



Durational aspects of Korean nasal geminates

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Abstract

The current study focused on the production of geminate nasal consonants across different word boundary types in Korean as a function of speech style to investigate whether temporal properties are preserved across varying speaking rates. Assimilated geminates in Korean, known as true geminates, are produced with distinctively longer consonant duration compared to singletons. Despite a large body of literature for geminates across different languages, geminates in Korean have been relatively less investigated with respect to the durational patterns in relative terms and temporal variabilities. In this study, singletons, word-internal geminates and word-boundary (fake) geminates produced by ten native Seoul Korean speakers were compared in terms of absolute consonant closure duration, preceding vowel duration, the relative ratios (consonant-to-preceding vowel duration) as well as the temporal variabilities in speech production. The results showed that word-internal geminates were produced with longer consonant duration and greater temporal variabilities than singletons and word-boundary geminates in absolute duration, indicating relatively greater flexibility in timing. However, only word-internal geminates were produced with distinctively longer consonant duration with significantly lower variability in relative duration regardless of speech styles. The results provide some insight into the representation of temporal information in the production of Korean geminate consonants.

Keywords: geminate nasal consonants in Korean, word boundary, absolute and relative duration, temporal variability

1. Introduction

Geminate consonants have been, in general terms, defined as double or long consonants, and gemination occurs when a geminate is pronounced for an audibly longer period of time than a singleton. Delattre (1971) and Ham (2001) report from their cross-linguistic survey that the singleton-to-geminate closure ratios show a different durational range from 1:1.4 in English to 1:2.29 in Turkish. Cohn *et al.*, (1999) and Ham (2001) proposed that the singleton-to-geminate ratios tend to be higher in mora-timed languages (e.g., Japanese, Hungarian) than syllable-timed languages (e.g., Italian, Bernese), indicating the correlation between phonological weight and phonetic duration of geminates.

The phonetically long consonants may arise in one of three ways: lexical, assimilation, concatenation. Lexical geminates (ex. [pap:a]

‘mush’ in Italian) are given in the lexicon and are part of the phonemic inventory. Assimilated geminates arise from one segment taking on the identity of the preceding or following segment at a morpheme boundary (ex. *non+li* -> [nol:i], ‘reason’ in Korean, *kor+te* -> [kot:e] ‘do’ infinitive in Bengali). Concatenated geminates can arise from the accidental sequencing of identical consonants that occurs across a morpheme or word boundary (ex. *un+named*, *fun name*). Lexical and assimilated geminates are known as true geminates and concatenated geminates as “fake” geminates (McCarthy, 1986). Korean assimilated geminates are known as true geminates in that, even when spanning a morpheme boundary as in *an+ne* [an:e] ‘guidance’, long segments contrast with short segments as in *ane* [ane] ‘wife’.

Among others, substantially longer consonant closure duration and shorter preceding vowel duration have been reported as salient

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phonetic cues to differentiate geminates from singletons in many languages. Although consonant duration measure is generally considered to be the most salient cue (Lahiri & Hankamer, 1988; Kaye 2005), preceding vowel duration was found to be a significant phonetic characteristic to distinguish not only singletons from geminates but also true geminates from fake geminates (Ridouane, 2010). In addition, as Local & Simpson (1999) state in their studies on geminates in Malayalam, durations in relative terms reflect differences in temporal organization better than absolute duration. Namely, the ratio of consonant to preceding vowel duration has been mentioned as a robust higher-order cue for the singleton/geminate distinction (Pickett *et al.*, 1999; Hansen, 2004).

Despite the phonetic distinctiveness of consonant closure duration in singleton/geminate contrasts, previous studies have shown that the length distinction is not preserved across varying speech rates. In Ladefoged & Maddieson (1996), for example, geminates were shown to be on average one-and-a-half to three times longer than singletons in careful speech (Ladefoged & Maddieson, 1996). Pickett *et al.* (1999) found an instance of perceptual overlap between singletons in slow speech and geminates in fast speech in Italian. Pind (1995) examined the durational pattern of geminates in Icelandic. He reported that the ratios of the consonant to the preceding vowel remained invariant while absolute consonant and vowel duration showed significant changes at different speech rates.

