EFFECTS OF MORPHOLOGICAL STRUCTURE ON INTERGESTURAL TIMING IN DIFFERENT PROSODIC-STRUCTURAL CONTEXTS IN KOREAN

Jiyoung Lee[1], Sahyang Kim[2] and Taehong Cho[1]

Hanyang Institute for Phonetics and Cognitive Sciences of Language (HIPCS), Hanyang University[1]; Hongik University[2]

Ljy1004@hanyang.ac.kr; sahyang@hongik.ac.kr; tcho@hanyang.ac.kr

ABSTRACT

This EMA study explores effects of morphological structure on intergestural timing in different prosodic-structural contexts in Korean by examining articulatory realization of homophonous pairs of different underlying morphological structures (tautomorphemic $(C_1)V_1C_2V_2$ *vs.* heteromorphemic $(C_1)V_1C_2+V_2$, where '+'=a morpheme boundary). The intergestural timing of C_2V_2 was found to be more stable in C_2V_2 than in C_2+V_2 in all prosodic contexts. The morphological effect was also observed with V_1C_2 timing. It was more stable in $(C_1)V_1C_2+V_2$ than in $(C_1)V_1C_2V_2$, which was augmented under focus-induced prominence. This indicates that the intergestural timing of V_1-to-C_2 gesture became more stabilized when C_2 is underlyingly syllabic-coda as in the hetero-morphemic condition ($(C_1)V_1C_2+V_2$). The observed stability difference as a function of morphological structure and its interaction with prominence was consistent phrase-initially and phrase-medially, though with some degree of difference. The results demonstrate that gestures are coordinated in reference to the interaction between underlying morphological structure and prosodic structure.

Keywords: Intergestural Timing, Prosodic Structure, Morphological Structure, Articulatory Phonology

1. INTRODUCTION

It has been well-established that higher-order linguistic structures affect low-level segmental articulation. For example, prosodic structure fine-tunes articulation by enhancing the articulatory contrast between consonant and vowel at the edges of higher prosodic domains (e.g., [7, 10, 13, 16]) and by maximizing segmental features with an articulatory expansion under focus-induced strengthening (e.g., [12, 16]). On the other hand, morphological structure is another type of linguistic structure that can modulate articulation (e.g., [8, 23, 24]). For example, Cho [8] found that a single morpheme [napi] ('butterfly') in Korean shows more stable inter-gestural timing (i.e., the timing coordination of articulation) than its heteromorphemic counterpart [nap+i] ('lead'+ Nom.), despite the fact that they have an identical, homophonous segmental sequence. In addition, Song et al. [23], found that children and adults show tongue height difference between the monomorphemic coda and bimorphemic coda clusters (e.g., bo<u>x</u> *vs.* ro<u>cks</u>). These studies suggest that morphological structural differences still exist in articulation after morphemes are post-lexically processed. These studies, however, focused on the morphological effects only in a limited prosodic context. For example, Cho's test words occurred only in a phrase-medial position with no control of prominence, leaving the question unanswered as to how the morphological effects on the gestural realization may be further modulated by higher-order prosodic factors such as prominence and prosodic boundary.

The present study, therefore, continues to investigate how the underlying morphological structure may modulate the intergestural timing by extending the scope of Cho's study to examine the interaction between the morphological structure and the higher-order prosodic structure as reflected in prominence and boundary factors. By taking prosodic information into account, this study aims to illuminate from an articulatory gestural point of view how the phonetic fine tuning due to morphological structure is further modulated by prosodic structure, which is assumed to serve as a frame for articulation (e.g., [2, 9, 15]).

In the framework of Articulatory Phonology (e.g., [3, 4, 5, 6]), the intergestural timing is assumed to be lexically specified and invariantly stored in our mental lexicon. According to the theory, the lexically-specified intergestural timing is realized by means of some degree of cohesion among articulatory gestures, resulting in stable intergestural timing within a lexical item than across lexical items (e.g., [3, 6]; see also [18]), as has been empirically supported by Cho's findings [8]. The specific question to be explored in the present study is then how the intergestural timing and stability varied by the morphological structure is further modulated by prosodic structure.

