A Phonetic Study of Korean Intervocalic Laryngeal Consonants*

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ABSTRACT

This paper aims at exploring a putative positional neutralization produced at the phonetics/phonology interface. It was designed to determine whether Korean intervocalic laryngeal consonants are phonetically distant from geminates, plain consonants, or laryngeal consonants in consonant clusters. It was found that the contrast between laryngeal singletons and geminates was neutralized intervocalically, and that both of these were patterned with heteroganic consonant sequences rather than with plain singletons.

1. Introduction

Informal listening tests, and some preliminary acoustic studies(Han, 1992, Yu, 1989), have suggested that the contrast between bare laryngeal consonants and germinate laryngeal consonants in Korean is neutralized intervocalically. For instance, [ik'i] 'moss' is neutralized with [ikk'i] 'being ripe'(which is composed of the morpheme /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 germination gives [itt'a] from /it'a/ 'later', while germinate reduction is active in casual speech to produce [it'a] from /itt'a/ 'there is'.

In this study we explore 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 laryngeal consonants in Korean have a phonologically germinate (at the output of phonology) and that in fast speech germinates

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are more compressible than singletons - leading to the impression that there is a categorical process of germinate reduction. We conclude that 'germinate reduction' is a result of phonetic realization and not a categorical rule.

2. Methods

We measured vowel and consonant duration associated with intervocalic consonants and consonants 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, aspirated stops, fricatives, and affricates in Korean. These words are written in broad phonetic transcription and do not reflect certain properties of the putative underlying representations of the morphemes.

We took duration measurements of the segments printed in bold face in the table. The words in the first column have plain, lax consonant closure, which in intervocalic position are produced with voicing throughout the consonant closure. The words in the second column contain a bare laryngeal consonant. The words in the third column contain a germinate laryngeal consonant. In these words the germination 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 or aspirate.

Each speaker read the words five times (in random order) for a total of 1350 tape-recorded tokens. The recordings were made at the Linguistics Laboratory at The Ohio State University. In each production the speakers 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.

Table 1. Words examined in the study. On the left side of each cell the word is written in broad phonetic transcription (C'is used to transcribe the laryngeal consonants, R stands for the sonorant consonants, and X is used for nonhomorganic obstruents) and on the right side of each dell is the English gloss.

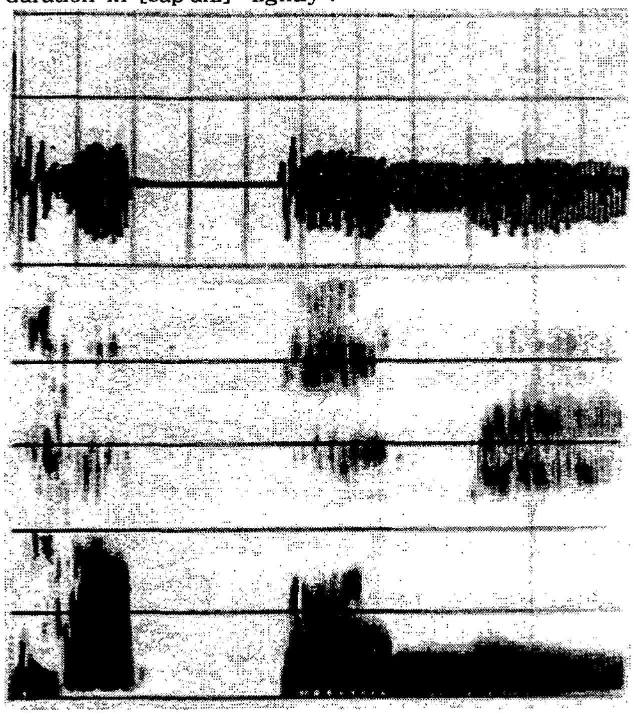
	Plain (C)	Tense (C')	Geminate (CC')
1	sapuni '4 minutes (nom)'	**sap'uni** 'lightly'	**sapp'uni** 'only shovel'
2	**ita** 'be'	**it'a** 'later'	**itt'a** 'there is'
3	təita 'be more'	**təit'a** 'more later'	**təitt'a** 'there is more'
4	**cokImita** 'is a little'	**cokImit'a** 'a little later'	cokImitt'a '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'
8	**nopurIn** 'nonsense word'	**nop^{h}urIn** 'old grass'	**nopp^{h}urIn** 'high blue'
9	macita 'be the eldest child'	mac^{h}ita 'finish'	macc^{h}ita 'hit back'