Oh & Redford (2012) examined the absolute and relative durations of assimilated and concatenated word-internal and cross-word boundary fake geminates in English (e.g. *immoral* vs. *unnamed* vs. *fun name*). The results showed that both types of concatenated geminates were shorter than assimilated geminates in relative but not in absolute terms. Similarly in Yang (2011), Korean singleton nasals and geminate nasals were shown to significantly differ in both absolute consonant duration and consonant to preceding vowel ratios in different speech rates. However, a greater degree of durational changes were shown for geminates than singletons in faster speech. These results suggest that some timing properties that distinguish singletons and geminates may be more susceptible to speech rates than others.

With the overarching goal of examining the durational patterns of Korean geminate nasal consonants, the current study addresses two questions: a) Does singletons, word-internal and word-boundary geminates differ in both absolute and relative terms? In other words, to what extent does the boundary effect influence length distinction? b) Which durational cues (absolute consonant, preceding vowel, consonant to vowel ratios) are likely to show greater temporal variability (i.e., the coefficient of variation) as a function of speech style? That is, are these temporal properties stable across individuals in different speech rates? To answer these questions, native Seoul Korean speakers were asked to produce Korean words and phrases containing singletons and geminates spanning different boundary types. They were asked to produce the given words in casual and careful speech as a means of exploring representation. The assumption was that careful speech will highlight the phonetic target, which are often obscured through phonetic reduction in casual speech (Johnson *et al.*, 1993). It was also expected that the phonetic targets would be less susceptible to change in duration due to different speech style.

2. Method

2.1. Participants

Ten native Seoul Korean speakers participated and they were all undergraduate students (5 male and 5 female) at the time of testing. All of the participants were native speakers of Seoul Korean who reported normal hearing. None of the participants had visited an English-speaking country or had been involved in an English training program in Korea. Participants were compensated with cash for a 30 minute-long production experiment.

2.2. Speech stimuli

The stimuli were 18 Korean words and phrases with singleton nasal consonants and geminate nasal consonants within and across a word boundary. The assumption was that the morpheme boundaries in word-internal geminates words that were derived historically from Chinese are not accessed by native Korean speakers during production. The phrases with word boundary (fake) geminates (WBG) were also chosen to match the words with singletons (SI) and word-internal geminates (WIG) in terms of the quality of preceding and following vowels (see <Table 1>). Some words had to be modified due to the difficulty of controlling the surrounding stimulus context and keeping the lexical items somewhat meaningful.

Table 1. Speech stimuli

Singletons (SI)	Word-Internal Geminates(WIG)	Word-Boundary Geminates (WBG)
아내[a.nɛ]	안내[an.nɛ]	한 내각[han.nɛkək]
서녀[sɔ.njɔ]	선녀[sɔ.njɔ]	선 녀석[sɔ.njɔsɔk]
이내[i.nɛ]	인내[in.nɛ]	흰 내면[hujin.nɛmjɔn]
가마[ka.ma]	감마[kam.ma]	감 마당[kam.matɔn]
가면[ka.mjɔn]	감면[kam.mjɔn]	감 면적[kam.mjɔntɛk]
거물[ka.mul]	검문[kam.mun]	검 문명[kam.munmjɔn]