Considering that segments in the initial position of a prosodic phrase are produced with phonetic strengthening as compared with the same segments that occur in the middle of the phrase (e.g., [7, 10, 11, 13, 16, 17]), it may be possible that the location of words within a prosodic phrase results in different impacts on the intergestural timing in association with the underlying morphological structures. In addition, given that a morpheme is the smallest meaningful unit in a language, prominence marking system may also make reference to the underlying morphological composition to signal an informational locus, possibly modulating the intergestural timing relations. The present study tests these possibilities by examining the intergestural timing relations of words stemming from different morphological structures in various prosodic boundary and prominence contexts.

2. METHOD

2.1. Speech Materials

There were two types of morphological sequences comprising homophonous pairs: 1) tautomorphemic sequences consisting of a single morpheme ((C_1)$V_1C_2V_2$; [papi], 'Barbie' and [api], a less polite term for 'father') and 2) heteromorphemic sequences consisting of two morphemes ((C_1)V_1C_2+V_2; [pap+i], 'meal+Particle' and [ap+i], 'pressure+ Particle'). To generate an identical segmental string across the two morphological structures, a case particle '+(i)ɾago' was used (e.g., [**papi**+ɾago], 'Barbie+ Particle' and [**pap+i**ɾago], 'meal+ Particle') The case particle [+(i)ɾago] in Korean is used, which indicate that any preceding word(s) or phrase(s) are directly cited. The parenthesized /+i/[1] in the particle [+(i)ɾago] is only activated when the preceding word has a coda consonant (e.g., 'pap').

As shown in Table 1, each target sequence was embedded in a test sentence where two factors were manipulated: Boundary (IP-initial *vs.* Wd-initial) and Focus (Focused *vs.* Unfocused). For the IP-boundary condition, every target sequence was placed after an Intonational Phrase boundary. For a Wd-boundary condition, a possessive pronoun [wuɾi]('our') preceded the target sequences, which made the sequences located in the middle of a phrase. For the focus condition, targets were designed to be morphologically contrastive (e.g., "Did you write **[papi]** or did you write **[pap]?**") (Note that targets are underlined, and contrasting words are in bold through the manuscript.), and for the unfocused condition, non-target words were made to be contrastive (e.g., "Did **you** write [papi] or did **that person** write [papi]?"

Table 1: Examples of the test sentences. Targets are underlined, and contrasting words are in bold. '#' and '+' refer to prosodic boundary and morphological boundary, respectively.

Conditions		Test sentences
#=IP	Foc	ʧikɨmjʌki **papi**+ɾago s*ʌnni, # **pap+i**ɾago s*ʌnni] Right here, did you write **Barbie** or did you write a **meal**?
	Unfoc	[ʧikɨmjʌki pap+iɾago **ni**ka s*ʌnni, # pap+iɾago **ʧje**ka s* ʌnni] Right here, did **you** write a meal or did **that person** write a meal?
#=Wd	Foc	[ʧikɨmjʌki wuɾi**papi+**ɾago s*ʌnni, wuɾi#**pap+i**ɾago s*ʌnni] Right here, did you write our **Barbie** or did you write our **meal**?
	Unfoc	[ʧikɨmjʌki wuɾipap+iɾago **ni**ka s*ʌnni, wuɾi#pap+iɾago **ʧje**ka s* ʌnni] Right here, did **you** write our meal or did **that person** write our meal?

2.2. Participants and Procedure

Ten native Seoul-Gyeonggi Korean speakers participated in this articulatory experiment (five females and five males in their 20s).

