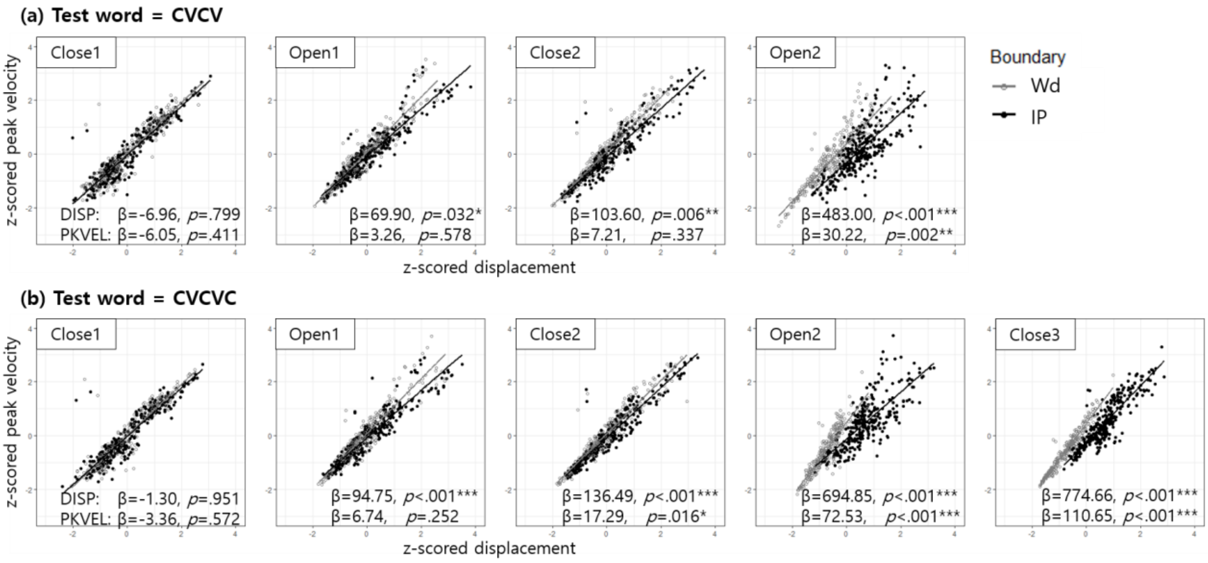
3.2. Displacement and peak velocity

DISP and PKVEL values are plotted in Figure 2. The two variables were highly correlated in Kendall's tau test (p<.001 for all gestures). Mixed effects models were separately fit to DISP and PKVEL values of each gesture with the identical model structure as in 3.1. All variables were centered in analyses below.

Positive coefficients of a main effect of Boundary on DISP indicate that the lip aperture was larger IP-finally than Wd-finally in all gestures but Close1 of both word types. Peak velocity was also higher IP-finally than Wd-finally, and in CVCVC this effect began earlier at Close2. A progressive effect was evident in both measures: the coefficient and significance level gradually increased as approaching to the final gesture.

In the IA vowel sequence, DISP and PKVEL decreased in Open1 and Close2 but increased in Open2 and Close3 (p<.001 for all). In the new information condition, both measures tended to

Figure 2: Z-scored distribution of DISP and PKVEL in CVCV (a) and CVCVC (b) words. Data points are plotted by Boundary, along with separate linear regression lines. An effect of Boundary was evaluated in mixed modeling and its coefficients and p-values are given at the bottom of each plot (upper= DISP, lower=PKVEL).



increase in general (reaching significance in 6 gestures for DISP and 7 gestures for PKVEL). Taken together with the results of duration, main effects of V-pattern and Info on DISP and PKVEL indicate that temporal and spatial patterns are systematically conditioned by vowel length or information status.

Interactions with Boundary, however, patterned in an opposite direction of the duration analysis. First, V-pattern interacted with Boundary in Close3 of CVCVC; the boundary effect on PKVEL decreased in words with a long second vowel /a/ (i.e., IA) (β=-51.28, p<.001). Second, Boundary:Info interaction in Close3 of CVCVC indicated a smaller boundary effect on DISP (β=-82.30, p=.002) and PKVEL (β=-21.33, p=.001) for words produced as new information.

