Intervocalic consonant sequences in Korean*

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Abstract: This paper reports the results of an instrumental phonetic study of intervocalic consonant sequences in Korean. The study explored a putative positional neutralization produced at the phonetics/phonology interface. It was designed to determine whether Korean intervocalic laryngeal consonants are phonetically distinct from geminates, plain consonants, or laryngeal consonants in consonant clusters. The results showed that the contrast between intervocalic tensed singletons and geminates was neutralized, and that both of these patterned with heterorganic consonant sequences rather than plain singletons. Moreover, we found that this neutralization persisted across (limited) variation in speaking rate, although intervocalic tense consonants were more compressible in faster speech than were post-consonantal tense consonants.

1. Introduction

Informal listening tests, and some preliminary acoustic studies (Han, 1992), have suggested that the contrast between bare tense consonants and geminate tense consonants in Korean is neutralized intervocalically. For instance, [ik'i] 'moss' is neutralized with [ikk'i] 'being ripe' (which is composed of the morphemes /ik/ and /ki/). It has also been suggested (Iverson & Kim-Renaud, 1994) that in Korean there are two processes associated with speaking style which conspire to maintain this neutralization. In careful or expressive speech emphatic gemination gives [itt'a] from /it'a/ 'later', while geminate reduction is active in casual speech to produce [it'a] from /itt'a/ 'there is'.

In this study we explored these issues in an acoustic/phonetic analysis of Korean intervocalic consonants and consonant sequences, focusing on variation in speaking style and on the cross-speaker reliability of typical acoustic patterns.

The evidence shows that intervocalic tense consonants in Korean are phonologically geminates (at the output of the phonology) and that in fast speech geminates are more compressible than singletons - leading to the impression that there is a categorical process of geminate reduction. We conclude that 'geminate reduction' is a result of phonetic realization and not a categorical rule.

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2. Methods

We measured vowel and consonant durations associated with intervocalic consonants and consonant sequences in Korean words produced by six native speakers of the Seoul dialect.

2.1 Subjects. Three female speakers (HO, MO, SI) and three male speakers (OJ, JC, MH) participated in the experiment. One subject was in his late twenties and the others were in their late thirties. The speakers reported no history of speech or hearing impairment.

2.2 Materials. We recorded productions of the words shown in Table 1 which illustrate intervocalic contrasts among lax and tense stops, fricatives, and affricates in Korean. These words are written in a broad phonetic transcription and do not reflect certain properties of the putative underlying representations of the morphemes.

	Plain (C)		Tense (C')		Geminate (CC')	
1	sapuni	'4 minutes (nom)'	sap'uni	'lightly'	sapp'uni	'only shovel'
2	ita	'be'	it'a	'later'	itt'a	'there is'
3	təita	'be more'	təit'a	'more later'	təitt'a	'there is more'
4	cokimita	'is a little'	cokimit'a	'a little later'	cokimitt'a	'there is a little'
5	osak	nonword	os'ak	'a shiver'	oss'ak	'tailor's fee'
6	iki	'selfishness'	ik'i	'moss'	ikk'i	'being ripe'
7	kaca	'let's go'	kac'a	'fake'	kacc'a	'let's have'

Table 1 (continued).

	Sonorant (RC')		NonSonorant (XC')	
1	samp'uni	'only three'	sakp'uni	'fee only'
2	ilt'a	'to read'	ipt'a	'to wear'
3	təilt'a	'to read more'	təipt'a	'to wear more'
4	cokimilt'a	'to read a little'	cokimipt'a	'to wear a little'
5	oms'ak	'flinch'	oks'ang	'roof'
6	iŋk'i	'popularity'	ipk'i	'wearing'
7	kamc'a	'let's wind'	kapc'a	'let's pay back'

Table 1. Words examined in the study. On the left side of each cell the word is written in broad phonetic transcriptions (C' is used to transcribe the tense consonants) and on the right side of each cell is the English gloss.