2.3. Procedure

A total of 18 speech stimuli shown in <Table 1> were embedded in the carrier phrase, *I repeatedly said _____ 'Na-nun kyey-sok _____(i)rago hayss-sum-ni-da'*, repeated 3 times, and randomly ordered into 3 different lists of phrases. Before the experiment, unfamiliar words were defined and clarified by the experimenter. For the first 3 repetitions, the experimenter explained that speakers would be producing each phrase in their casual speaking style. After a short break, participants were asked to produce the lists in a careful speaking style. The careful speaking style was explained as being the clear speech style one might use with a foreigner. Speakers first produced the phrase in a casual style. Then, the experimenter asked, *What did you say? 'Mwe-ra-go ha-syess-e-yo?'*, which was the cue to produce the same sentence using a careful style. Speakers produced a total of 54 phrases twice, once in a casual and once in a careful speech style. All recordings were made in the sound-insulated booth in the University Phonetics-Phonology Laboratory using a SHURE SM10A microphone and Marantz PMD660 solid state recorder.

2.4. Data analysis

Ten speakers produced eighteen words repeated 3 times in two speech styles, yielding a total of 1080 tokens. Consonant, preceding

vowel duration and pausing duration measurements were obtained by segmenting the waveform, in reference to the spectrogram. The consonant-to-preceding vowel duration (CV1) was calculated as the proportion of total nasal duration to preceding vowel duration has been reported to best distinguish singleton and nasals in languages with phonemic duration (Idemaru & Guion, 2008; Pickett *et al.*, 1999). Tokens produced with a gap longer than 100 milliseconds were excluded from the analysis as it would indicate hesitancy between speech elements (see Lounsbury, 1954; Goldman-Eisler, 1958). When the pause occurred, the end of first syllable and the beginning of the second syllable was easily identified with the nasal waveform. A mixed-design ANOVA was conducted with absolute duration and the per word coefficient of variability (standard deviation in duration divided by mean duration) as the dependent variable and stimuli type (singleton vs. word-internal geminates vs. word-boundary geminates) and speech condition (casual speech vs. careful speech) as the independent variable. Both speaker and item were treated as random effects. The effect of place of articulation was not a topic of interest and thus was excluded from the analyses.

3. Results

Mean closure duration for singleton and geminate nasal consonants within and across word boundary produced by 10 Seoul Korean speakers is shown in <Figure 1>. There were statistical differences across the stimuli type [$F(2,495) = 284.276, p = .000$], condition [$F(1,495) = 18.783, p = .000$] as well as a significant interaction between stimuli type and speech condition [$F(2,495) = 4.489, p = .008$]. The pattern in <Figure 1> showed that consonant closure duration increased in a linear fashion with stimulus type in casual speech, while absolute closure duration of word-internal geminates evidently increased in careful speech [$F(1,129) = 4.864, p = .029$]. The effect of speech style on singleton was only marginal ($p = .08$). Consonant closure duration of word-internal geminates was not only distinctive from other stimuli types but also manifested a greater effect of speech style.

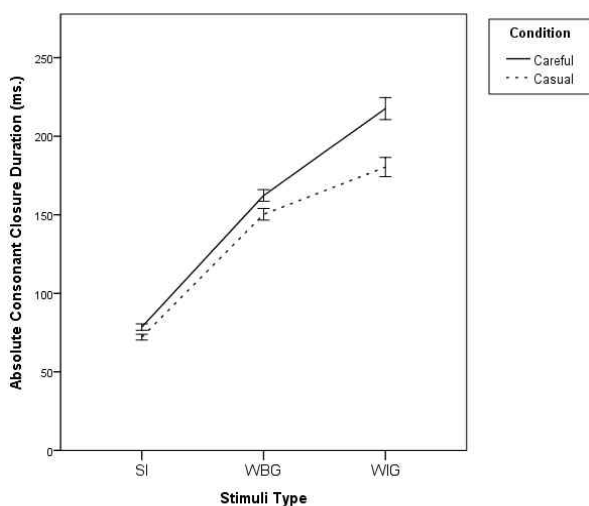


Figure 1. Mean consonant closure duration as a function of stimuli type and speech condition.

