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# Effects of prosodic boundary and syllable structure on the temporal realization of CV gestures



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## ABSTRACT

An articulatory study was conducted to explore effects of prosodic boundary and syllable structure on temporal realizations of /ma/ in C#V vs. #CV in Korean (where '#' denotes an Intonational Phrase or a Word boundary). The vocalic gesture underwent boundary-induced lengthening more in C#V than in #CV, implying that the boundary effect is largely localized to the initial element whether consonantal or vocalic. CV coordination patterns were temporally neutralized between #CV and C#V in the phrase-internal Word boundary condition, showing a possible 'resyllabification' of 'C' with the following vowel in C#V in the articulatory temporal measures taken in the present study. It was suggested that CV gestures in C#V, whose phasing relationship has to be determined postlexically, reorganize temporally in an in-phase coupling mode just like the way CV gestures are phased in #CV. Finally, while there was leftward shifting of the consonantal gesture in C#V with some temporal variability across an IP vs. a Word boundary, intergestural timing in #CV remained invariant regardless of boundary strength. But the most stable temporal pattern was observed with an IP boundary in #CV, interpretable as an important temporal characteristic of domain-initial strengthening. Some of these results were further discussed in terms of their implications for the theory of  $\pi$ -gesture and the gestural coupling model of syllable structure.

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## 1. Introduction

One of the important theoretical assumptions in Articulatory Phonology (Browman & Goldstein, 1990, 1992, 2000; Goldstein & Fowler, 2003) is that linguistic information such as phonological contrast and lexical distinction may be encoded by differential intergestural timings—i.e., how gestures are temporally coordinated with each other. For example, a subtle change in timing between the consonantal release gesture for a stop and the laryngeal gesture that initiates vocal fold vibration may result in a category change from voiced to voiceless (or vice versa) especially when the change occurs around the category boundary (see Cho & Ladefoged, 1999, for VOT defined in terms of intergestural timing). Some degree of stability in intergestural timing must therefore be guaranteed to maintain the underlying phonological and lexical information in a given language. But at the same time, some degree of variability must also be allowed, given that speech timing by nature is variable in connected speech, and that it is modified by various other factors (e.g., intrinsic factors such as the tongue height for vowels and the place of articulation for consonants, and extrinsic factors such as segmental and suprasegmental contexts; see Cho (to appear) for a review on speech timing). Understanding the sound structure of language as a dynamical system therefore requires understanding not only how individual gestures are temporally realized, but also how their coordination and temporal stability (or variability) vary as a function of multiple linguistic and extralinguistic factors.

In the present study, we continue to explore the dynamical nature of speech timing by investigating how two interrelated factors, prosodic boundary and syllable structure, interactively influence the temporal realization of CV gestures in Korean. The goal of this study is two-fold: first, to understand how the temporal realization of individual consonantal and vocalic gestures is influenced by prosodic boundary strength (an Intonational Phrase (=IP) boundary vs. a Prosodic Word (=Wd) boundary) in different syllable structure conditions (C#V vs. #CV); and second, to understand how timing between the two gestures (i.e., CV coordination) and their temporal stability are modified by an interaction between prosodic boundary and syllable structure. In the remaining part of this section, specific research questions will be introduced along with some theoretical motivations.

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It has been well documented in the literature that temporal realizations of consonantal and vocalic gestures are influenced by prosodic boundary, such that they are produced with longer articulatory durations at a larger prosodic boundary (e.g., an IP boundary) than at a smaller prosodic boundary (e.g., a Wd boundary) (e.g., Byrd, Krivokapić, & Lee, 2006; Byrd & Saltzman, 2003; Cho, 2005, 2006, 2008; Cho & Keating, 2001, 2009; Cho & McQueen, 2005; Edwards, Beckman, & Fletcher, 1991; Fougeron, 2001; Krivokapić & Byrd, 2012; Tabain, 2003; see Fletcher, 2010 or Cho, 2011, for a review). One of the important questions regarding the boundary-related lengthening effect concerns its scope on domain-initial (postboundary) segments. It has been observed that the postboundary lengthening effect (also known as the domain-initial strengthening effect) is by and large limited to the initial consonant and its effect on the following vowel is null or, if it exists, attenuated (e.g., Barnes, 2002; Byrd et al., 2006; Cho, 2006; Cho & Keating, 2001, 2009; see also Byrd & Choi, 2010 and Bombien, Mooshammer, Hoole, & Kühnert, 2010 for relevant boundary effects on consonant clusters in English and German, respectively). These studies, however, have some limitations. They often considered #CV contexts only (but see Fougeron, 2001, for boundary effects on #V in French), such that the vowel under investigation was not placed in the strictly initial position. In addition, some of the previous studies (Barnes, 2002; Cho & Keating, 2001, 2009; Cho, Lee, & Kim, 2011) were based only on acoustic data, so we do not have much information available on how vowels are articulatorily manifested in the not-strictly-initial (#CV) vs. the strictly domain-initial (i.e., #V) context.