We took duration measurements of the segments printed in bold face in the table. The words in the first column have plain, lax consonants, which in intervocalic position are produced with voicing throughout the consonant closure. The words in the second column contain a bare tense consonant. The words in the third column contain a geminate tensed consonant. In these words the gemination occurs across a morpheme boundary. The words in the fourth column contain a sonorant/obstruent sequence and the words in the fifth column contain a sequence of heterorganic obstruents. In the last two columns the second consonant in the sequence is tense.

Each speaker read the words five times (in random order) for a total of 1050 tape-recorded tokens. The recordings were made at the Linguistics Laboratory at The Ohio State University. In each production the speaker read aloud a disambiguating meaningful utterance containing the target word and then the target word in isolation. We took measurements from the isolated word reading.

2.3 Measurements. Figure 1 illustrates the duration measurements that we took in this study. This figure shows a spectrogram and time-aligned acoustic waveform of the word [sap'uni] 'lightly'. The vertical cursors mark the consonant closure interval in [p']. Using such time-aligned waveform and spectrogram displays, we measured the duration of the vowel preceding the consonant of interest, the release phase of the consonant and, when possible, the closure interval of the sonorant or obstruent in the intervocalic clusters. Note that it was not possible to distinguish the closure intervals in nonhomorganic stop clusters.

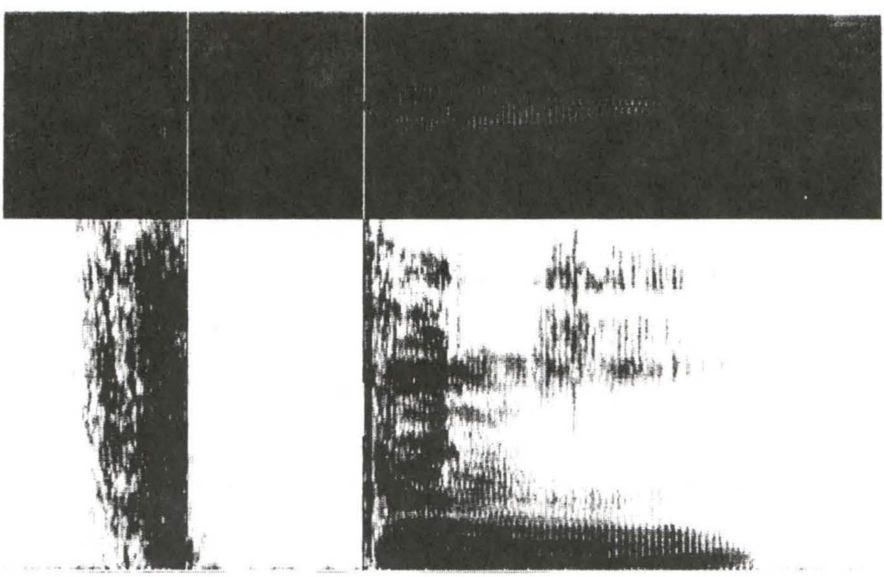

Figure 1. An example spectrogram and waveform display illustrating the consonant closure duration in [sap'uni] 'lightly'.

3. Intervocalic Bare Tense Consonants

Figure 2 shows results averaged over speakers and words. The horizontal axis shows a time line that plots cumulative duration during the course of the word. The vowel portion of each word (the unfilled portion of each bar) starts at 0. Then, for words that had a non-identical sequence of sounds, the X or R interval is shown with light-hatch fill. The dark-hatched portion of each bar shows the interval of the consonant closure of the lax or tense consonant, and the filled portion of each bar shows the release interval. The horizontal bars show the different types of intervocalic consonants. Starting from the top, C stands for the plain lax consonants, C' stands for the bare tense consonants, CC' stands for the geminate tense consonants, RC' stands for the sonorant-obstruent sequence, and XC' stands for the heterorganic obstruent sequence.