In order to investigate the durational stability within each stimuli type, temporal variability was assessed by dividing standard deviation by mean duration of each word by each speaker. Higher the coefficient of variation indicates greater dispersion in the variable. The results showed a significant main effect of stimuli type [$F(2,35) = 24.254, p = .000$] and a marginal interaction between type and speech style [$F(2,35) = 3.160, p = .055$]. As seen in <Figure 2>, singletons were produced with greater variability in careful speech but word-internal geminates showed overall higher temporal variability than other stimuli types regardless of speech condition. The results suggested that word-internal geminates were produced distinctively longer but with considerably higher temporal variability than other stimuli types.

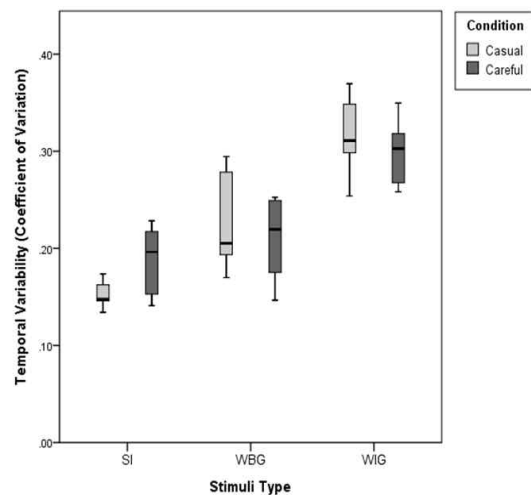


Figure 2. Variability of consonant duration as a function of stimuli type and speech condition.

The analyses on absolute preceding vowel duration returned a significant main effect of type [$F(2,495) = 140.411, p = .000$], condition [$F(1,495) = 24.984, p = .000$] and the interaction between the two variables [$F(2,495) = 3.266, p = .039$]. Separate analysis of each stimuli type showed a significant effect of condition: singleton [$F(1,139) = 8.550, p = .000$], word-boundary [$F(1,190) = 12.700, p = .000$], word-internal [$F(1,166) = 5.479, p = .020$]. Vowels preceding geminates were substantially shorter than those preceding singletons. Pairwise comparisons returned a significant difference between singletons and word-internal and boundary geminates, but no difference between the two types of geminates in either speech condition. Taken together with the absolute consonant duration, the primary durational difference between the word-boundary and word-internal geminates appears to be the consonant closure duration, which becomes significantly longer with greater temporal variability when carefully spoken.

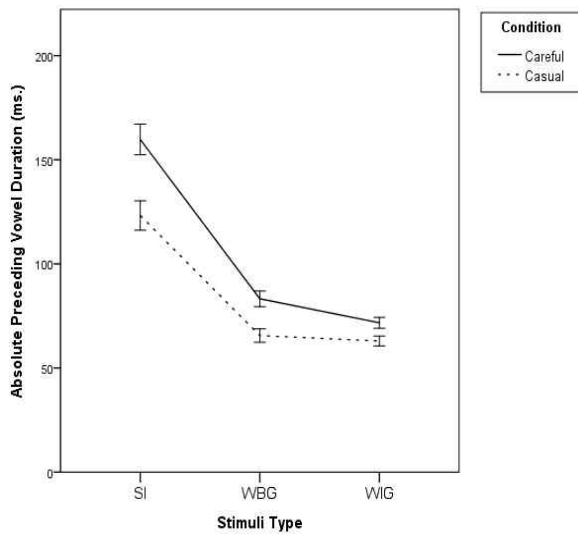


Figure 3. Mean preceding vowel duration as a function of stimuli type and speech condition.

The temporal variability of preceding vowel duration returned a significant main effect of stimuli type [$F(2,35) = 17.279, p = .000$] and speech condition [$F(1,35) = 5.287, p = .028$]. The interaction, however, was not significant [$F(2,35) = 0.128, p = .880$]. Also, singletons and word-boundary geminates did not show any effect of type [$F(1,23) = 0.662, p = .424$] or condition [$F(1,23) = 4.277, p = .055$]. As shown in <Figure 4>, the temporal variability of preceding vowel duration was significantly lower for word-internal geminates regardless of speech condition. This is consistent with previous studies posing that vowel duration provides a highly reliable cue especially in syllable-timed languages (Cohn *et al.*, 1999).