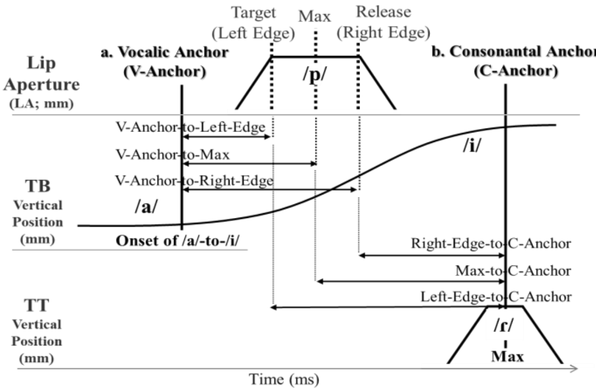
During the experiment, each test sentence was presented as a written text on a computer screen. In order to induce the intended prosodic structure, written texts included typographical cues for boundary and focus. At the IP boundary, a comma and a space were inserted and in the Wd boundary condition, there was no space between the possessive pronoun and the following target sequence (e.g., ourBarbie). The contrastive words were highlighted in red and bold. Speakers were asked to read the sentences, following the intended prosodic renditions guided by the typographical cues. During the recording sessions, two experimenters checked for each token whether the intended prosodic rendition was produced or not. Each participant produced 240 sentences (4 target sequences x 2 boundary types x 2 focus types x 15 repetitions). Out of 2400 tokens collected, 171 tokens were excluded from the data analyses as they did not match with the intended prosodic renditions.

The articulatory data were collected using the electromagnetic articulography (EMA, AG501, Carstens Electronics). Five sensors were attached to the five primary articulators: tongue tip (TT), tongue body (TB), lower lip (LL), upper lip (UL), and the middle of the lower gumline (LG). Two more sensors were used as reference points at the nose bridge and at the middle of the upper gumline. The data from UL, LL, TT, and TB were analyzed.

2.3. Measurement and Statistical Analysis

The Mview software (the Matlab-based software algorithm developed by Mark Tiede) was used to analyze the obtained kinematic data. The movement onset and target of each gesture were defined at the time point where the related local velocity reached a 20% threshold. Max constriction time point was also obtained (cf. [19, 21]). Note that the release of one gesture was the onset of the very following gesture.

Figure 1: Schematized representation of time intervals delineated by two anchor points: a. Vocalic Anchor (V-Anchor; the onset of /a/-to-/i/ movement of the TB gesture) and b. Consonantal Anchor (C-Anchor; the max constriction of the TT gesture for /ɾ/).



Two anchor points were used: a. vocalic anchor (V-Anchor, cf. [22]) and b. consonantal anchor (C-Anchor, cf. [19, 21]). As in Figure 1, the obtained temporal landmarks (Target, Max, and Release) were redefined as Left-Edge, Max, and Right-Edge, respectively. Six time-intervals were calculated between each landmark and each anchor point (cf. [19, 21]). For example, V-Anchor-to-Left-Edge meant the time interval between V-Anchor and Left-Edge (Target). SDs (standard deviations) and RSDs (%-relative standard deviations; SD/mean*100) of each interval were computed as the indices for the stability of intergestural timing. Mean, SD, and RSD (%) were calculated for every condition pooled within each speaker.

Time interval values and RSDs (%) of the intervals were analyzed by Linear Mixed-effects models with the lme4 package in R. Morphological structure (Hetero *vs*. Tauto), Focus (Foc *vs*. Unf), Boundary (IP *vs*. Wd), Types of initial syllable-onset of target sequences (P-initial *vs*. Vowel-initial)[2], and all their interactions were employed as fixed factors, and subjects as a random factor. A deviation coding was used for each fixed factor. The nearly maximal models[3] were fitted for the raw time interval values (cf. [1]). In terms of RSDs, however, since there was only one observation per condition per person, random intercept (RI) model (cf. [1]) was used with a constant formula[4] for all RSDs. Also, planned *t*-test comparisons were carried out for the RSD values.