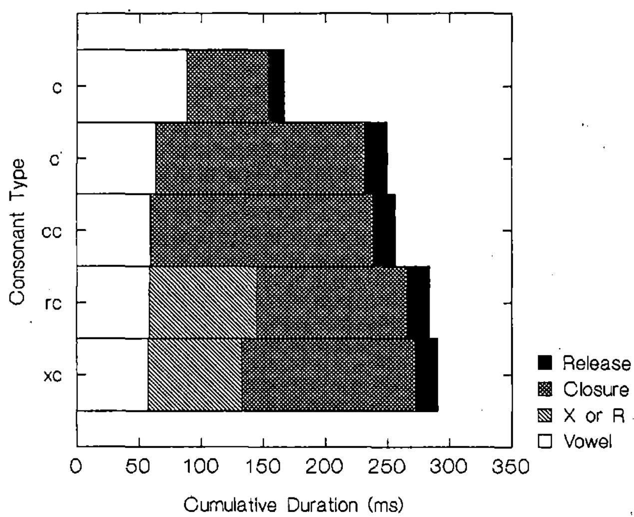

Figure 2. Overall results averaged over speakers and words, comparing different intervocalic consonant types.

Three points are apparent from these data, and were found to be reliable across speakers and word-sets in repeated measures analyses of variance. Taken together these three observations suggest that intervocalic bare tense consonants are realized as geminates.

First, vowels preceding lax consonants were longer than vowels preceding any of the other consonant types. (There was a main effect of consonant type on vowel duration [$F(4,20)=70.752$, $p<0.01$] and a post-hoc comparison of means found that vowels before lax consonants were longer than the other vowels which did not differ from each other. This is illustrated by a list of the different consonant types where underlining indicates the consonant types that had comparable vowel durations. (See Table 2. In this section we are discussing the 'all speakers' row of the table. We will return to speakers OJ and SI in the next section.) In particular, we find it interesting that vowels before bare tense consonants (C') patterned with vowels before consonant sequences. It might be argued that vowels before lax consonants are longer because the lax consonants are voiced; and thus follow a well-known cross-linguistic tendency for vowels to be longer before voiced consonants than before voiceless ones. However, the fact that vowels before sonorant/obstruent sequences are short suggests that voicing is not the relevant factor. The relevant generalization seems to be that vowels are short before consonant sequences, provided we consider the bare tense consonants to be sequences.

	vowel duration	total C closure	consonant closure
all speakers	rc' xc' cc' c' c	c c' cc' rc' xc'	c rc' c' cc'
speaker SI	rc' xc' cc' c' c	c c' cc' rc' xc'	c rc' c' cc'
speaker OJ'	rc' xc' cc' c' c	c c' cc' rc' xc'	c rc' c' cc'

Table 2. Results of Bonferroni post-hoc comparisons of means (ordered from shortest to longest). Labels for the consonant types are as given in Table 1. Consonant types that are connected by a line were not reliably different on a given measure. The first row shows results of repeated-measures analyses of variance of the data pooled across speakers, while the second and third rows show results for two selected speakers.

Second, there was a two-way split in total consonant sequence closure duration, which in the RC' and XC' sequences is the combination of both the light- and dark-hatched portions of the bars. Plain lax consonants have short closure durations while the other consonant types have long total closure durations. (There was a main effect of consonant type on total closure duration [$F(4,20)=89.563$, $p<0.01$] and a Bonferroni post-hoc comparison of means gave the results shown in Table 2, top row, second column.) One point of interest here is that there was no reliable difference in the durations of the geminate tense consonants and the heterosegmental sequences. That is, total closure duration in CC' is not statistically different from total closure duration in RC' or XC'. As with the vowel duration data, the bare tense consonants patterned with the consonant sequences and not with the plain lax consonant. Total closure duration in the C' words was not reliably different from the total closure duration in the CC' words.