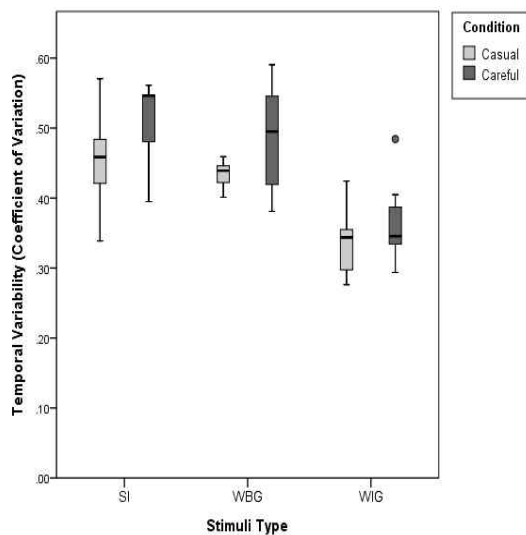


Figure 4. Variability of preceding vowel duration as a function of stimuli type and speech condition.

Given that the pattern of absolute (consonant and preceding vowel) duration and its variability changed not only across stimuli type but also between casual and careful speech condition, the durational stability of relative duration as a function of different speech style was examined. The consonant-to-preceding vowel duration ratios

(i.e., relative duration) showed a significant main effect of stimuli type [$F(2, 495) = 270.009, p = .000$], a significant interaction between the variables [$F(2,495) = 4.951, p = .007$] and a marginal effect of speech condition [$F(1, 495) = 3.660, p = .056$]. As illustrated in <Figure 5>, although the effect of stimuli type was largely driven by singletons, the word-boundary and word-internal geminates were distinctive, especially in careful speech.

The singleton ratios of less than 1 indicate that consonant closure duration was shorter than preceding vowel duration regardless of speech condition. A separate analysis on the two geminate types revealed a significant main effect of stimuli type [$F(1, 358) = 24.290, p = .000$] and type by condition interaction [$F(1,358) = 6.952, p = .009$], suggesting that the stimuli type behaved differently as a function of speech style. As shown in <Figure 5>, the relative timing information was preserved only for the word-internal geminates, regardless of speech condition.

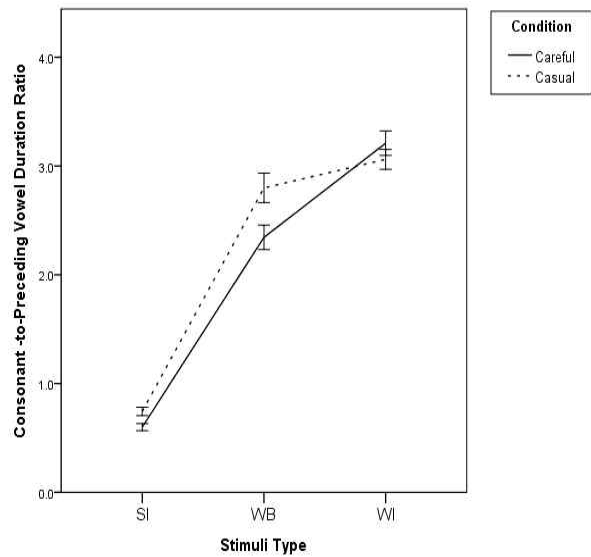


Figure 5. Consonant-to-preceding vowel ratios as a function of stimuli type and speech condition.

The temporal variability of relative duration showed a main effect of stimuli type [$F(2, 35) = 8.197, p = .001$] but no effect of speech condition [$F(1, 35) = 2.916, p = .097$] or interaction [$F(2, 35) = 0.230, p = .796$]. As in <Figure 6>, word-internal geminates greatly differ from other stimuli types in that they are produced with significantly lower variability in both speech conditions ($p < .000$).