	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'
8	**nonp^{h}urIn** 'field grass'	**nokp^{h}urIn** 'green and blue'
9	maŋc^{h}ita 'be screwed up	**makc^{h}ita** 'hit hard'

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 always 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'.

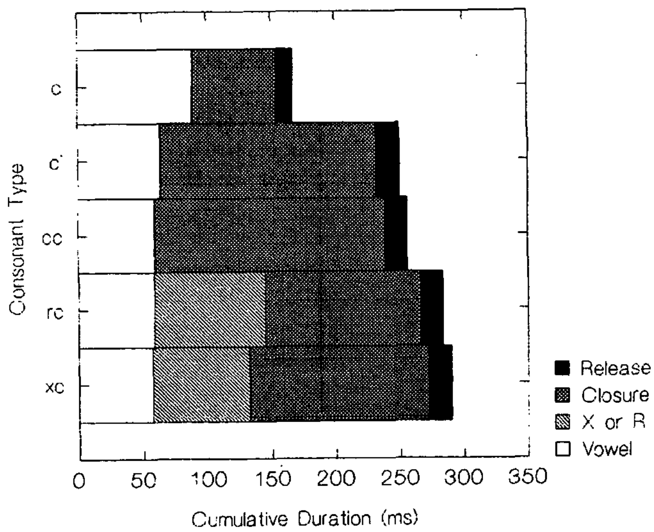


3. Intervocalic Laryngeal Consonants

3.1. 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 fad a nonidentical sequence of sounds, the X or R interval is shown with light-hatch fill. The darkhatched 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 germinate 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 measure analyses of variance. Taken together these three observations suggest that intervocalic bare tense consonants are realized as germinates.

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 section 4.) 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 a 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.

Table 2. Results of Bonferroni post-hoc comparisons of means (order 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 third rows show results for two selected speakers.

	vowel duration	total 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′

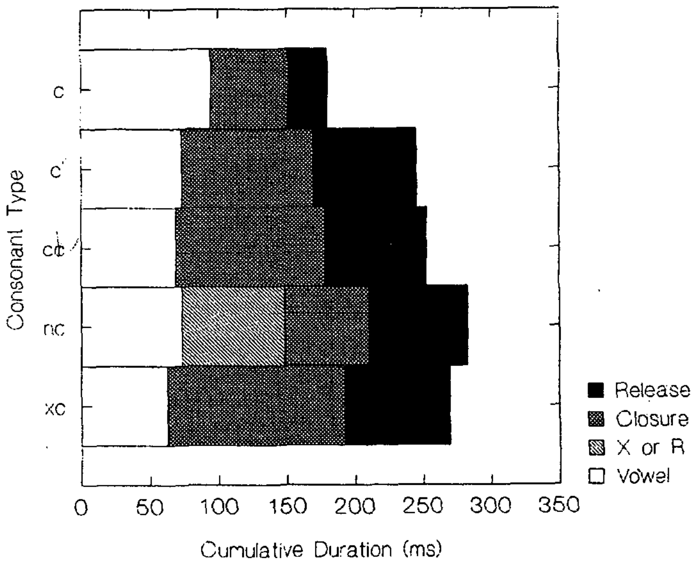
Second, there was a two-way split in total consonant sequence closure duration, which in the RC′ and XC′ sequences is the combination of both the light-and dark-hatched portions of the bars. Plain lax consonants have short closure durations while the other consonant types have long total closure durations.(There 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 germinate 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 germinate 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 germinate in intervocalic position.