Third, in addition to the two-way split in total consonant sequence closure duration just discussed, there is a three-way split in the test-consonant closure duration (the portion of the bars marked with dark-hatching). In this analysis we found that the closure duration of the plain lax consonant was shorter than the closure duration in the sonorant/obstruent sequence, which in turn was shorter than the closure duration in the geminate and bare tense consonants. Note that because measurement of the closure interval was only rarely possible with the heterorganic obstruent sequences we did not include the XC' words in this analysis. (There was a main effect for consonant type [$F(3,15)=59.33$, $p<0.01$] and a Bonferroni post-hoc comparison of means gave the results shown in Table 2, third column, first row.) The tense consonants in sonorant/obstruent sequences are by all accounts singletons. Therefore, this comparison suggests that closure duration in tense consonants are inherently longer than in lax consonants: a phonetic fact about the realization of tense consonants. The comparison also suggests that closure duration in intervocalic bare tense consonants is longer than in singleton tense consonants (the C' in RC'). We take this to reflect the (surface) phonological representation, namely that tense consonants are geminates in intervocalic position.

4. Emphatic Gemination and Geminate Reduction

These data show that intervocalic bare tense consonants and geminate tense consonants did not differ phonetically. However, several authors have suggested that one or both of these consonant types may be realized as geminates in careful speech or as singletons in casual speech. For instance, Iverson & Kim-Renaud (1994) adopt an analysis in which bare tense consonants and geminate tense consonants are neutralized, but may be realized either as geminates or as singletons depending on speaking style. In their analysis, a process of geminate reduction (1) affects geminate tense consonants in casual speech, and a process of emphatic gemination (2) affects bare tense consonants in careful speech, yielding variable, but always neutralized, realizations as in (3).

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(1) Geminate Reduction          (2) Emphatic Gemination
      X X  =>   X                     X     =>    X X
      \ /       |                     |           \/
       c        c                     c            c
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(3) Careful speech . . . . . . Casual speech
akk'i . . . . ak'i — /ak'i/ 'to hold dear'
akk'i . . . . ak'i — /ak-k'i/ 'instrument'

We were able to provide a preliminary test of this analysis because our speakers adopted different speaking styles.

Figure 3 shows average segment durations indicating rate-of-speech differences among our speakers. Speaker OJ read the words more quickly while speaker SI adopted a slower, more careful rate. Assuming processes of geminate reduction and emphatic gemination we predict that speaker OJ is more likely to have produced the intervocalic tense consonants as singletons while speaker SI is more likely to have produced them as geminates.

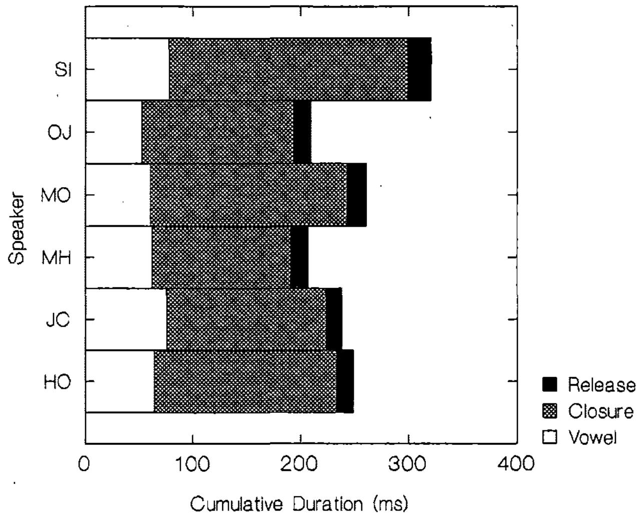

Figure 3. Vowel, consonant closure, and release durations by speaker averaged over words and consonant types. These data indicate differences among the speakers in rate of speech.