That said, a question arises as to whether the attenuated or the null lengthening effect on the not-strictly-initial vowel that has often been observed in the acoustic dimension will also be observable in the articulatory dimension. Two alternative possibilities can be considered. On the one hand, it is possible that the null/weak lengthening effect on the acoustic vowel duration is indeed a reflex of the temporal realization of the underlying vocalic gesture which does not undergo domain-initial lengthening in the #CV context (i.e., when the vowel is not strictly initial). If this is the case, we should be able to observe differences in vocalic gestures between #V and #CV contexts. On the other hand, it is also possible that the vocalic gesture may indeed undergo domain-initial strengthening in the #CV context, but it is not reflected in the acoustic dimension. Given that C and V gestures are likely independent from each other, operating on separate articulatory tiers (Browman & Goldstein, 1992; Fowler, 1983), and given that consonantal articulation is lengthened domain-initially, the temporal expansion of consonantal gesture may have an effect of hiding some portion of the vocalic gesture (i.e., with extended CV overlap). As a result, some portion of the vowel in #CV may be masked in the acoustic dimension, often failing to show a significant boundary effect on the acoustic vowel duration. If this were the case, the vocalic gestures in both #V and #CV would show boundary-related lengthening in the articulatory dimension. We test these possibilities by comparing the boundary effects in two syllable structure conditions—i.e., in #CV and C#V. The comparison of the two conditions will also allow us to test whether or not the domain-initial lengthening effect indeed varies between #CV and C#V in such a way that the magnitude of the boundary effect is larger on the strictly initial vowel (in C#V) in line with the assumption that the domain-initial strengthening may be local to the initial segment whether consonantal or vocalic (Fougeron, 2001; see Cho & Keating, 2009 for a related discussion).

Exploring these possibilities will have further implications for the scope of boundary-induced lengthening in connection with the theory of  $\pi$ -gesture (Byrd, 2000, 2006; Byrd, Kaun, Narayana & Saltzman, 2000; Byrd & Saltzman, 2003; Byrd et al., 2006; Saltzman, 1995).<sup>1</sup> The  $\pi$ -gesture is assumed to be anchored to a prosodic boundary, governing temporal realization of gestures at the juncture, and has its domain of influence which waxes and wanes, so that its effect is strong at the juncture and becomes attenuated in a gradual fashion in both directions (into both preboundary and postboundary segments). A relevant question for the purpose of the present study is then whether the  $\pi$ -gesture influences the temporal realization of the domain-initial vocalic gesture to the same extent regardless of whether the vowel is strictly initial or not (i.e., C#V vs. #CV). Considering the overlapping nature of CV gestures (e.g., Browman & Goldstein, 2000; Fowler, 1983; Löfqvist & Gracco, 1999; Öhman, 1966; Perkell, 1969), and the independent realization of the vocalic gesture in a separate functional articulatory tier in the framework of Articulatory Phonology (e.g., Browman & Goldstein, 1990, 1992), it is reasonable to assume that the vocalic gesture is domain-initial (i.e., immediately adjacent to the prosodic boundary) in both C#V and #CV, although V in #CV is not domain-initial in the conventional left-to-right phonetic notation system. In this theoretical framework, the influence of  $\pi$ -gesture on the vowel should in principle remain unchanged, resulting in comparable lengthening effects in #CV and C#V. Testing this possibility will therefore shed light in some detail on how a  $\pi$ -gesture is actually anchored to the articulatory gesture in different syllable structure conditions.

In addition to examining the boundary effect on the vocalic gesture in #CV and C#V conditions, comparison of temporal realizations in #CV vs. C#V will allow us to explore some other interesting questions. It will be examined whether there is any asymmetric boundary effect on the consonantal gesture between the two conditions—i.e., in coda (C#V) and onset (#CV) position. As the consonant is immediately adjacent to the boundary in both coda and onset positions, one may predict that both will show comparable lengthening effects. However, considering that the onset/coda asymmetry has often been reported in the literature, showing a longer consonantal duration in coda than in onset position at the word level (e.g., Byrd, 1996; Keating, Wright, & Zhang, 1999), it is possible that the coda-onset asymmetry emerges at a phrase level as well, reflected in the magnitude of boundary-related lengthening—i.e., with a more robust boundary effect on the coda consonant before a boundary than on the onset consonant after it. It will also be interesting to examine whether temporal realization of consonantal and vocalic gestures differs as a function of syllable structure even in the potentially neutralizing (phrase-internal) Word boundary condition. In an acoustic study on French, Fougeron (2007) showed that, although a word-final consonant is 'resyllabified' as an onset of the following syllable across a Word boundary when words are concatenated in running speech (a phenomenon known as *enchaînement*), the resyllabification is not complete, cueing the underlyingly different lexical boundaries. The present study will explore this issue in Korean along the articulatory dimension. (See below for further elaboration of the resyllabification issue in terms of intergestural timing.)

The second general goal of the present study is to investigate how the coordination of consonantal and vocalic gestures and their stability are conditioned by the interaction between syllable structure and prosodic boundary. In Articulatory Phonology, it is hypothesized that intergestural timing is lexically specified, and therefore gestures that belong to the same lexical item are expected to be more stably timed than gestures that do not. While this is an important theoretical assumption of Articulatory Phonology, only a few studies have tested it systematically (e.g., Byrd, 1996; Cho, 2001), and therefore more empirical data are required to understand what it means from the kinematic point of view for two adjacent gestures to belong to the same vs. different lexical items. We therefore continue to explore this question, but this time by including the prosodic boundary factor, so that we can observe how CV coordination and its temporal stability is further modulated by prosodic boundary strength.

The lexical effect, which is dubbed with the syllable structure effect in this study (i.e., #CV gestures belong to the same lexical item and C#V gestures to different lexical items), will be considered in both IP and Wd boundary conditions. But the locus of attention will be on the Wd boundary

<sup>1</sup> In an effort to incorporate boundary-induced lengthening effects into the framework of a gestural model, Byrd and her colleagues proposed that temporal variation in the vicinity of a prosodic boundary can be understood in terms of the influence of a so-called  $\pi$ -gesture (prosody gesture) that is governed by prosodic constituency in the task dynamics model (e.g., Saltzman & Munhall, 1989; see Hawkins, 1992, for an overview for non-specialists). A  $\pi$ -gesture is assumed to modulate the rate of the clock that controls articulatory activation of constriction gestures in dynamical systems, determining their articulatory movement speed.

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