3. 2. Intervocalic Bare Aspirated Consonants

Figure 3 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 sonorant preceding C′, the 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 aspirated 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 aspirated consonants, CC′ stands for the germinate aspirated consonants, RC′ stands for the sonorant-obstruent sequence, and XC′ stands for the heterorganic obstruent sequence. In this section, we will define the consonant duration as including the release interval in addition to consonant closure.

Figure 3. Overall results for aspirated consonants averaged over speakers and words, comparing different intervocalic consonant types.



As with the tense consonants, three points are apparent from tense 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 aspirated consonants are realized as germinates.

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 [$F(4,20)=35.1$, $p<0.01$] 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 3. In this section we are discussing the 'all speakers' row of the table. We will return to speakers OJ and SJ in section 4.) In particular, we find it interesting that vowels before bare aspirated consonants (C″) patterned with vowels before consonant sequences. The fact that vowels before bare sonorant/obstruent sequences are short suggests that voicing is not a relevant factor. The relevant generalization seems to be that vowels are short before consonant sequences, provided we consider the bare aspirated consonants to be sequences as we have seen in Figure 2.

Table 3. 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 third rows show results for two selected speakers.

	vowel duration	total consonant duration	consonant duration
all speakers	xc′ c′ cc′ rc′ c	c c′ cc′ rc′ xc′	c rc′ c′ cc′
speaker SI	xc′ c′ cc′ rc′ c	c c′ cc′ rc′ xc′	c rc′ c′ cc′
speaker OJ	xc′ c′ cc′ rc′ c	c c′ cc′ rc′ xc′	c rc′ c′ cc′

Second, there was a two-way split in total consonant sequence duration, which in the RC′ and XC′ sequences is the combination of the light-, dark-hatched and filled 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 [$F(4,20)=64.9$, $p<0.01$] and a Bonferroni post-hoc comparison of means gave the results shown in Table 3, top row, second column.) Hetero-segmental sequences were longer than C′ and CC′. As with the vowel duration data, the bare aspirated consonants patterned with the consonant sequences and not with the plain lax consonant. Total consonant duration in the C″ word not reliably different from the total closure duration in the CC′ words.

Third, there was a two-way split in the total test-consonant duration. Notice that we defined the consonant duration as the consonant closure and the release interval (the combination of both the dark-hatched and filled portions of the bars). In this analysis we found that the consonant duration of the plain lax consonant and of the sonorant/obstruent sequence was shorter than the consonant duration in the germinate and bare aspirated 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 [$F(3,15)=35.8$, $p<0.01$] and a Bonferroni post-hoc comparison of means gave the results shown in Table 3, third column, first row.) The aspirated consonants in sonorant/obstruent sequences are by all accounts singletons. Therefore, this comparison suggests that consonant duration in aspirated consonants are inherently longer than in lax consonants : a phonetic fact about the realization of aspirated consonants. These results show that consonant duration in aspirated stops is similar to consonant duration in tense consonants. C′ is no different than CC′.

4. Emphatic Germination and Germinate Reduction

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

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(1) Germinate Reduction          (2) Emphatic Germination
    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-ki/	′instrument′
$ipp^{h}ak$	$ip^{h}ak$	/ip-hak/	′entering school′

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

Figure 4 shows average segment durations indicating rate-of-speech differences among our speakers. Speakers OJ read the words more quickly while speakers SI adopted a slower, more careful rate. Assuming processes of germinate reduction and emphatic germination we predict that speaker OJ is more likely to have produced the intervocalic tense consonants as singletons while speaker SJ is more likely to have produced them as germinates.

Figure 4. Vowel, consonant closure, and release duration by speaker averaged over words and consonants types. These data indicate differences among the speakers in rate of speech.