Figure 4 shows duration data for speaker SI, and Figure 5 shows the results for speaker OJ. Both speakers show about the same pattern of durations that we found in the overall data (as one would predict given the results of our statistical analyses which tested for the consistency of the patterns across speakers). In both fast and slow speech, the intervocalic tense consonants behaved like geminates. They were preceded by short vowels, had closure intervals which were comparable to the interval occupied by a two consonant sequence, and had closure intervals that were longer than those found in post-consonantal tense consonants (see the results of post-hoc tests shown in the second and third rows of Table 2). There is one difference between the speakers to which we will return below. Speaker OJ produced the C' and CC' words with shorter total closure durations than in the XC' and RC' sequences.

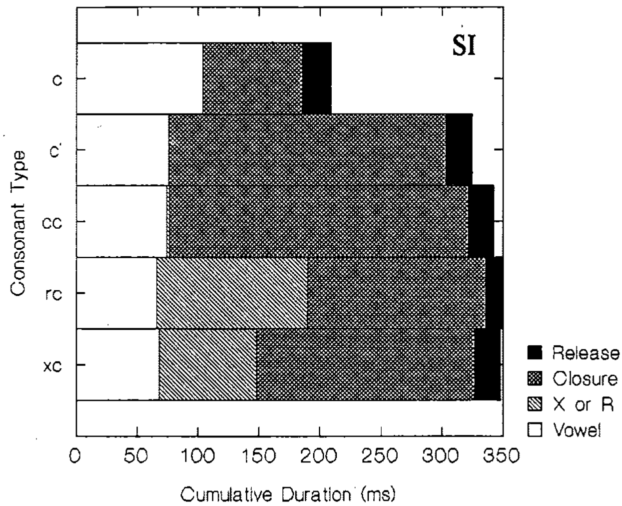

Figure 4. Duration results (as in Figure 3) for speaker SI.

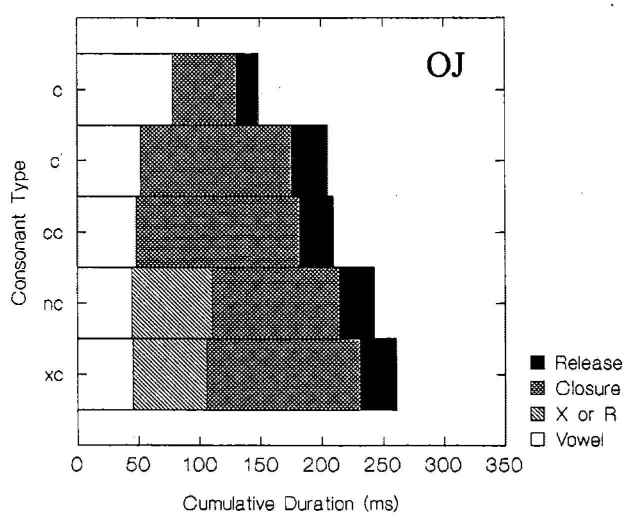

Figure 5. Duration results (as in Figure 3) for speaker OJ.

Another prediction of the emphatic gemination/geminate reduction analysis of speaking style variation is that the relative durations of tense consonants will fall in a bimodal distribution. That is: durations will tend to be either long or short with no intermediate values, because in any set of data within which there is some variation of speaking style we expect to find examples of both geminate and nongeminate tense consonants. To test this prediction we computed histograms of the relative closure durations of bare and geminate tense consonants. To control for speaking rate, we defined relative duration as the ratio the closure duration to the total duration of VC sequence.

Figure 6 is an illustration of a bimodal distribution of the consonant closure duration data from the lax consonants (C) and the geminate tense stops (CC'). Relative duration is shown on the horizontal axis and the bars represent the number of tokens that had a particular relative closure duration. The distribution has two peaks, one for the lax consonants and one for the geminate tense consonants. In a somewhat literalistic interpretation of the durational values of timing slots we could say that we have a group of tokens with one slot on the timing tier (the lax consonants) and another group of tokens with two slots on the timing tier (the geminate tense consonants).