3. RESULTS

3.1. C-Anchor Context (CV Gestural Timing)

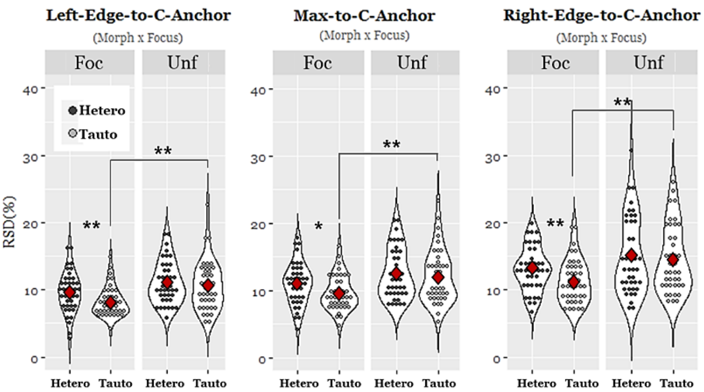
The time intervals defined by C-Anchor (the intergestural timing of C_2V_2) showed a main effect of Morphological structure (Left-Edge: β=-1.31, SE=0.63, t=-2.07, p<.04; Max: β=-1.92, SE=0.71, t=-2.72, p<.014; Right-Edge: β=-1.8, SE=0.7, t=-2.58, p<.018), with longer C_2V_2 intergestural timing in tautomorphemic $(C_1)V_1\mathbf{C_2V_2}$ than in hetero-morphemic $(C_1)V_1\mathbf{C_2{+}V_2}$. Focus and Boundary had significant main effects on all three intervals, which were always longer under focus than under no focus, and again longer phrase-initially than phrase-medially. Neither of the two factors interacted with Morphological structure.

Table 2: Mean (ms), SD and %-RSD of time intervals defined by C-Anchor, pooled across Boundary and Focus conditions (All) and separated by Focus conditions (Focused, Unfocused). Note that as shaded in grey, RSD values were always lower in the tautomorphemic condition than in the heteromorphemic condition.

		Consonantal Anchor (to-C-Anchor)					
		Left-Edge		Max		Right-Edge	
		Hetero	Tauto	Hetero	Tauto	Hetero	Tauto
All	Mean	142.04	143.34	121.61	123.58	104.18	106.00
	Sd	14.49	13.26	14.02	13.13	14.23	13.26
	Rsd (%)	10.36	9.42	11.72	10.81	14.04	12.86
Foc	Mean	148.9	149.59	127.07	128.55	108.64	110.28
	Sd	14.38	12.32	13.99	12.33	14.16	12.29
	Rsd (%)	9.63	8.25	10.97	9.6	13.11	11.26
Unfoc	Mean	135.18	137.09	116.16	118.61	99.72	101.73
	Sd	14.6	14.21	14.05	13.92	14.3	14.23
	Rsd (%)	11.08	10.6	12.46	12.03	14.98	14.45

As for the stability of CV gestural timing, RSDs showed a main effect of Morphological structure (Left-Edge: β=0.93, SE=0.42, t=2.22, p<.028; Max: β=0.9, SE=0.47, t=1.93, p<.056; Right-Edge: β=1.19, SE=0.59, t=2.01, p<.047), confirming that CV gestures were more stably produced in the tautomorphemic sequence than in the hetero-morphemic one. Focus also showed a main effect on RSDs (i.e., more stable production under focus). Although there was no statistically significant interaction between morphological structure and focus structure, planned *t*-test comparisons showed heteromorphemic $\mathbf{C_2{+}V_2}$ and tautomorphemic $\mathbf{C_2V_2}$ may have some difference in RSDs as a function of focus. As presented in Figure 2, under focus, the RSDs of CV gestural timing was significantly lower in tautomorphemic $\mathbf{C_2V_2}$ than in heteromorphemic $\mathbf{C_2{+}V_2}$, which was not significant in the unfocused condition (Left-Edge: t(9)=3.26, p<.01; Max: t(9)=2.92, p<.018; Right-Edge: t(9)=4.16, p<.002). This interaction also partly stemmed from the fact that CV gestures in the tautomorphemic sequence showed enhanced stability under focus (Left-Edge: t(9)=-4.01, p<.003; Max: t(9)=-3.26, p<.01; Right-Edge: t(9)=-3.23, p<.01), which was not observed in the heteromorphemic sequence. There was neither statistical main effect nor interaction related to boundary in RSDs.

Figure 2: Violin graphs for the Focus x Morphological structure interaction on the RSDs (%) of the three intervals defined by C-Anchor. Each red diamond, located in the middle of the graphs, indicates the mean of each condition.