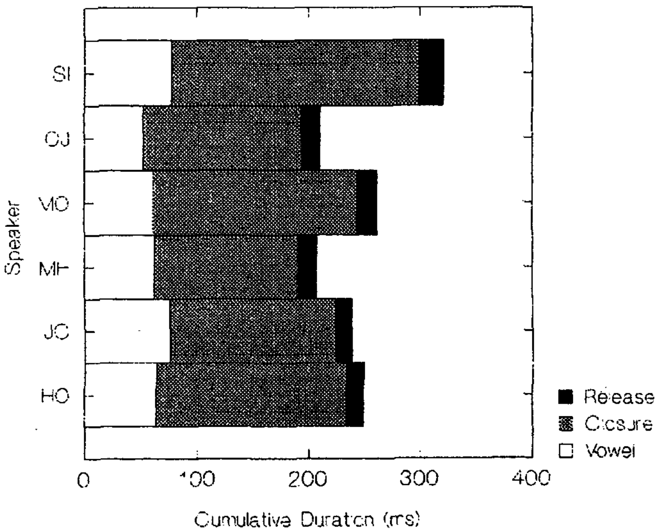


Figure 5 shows duration data for tense consonants for speakers SI, and Figure 6 shows the results for speaker OJ. Both speakers show about the same pattern of durations that we found in the overall data (as one would predict given the results of our statistical analyses which tested for the consistency of the patterns across speakers). In both fast and slow speech, the intervocalic tense consonants behaved like germinates. They were preceded by short vowels, had closure intervals which were comparable to the interval occupied by a two consonantal sequences, 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. Speakers OJ produced the C′ and CC′ words with shorter total closure durations than in the XC′ and RC′ sequences. Another prediction of the emphatic germination/germinate reduction analysis of speaking style variation is that the relative durations of tense consonants will fall in a binodal 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 germinate and nongeminate tense consonants. To test this prediction we computed histograms of the relative closure durations of bare and germinate tense consonants. To control for speaking rate, we defined relative as the ratio of the closure duration to the total duration of AC sequence.

Figure 5. Duration results (as in Figure 4) for speaker SI.

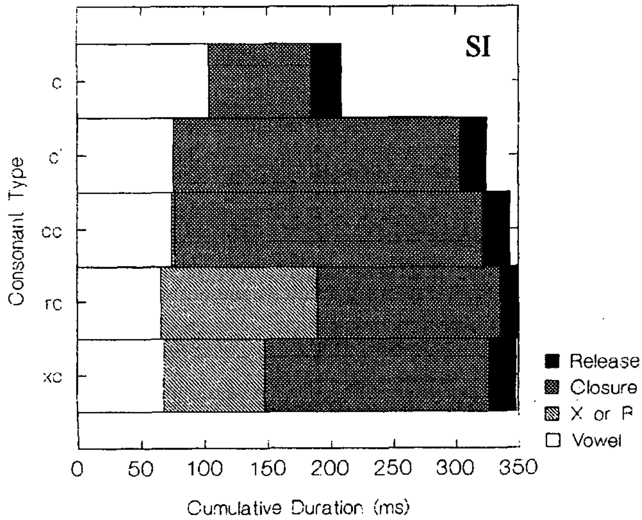


Figure 6. Duration results (as in Figure 4) for speaker OJ.

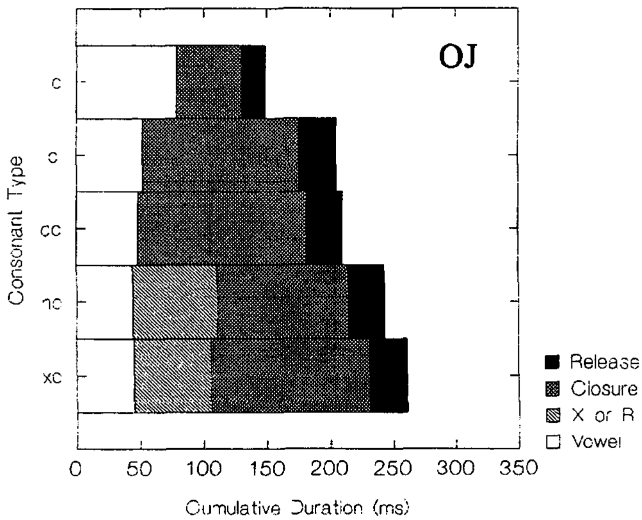


Figure 7 is an illustration of a binodal distribution of the consonant closure duration data from the lax consonants (C) and the germinate tense stops (CC′). Relative duration is shown on the horizontal axis and the bars represent the number of tokens that had a particular relative closure duration. The distribution has two peaks, one for the lax consonants and one for the germinate 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 slots on the timing tier (the germinate tense consonants).