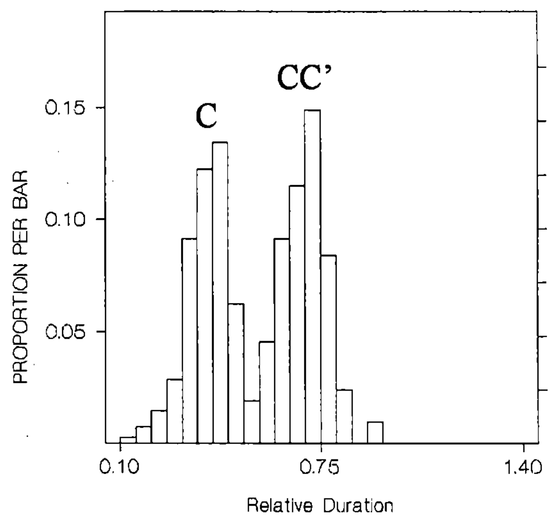

Figure 6. Distribution of consonant closure duration relative to total duration of the VC sequence for pooled data from the lax consonant and geminate tense consonants. These data clearly fall in two groups; one for C and one for CC'.

Figure 7 shows a similar plot of the relative closure durations of bare tense consonants and geminate tense consonants. This plot shows that there was no tendency for a bimodal distribution for these consonant types. Therefore we have no evidence in favor of analyzing speaking style variation in Korean using categorical rules like emphatic gemination and geminate reduction.

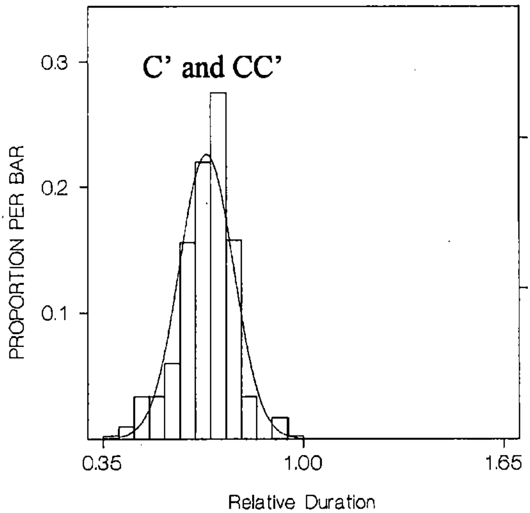

Figure 7. Distribution of consonant closure duration measurements showing pooled data for bare tense consonants and geminate tense consonants. A normal curve is fitted to the distribution.

Why do linguists hear categorical changes like geminate reduction and emphatic gemination in intervocalic tense consonants? Our data suggest that one possible answer is that intervocalic tense consonants are more compressible in fast speech than are post-consonantal tense consonants. Notice in Table 2 that in speaker OJ's productions total consonant sequence closure duration fell into three groups rather than the two groups seen in the overall analysis and in the analysis of speaker SI's productions. Comparing Figures 4 and 5 we see that C' and CC' total closure durations for speaker OJ were on average about 50 ms shorter than were the total closure durations in the RC' and XC' sequences. SI did not show this distinction between the consonant types. Apparently, although speaker OJ maintained a contrast between the consonant closure duration for C'/CC' and the consonant closure in RC' sequences (third column of Table 2) - which, along with the vowel duration data, is evidence that the intervocalic tense consonants remained geminates - at his faster rate-of-speech the intervocalic tense consonants were more compressible than were the intervocalic consonant sequences RC' and XC'.