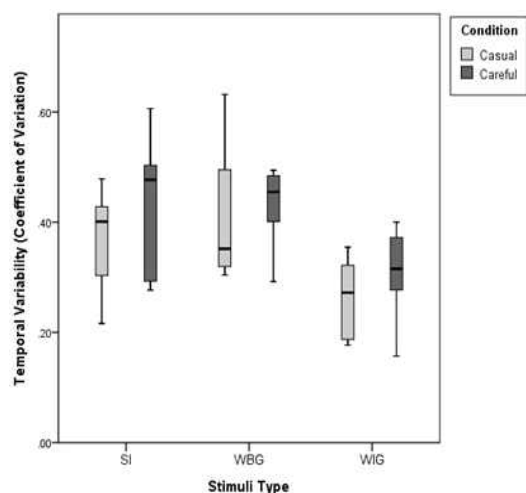


Figure 6. Variability of ratios as a function of stimuli type and speech condition.

Although word-internal and word-boundary geminates show different patterns in the absolute consonant and preceding vowel duration, these temporal cues are likely to be enhanced by additional factors such as boundary cues. Speakers did not produce any pause gap in word-internal geminates but did produced a few gaps in singletons and word-boundary geminates. Under the assumption that hyper-articulated (i.e., careful) speech provides insight into the speaker's representation of phonetic targets, the pattern of gap duration between casual and careful speech was examined. As shown in <Figure 7>, only the gaps produced in word-boundary geminates showed an effect of speech condition [$F(1, 8) = 79.350, p = .013$]. The results were taken to indicate that gaps were highlighted only in geminates across word-boundary as a way of marking meaningful information.

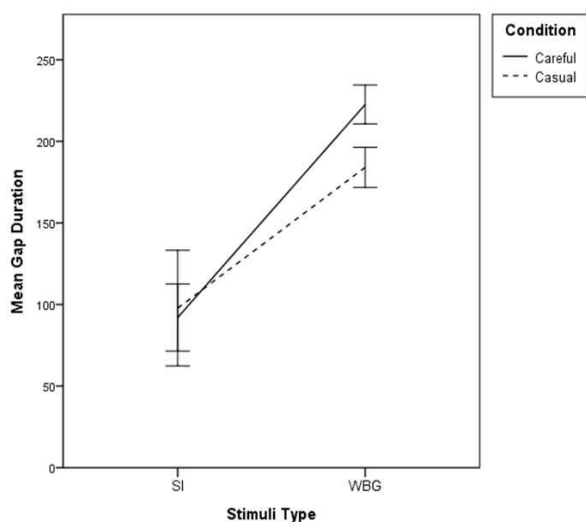


Figure 7. Mean silent gap duration of singletons and word-boundary geminates in casual and careful speech.

4. Discussion

The primary phonetic correlate of consonant gemination across languages is known to be lengthened consonant duration and the current study consistently shows that Korean speakers distinguish word-internal geminates from singletons with straightforward increase in consonant closure duration. On one hand, the durational difference was especially pronounced for word-internal geminates in careful speech. The elongated absolute consonant duration of word-internal geminates, which are differently realized from singletons and word-boundary geminates, represent the inherent length of the stimuli. In addition, the absence of pausing even in careful speech also argue for a representation that is distinctive from double consonants that spanned a word boundary.

The temporal variability of absolute consonant closure duration, on the other hand, was significantly greater for word-internal geminates than word-boundary geminates or singletons. Taking into account that Korean speakers often delete nasal geminates spanning a morpheme boundary when spoken casually (Yang, 2005), it is likely that the participants differed in the degree of faithfully articulating coda nasal of the first syllable especially in casual speech. Under the assumption that temporal variability is a *marker of timing control* (Redford & Oh, 2017), high variability of consonant closure duration in both speech conditions may indicate greater flexibility in timing. Put differently, the shorter closure duration and lower temporal variability of singletons appear to have more specific target duration to achieve in speech production.