3.3. The nature of the spatial expansion

The analyses above demonstrate a robust boundary-induced strengthening effect on both displacement and peak velocity. However, since they co-vary, it is possible that one effect has arisen as a consequence of the other. To test this, DISP was regressed for each gesture, with PKVEL as an additional control factor. A main effect of Boundary turned out to remain significant in all models except the ones fit to Close1 of both word types (p=.006 in Open1 of CVCV, p<.001 elsewhere), indicating that the spatial expansion did not depend on the change in peak velocity. In contrast, when models were fit to PKVEL with DISP as a control factor, a reverse effect was found (i.e., PKVEL decreased IP-finally) in all gestures from Open1, except Close2 and Open2 in CVCVC (with varying significance levels). Thus, the increase in peak velocity was largely attributable to the variance predicted by displacement, and peak velocity would have decreased if the gesture had travelled an equal distance during the lengthened activation time in IP-final position.

4. DISCUSSION AND CONCLUSION

First, our results showed that the PBL effect in Korean is gradient, and it is distributed over almost the entire sequences of lip opening/closing gestures in bisyllabic words, regardless of the segment type (intrinsically long /i/ vs. short /a/), the syllable structure (closed vs. open at the end) and the information status of the test word (‘given’ vs. ‘new’). From an articulatory gestural point of view, the durational findings can be explained by the π-gesture model [5], to the extent that the degree of lengthening is generally observed to be the greatest near the juncture and gradually decreases in distant position. Our findings, however, are inconsistent with a view that a fixed prosodic π-gesture duration is assigned to a given boundary level [4]. Together with previous findings that post-boundary effects in Korean extend to the second syllable [10, 11], the results suggest that cross-linguistically variable scopes of boundary effects need to be specified in dynamical models.

In line with [6, 14], we interpret the results as driven by the prominence system in Korean. In the languages with lexical prominence, for example, boundary strength may not be able to exert its influence on the boundary-adjacent vowel gesture when the stressed vowel is in the phrase-final syllable, drawing prominence-induced strength [8, 15]. Korean, without such prominence system, appears to have more freedom to assign boundary strength to gestures within the π-gesture’s maximal reach. More broadly, these results are consistent with the view that prosodic boundary markings in Korean are closely related with prominence markings, in such a way that the boundary gives rise to temporal expansion across the board, whose phonetic consequence (salience) may give prominence to the word at the prosodic juncture.

Next, the preboundary effects observed in the present study show an increase in both displacement and peak velocity. This sort of kinematic strengthening is therefore not attributable to stiffness-modulation which is often considered as dynamical underpinning of PBL (cf. [2, 3]). The results appear to be more consistent with in the clock-slowing-down modulation of the π-gesture model. That is, given the elongated activation time near the edge, gestures were made with more faithful target attainment without being truncated by neighbouring gestures. The increased peak velocity may be understood by its kinematic relationship with displacement. In line with [15], our data indicated that the effect on displacement remained when its mutual dependence with peak velocity was taken into account but not vice versa. This relationship leads us to characterize the strengthening effect as driven by spatial expansion due to sufficient activation time. Note, however, that such a process does not necessarily entail an increase in peak velocity. Therefore, one cannot entirely rule out an alternative interpretation. That is, the boundary-related spatial modulation may operate under the speaker control in accordance with the boundary strength. For example, the increased displacement and peak velocity may have arisen due to an extended articulatory target that modulates intergestural timing within the given temporal quantity. It remains to be seen whether phrase-final strengthening patterns in both displacement and stiffness are generalizable in languages in which the boundary strength does not interact with lexical-level prominence.

In sum, the articulatory patterns observed in this paper characterize the preboundary effects in Korean as prosodic strengthening in both the spatial and temporal dimensions distributed over the entire word. These characteristics are interpreted as arising from the language-specific prominence system.

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