Figure 7. Distribution of consonant closure duration relative to total duration of the VC sequence for pooled data from the lax consonant and germinate tense consonants. These data clearly fall in two groups; one for C and for CC′.

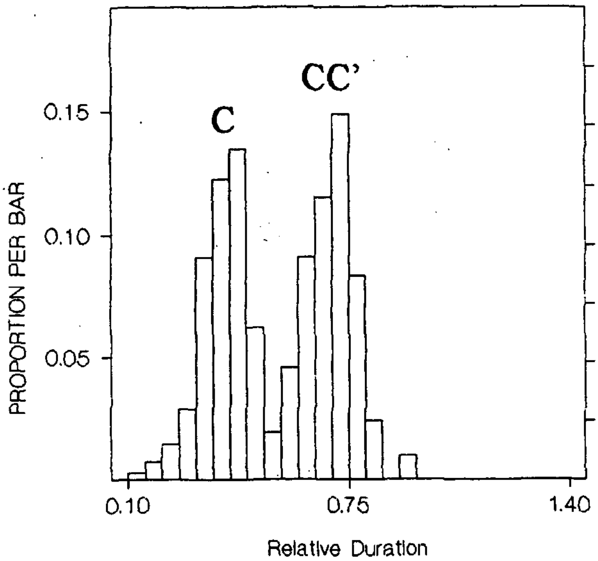


Figure 8 shows a similar plot of the relative closure durations of bare tense consonants and germinate tense consonants. This plot shows that there was no tendency for a binodal distribution for these consonant types. Therefore we have no evidence in favor of analyzing speaking style variation in Korean using categorical rules like emphatic germination and germinate reduction.

Figure 8. Distribution of consonant closure duration measurements showing pooled data for bare tense consonants and germinate tense consonants. A normal curve is fitted to the distribution.