The clear durational difference between singletons and word-internal geminates may provide some explanation for the non-significant effect of changes in preceding vowel duration on singleton/geminate discrimination reported in Kim (2013). In Kim (2013), the preceding vowel and consonant duration of singleton and geminates were manipulated and given to Korean and non-Korean speakers for an identification task. In order to examine the effect of preceding vowel duration on singleton and geminate distinction, the preceding vowel duration was manipulated so that it varied from 25 to 150 milliseconds while keeping the singleton and geminate duration distinctive (95 msec. for singletons and 194 msec. for geminates, for example). The results showed that Korean listeners were able to distinguish singletons and geminates 100 percent regardless of the preceding vowel duration. The result may be interpreted to indicate that the salient primary cue (i.e., consonant closure duration) may have been sufficient for Korean listeners to disregard the durational changes in the subsidiary cues.

When the primary cue is obscured, however, the secondary cue appears to play an important role in phoneme length perception. The relative ratio between consonant and preceding vowel duration has been reported to result in perceptual shifts (Pickett *et al.*, 1999; Pind, 1995). Similar to the results found in other languages (Cohn *et al.*, 1999; Ham, 2001), word-internal geminates in Korean exhibited closed syllable shortening (i.e., vowels preceding singletons is significantly longer than vowels preceding geminates). Cohn and her colleagues proposed that the shorter preceding vowel of geminates can be explained as a strategy to hold the timing of vowel-consonant sequences constant in a syllable-timed language. According to Ham (2001) "the shortened vowel duration is indicative of an overall timing strategy (for compensation) which seeks to equalize the temporal interval between syllables" (p 169). What calls our attention is that the preceding vowel duration was not

only significantly shorter for word-internal geminates but the temporal variability of preceding vowel duration was also lower regardless of speech condition. The results suggest that the preceding vowel duration is likely to make heavier contribution to the perceptual identification for geminates than singletons. The current study, however, can not address the question of relative weight of the temporal cues.

The increase in temporal variability for consonant and vowel duration in careful speech (<Figure 2>), however, calls for a more reliable cue. Although duration in absolute terms is greatly affected by speech rate, relative duration as a function of speech rate remained constant for all stimuli types. Moreover, the variability of relative duration between casual and careful conditions is statistically the same across stimuli types, meaning that the relative timing information of each stimuli type was preserved in a more stable manner regardless of speech condition. As reported in previous findings in the literature on phonemic length perception, relative duration provides a robust higher-order cue to the singleton/geminate contrast (Pickett *et al.*, 1999; Idemaru & Guion, 2008).

One way to view the distinctive and stable relative timing of word-internal geminates is that length is intrinsic to the representation and specified in the gestures for word-internal geminates. Thus, gestural timing of geminates is stored as “phonetic template” or “gestural scores” and used as motor instructions for complex articulatory gestures – a view that was formalized in Articulatory Phonology (Browman & Goldstein, 1990, 1992). Accordingly, for words such as wife ‘*ane*’ and guidance ‘*anne*’ with singleton and word-internal geminates, respectively, the gestural scores differ in the relative timing and the difference is reflected in the elongated vowel duration and higher temporal variability of singletons. Although the relative timing of word-boundary geminates is shorter to that of word-internal geminates possibly due to the exclusion of the tokens produced with a pause gap, the variability of word-boundary geminates was greater as the effect of stronger boundary (Byrd & Saltzman, 1998; Cho, 2001). Additional boundary cues are likely to distinguish word-boundary geminates from word-internal geminates. Not only the greater numbers of gap tokens but also the lengthened gap duration especially in careful speech for word-boundary geminates show that gaps were inserted to highlight the boundary itself, which supports the proposal that the phonetic target is hyperarticulated in careful speech (Johnson *et al.*, 1993).

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