3.2. V-Anchor Context (VC Gestural Timing)

V-Anchor point was employed to examine the V_1C_2 gestural timing. Morphological structure showed no main effect on the three intervals defined by V-Anchor, albeit all the intervals were longer in hetero-morphemic $(C_1)\mathbf{V_1C_2}{+}V_2$ than in tautomorphemic $(C_1)\mathbf{V_1C_2}V_2$. Focus and Boundary had significant main effects on the three time-intervals, being longer under focus and at the IP-initial position, but no interaction with Morphological structure was found.

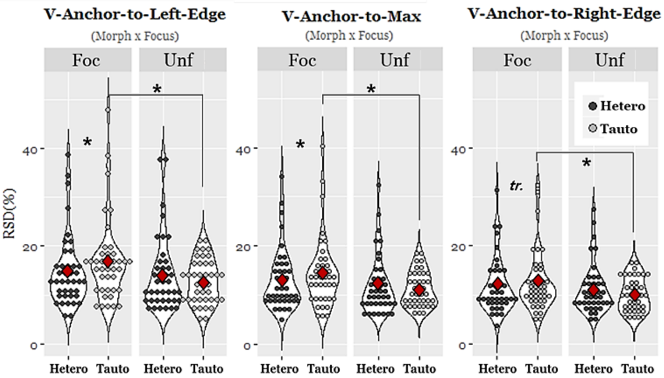
Table 3: Mean (ms), SD and %-RSD of time intervals defined by V-Anchor, pooled across Boundary and Focus conditions (All) and separated by Focus conditions (Focused, Unfocused). The cells shaded in grey represented lower RSD values by comparing the heteromorphemic with the tautomorphemic condition.

		Vocalic Anchor (V-Anchor-to)					
		Left-Edge		Max		Right-Edge	
		Hetero	Tauto	Hetero	Tauto	Hetero	Tauto
All	Mean	97.13	95.56	117.53	115.33	134.97	132.9
	Sd	14.74	14.79	15.41	15.40	16.14	15.61
	Rsd (%)	14.19	14.76	12.29	12.8	11.28	11.33
Foc	Mean	108.02	107.26	129.81	128.30	148.25	146.57
	Sd	16.71	18.65	17.49	19.09	18.01	19.00
	Rsd (%)	14.9	16.77	13.1	14.45	11.83	12.61
Unfoc	Mean	86.24	83.86	105.26	102.35	121.7	119.23
	Sd	12.78	10.94	13.32	11.71	14.28	12.21
	Rsd (%)	13.49	12.75	11.48	11.15	10.73	10.05

As for the stability of VC gestural timing, RSDs showed no main effect of Morphological structure. Nonetheless, there was a marginal interaction between Morphological structure and Focus on V-Anchor-to-Left-Edge (β=-3.17, SE=1.91, t=-1.66, p<.1). As given in Table 3, heteromorphemic $(C_1)\underline{\mathbf{V_1C_2}}+V_2$ showed lower RSDs compared to tautomorphemic $(C_1)\underline{\mathbf{V_1C_2}}V_2$, which was again augmented under focus. Planned *t*-test comparisons revealed that under focus, the VC gestures showed lower RSD values (suggesting more stability) in the heteromorphemic condition than in the tautomorphemic condition, as shown in Figure 3 (Left-Edge: $t(9)=-2.76$, $p<.023$; Max: $t(9)=-3.17$, $p<.012$; Right-Edge: $t(9)=-1.94$, $p<.086$). Interestingly, as shown in the CV timing, tautomorphemic $(C_1)\underline{\mathbf{V_1C_2}}V_2$ was again more influenced by focus in terms of the intergestural stability. This time, however, when receiving focus, the VC gestural timing was less stable in the tautomorphemic than in the heteromorphemic condition (Left-Edge: $t(9)=2.61$, $p<.03$; max: $t(9)=2.49$, $p<.035$; Right-Edge: $t(9)=2.26$, $p<.05$).