We investigated this compressibility explanation further by comparing consonant closure durations of intervocalic tense consonants and post-consonantal tense consonants. Figure 8 shows the difference between the average consonant closure duration in the C' and the average duration of post-consonantal tense consonants (the C' of RC'), for each speaker. The speakers are ordered from slowest (SI) to fastest (OJ). For speaker SI, closure duration in C' was about 80 ms longer than C' closure duration in the RC' sequence, while for speaker OJ the difference was only 20 ms, but still reliably different. We see in this figure a good correlation between speaking rate and the difference between closure durations in the bare C' and C' in the RC' sequences. As speaking rate increased the difference decreased. The results for the closure durations in geminate tense consonants were very similar (Figure 9). This pattern of results indicates that as speaking rate increased geminate tense consonants (taken here to include both C' and CC') shrank more quickly (were more compressible) than post-consonantal tense consonants.

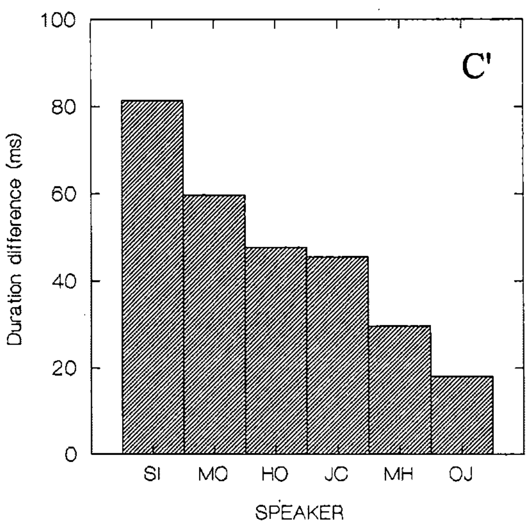

Figure 8. The average difference in the duration of consonant closure in the C' words and the consonant closure duration in the C' of the RC' words for each speaker. Speakers are ordered from slowest talker to fastest talker.

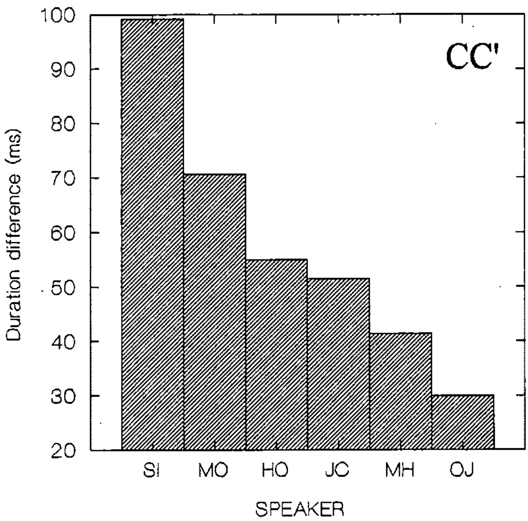

Figure 9. The average difference in the duration of consonant closure in the CC' words and the consonant closure duration in the C' of the RC' words for each speaker. Speakers are ordered from slowest talker to fastest talker.

5. Conclusions

We found evidence for two phonetic aspects of Korean tense consonants. First, our data suggest that closure durations in tense consonants are longer than those in lax consonants. Second, we have preliminary data across speaking rates which suggests that intervocalic tense consonant shortening or lengthening as a function of speaking style should be described in terms of phonetic realization processes rather than in terms of categorical phonological rules of Emphatic Gemination or Geminate Reduction.

We also have evidence suggesting that intervocalic tense consonants (whether underlying or derived by geminate reinforcement) in Korean are geminates at the output of the phonology. This result, taken together with previous research, suggests that the inventory of intervocalic consonants in Korean includes lax (C), and geminated tense (CC') consonants but no tense singletons (C'), while in initial position the inventory includes lax (C) and tense (C') consonants but no tense geminates (CC'). Putative phonological processes such as geminate reinforcement (CC => CC') and tense consonant gemination (C' => CC') conspire to limit the number possible realizations of intervocalic consonants to a set of easily perceived contrasts, at the cost of the resulting homophony of certain forms such as [ikk'i] 'moss' and [ikk'i] 'being ripe'.

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