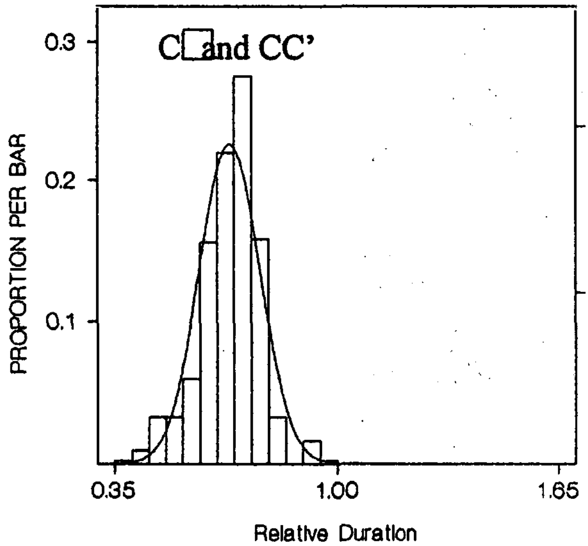


Figure 9. Duration results for aspirated consonants for speaker SI

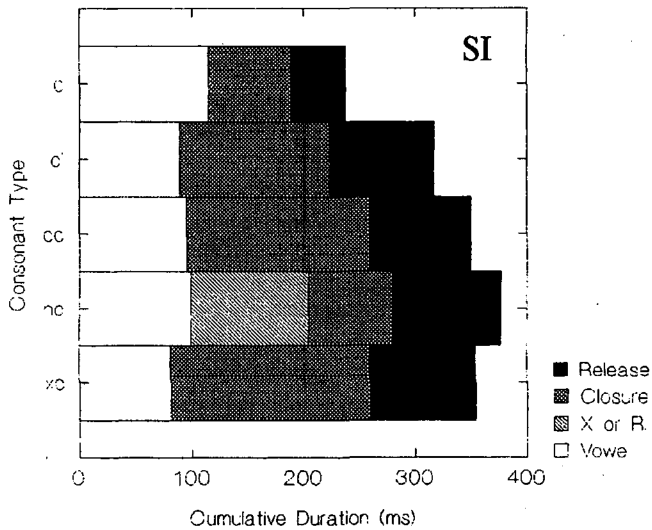
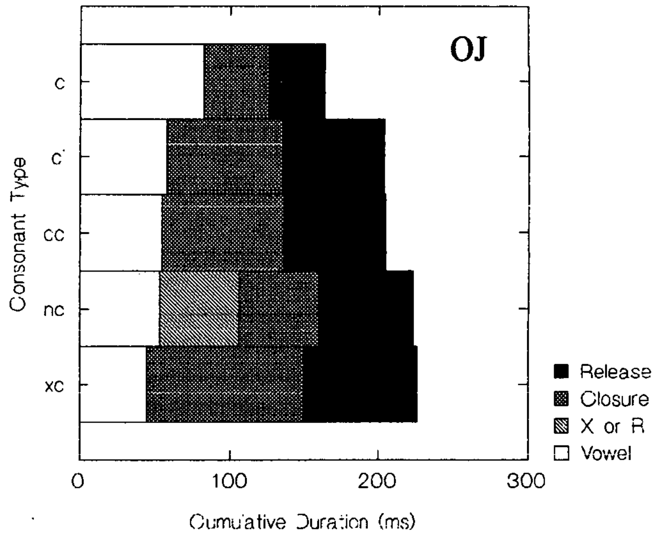


Figure 10. Duration results for aspirated consonants for speaker OJ



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 aspirated consonants behave like germinates. 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.

Why do linguists hear categorical changes like germinate reduction and emphatic germination 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-consonant 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 SJ'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 germinates - at his faster rate-of-speech the intervocalic tense consonants were more compressible than were the intervocalic consonant sequences RC′ and XC′.

We investigated the compressibility explanation further by comparing consonant closure durations of intervocalic tense consonants and post-consonantal tense consonants. Figure 11 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 germinate tense consonants were very similar (Figure 12). This pattern of results that as speaking rate increased germinate tense consonants (taken here to include both C′ and CC′) shrank more quickly (were more compressible) than post-consonantal tense consonants.

Figure 11. 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.

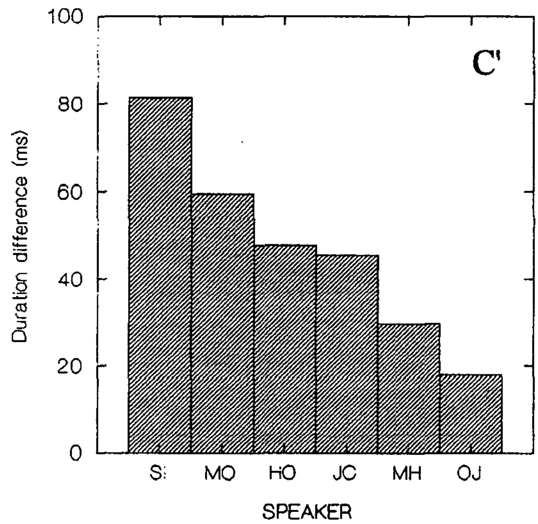
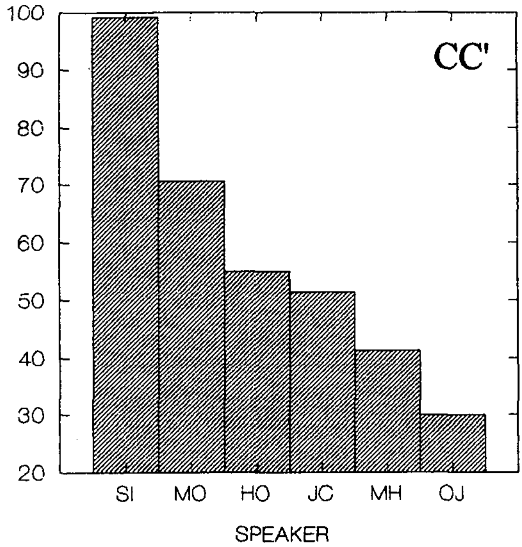


Figure 12. The average difference in the duration of consonant closure in the CC′ words and the consonants closure duration in the C′ of the RC′ words for each speaker. Speakers are ordered from slowest talker to fastest talker.