Although Boundary did not show any main effect or any interaction with Morphological structure or Focus on RSDs, the aforementioned interaction between Morphological structure and Focus was far more robust phrase-initially than phrase-medially.

Figure 3: Violin graphs for Focus x Morphological structure interaction on the RSDs (%) of the three intervals defined by V-Anchor. Each red diamond, located in the middle of the graphs, indicated the mean of each condition.



4. SUMMARY AND CONCLUSION

The results from C-Anchor indicate that CV gestures are longer in duration and more stable in production when being part of a single morpheme, $(C_1)V_1\underline{\mathbf{C_2V_2}}$ (e.g., [pa**pi**], 'barbie') than when concatenated from multiple morphemes, $(C_1)V_1\underline{\mathbf{C_2+V_2}}$ (e.g., [pa**p+i**], 'meal+Particle'). The effect of morphological structure is not only maintained across focus or prosodic boundary conditions, but also augmented under focus. The focused CV gestures showed greater stability when in the same morphological structure than across a morphological boundary.

Turning to the results from V-Anchor, it is again shown that the intergestural timing relations are attuned by the underlying morphological structures. This time, however, VC gestures are found to be longer in duration and more stably produced in heteromorphemic $(C_1)\underline{\mathbf{V_1C_2}}+V_2$ than in tauto-morphemic $(C_1)\underline{\mathbf{V_1C_2}}V_2$. This implies that not only the underlying morphological structure but also its subordinate syllable structure is reflected on the intergestural timing stability. The effect of Morphological structure on VC gestures is strengthened under focus-induced effect although this is the exact reverse of what is observed on CV gestures. Another interesting finding is that the interaction between Morphological structure and Focus on the VC gestural stability is far more robust, located in the phrase-initial than in the phrase-medial position. With regard to the CV gestures, however, the same interaction on the stability is consistently observed across boundary conditions. Since the VC gestures, underlyingly belonging to the first syllable, are more adjacent to the phrase edge than the CV gestures, it appears that the VC gestures are more influenced by boundary-induced effects than the CV gestures are (e.g., [7, 10, 13, 16]).

On the other hand, the prominence marking system, coming from information structure, appears to make reference to the underlying morphological structure and enhance the internal gestural cohesion, presumably for making clearer phonetic contrasts on the morphological structure of the target sequences. For example, the results show that the consonantal gesture is more stably coordinated with the preceding vocalic gesture in heteromorphemic $C_1\underline{\mathbf{V_1C_2}}+V_2$, in which the VC gestures belong to a single morpheme, than in tautomorphemic $C_1\underline{\mathbf{V_1C_2}}V_2$ where a syllable boundary exists between the VC gestures.

These findings, taken together, reinforce Cho's [8] earlier findings on the effects of morphological structure on phonetic realization in Korean (e.g., [23]), and further demonstrate that morphological structure interacts with prosodic structure, modulating the intergestural timing. The results also support the view of Articulatory Phonology (e.g., [3, 4, 5, 6]), in which the intergestural timing relations are lexically-specified and preprogramed in our mental lexicon and thus stably produced with some degree of cohesion among articulatory gestures. According to Marselen-Wilson et al. [20], every decomposable morpheme is considered to form an independent lexical item, and therefore it is reasonable to postulate that a stable intergestural timing relation is also preprogramed for each decomposable morpheme as was discussed in [8]. That may account for why the intergestural timing and its stability are modulated differently depending on underlying morphological structure, although having identical segmental or gestural makeups. This account is further supported by the focus-induced results, suggesting that prominence marking system enhances the stability of the intergestural timing relations in the direction of reinforcing the underlying morphological structure and its subordinate syllable structure. More broadly, the results of the present study highlight the role of prosodic structure on fine-grained phonetic realization from an articulatory gestural point of view.

5. ACKNOWLEDGEMENT

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[1] There is no meaning difference between [+iɾago] and [+ɾago].

[2] Reference level was defined as the underlined one in the sentence.

[3] for raw time interval values: (dv~morph * focus * boundary * onset + (1 + morph * focus * boundary + onset | subj))

[4] for RSDs: (dv ~ morph * focus * boundary * onset + (1 | subject))