As with the compressibility explanation for tense consonants, we also investigated the compressibility explanation by comparing consonant durations of intervocalic aspirated consonants and post-consonantal aspirated consonants. Figure 13 shows the difference between the average consonant duration in the C″ and the average duration of post-consonantal aspirated 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 60 ms longer than C′ duration in the RC′ sequence, while for speaker OJ the difference was only 25 ms, but still reliably different. We see in this figure a rough correlation between speaking rate and the difference between consonant durations in the bare C′ and C′ in the RC′ sequences. The results for the consonant durations in germinate aspirated consonants were very similar (Figure 14). This pattern of results indicates that as speaking rate increased germinate aspirated consonants (taken here to include both C′ and CC′) shrank more quickly (were more compressible) than post-consonantal aspirated consonants.

Figure 13. The average difference in the consonant duration in the C′words and the consonant duration in the C′ of the RC′ words for each speaker. Speakers are ordered from slowest talker to fastest talker.

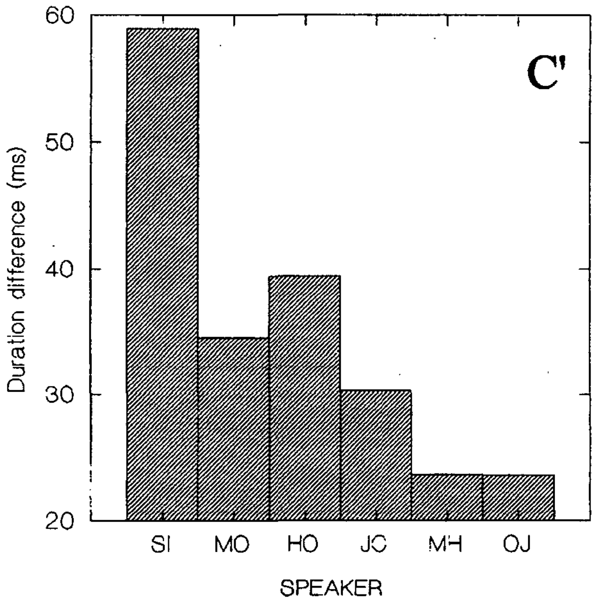
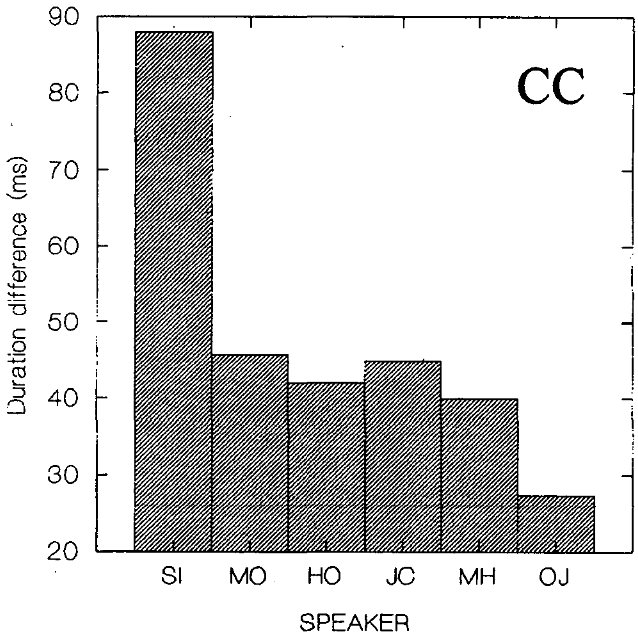


Figure 14. The average difference in the consonant duration in the CC′s words and the consonant duration in the C′ of the RC′ words for each speaker. Speakers are ordered from slowest talker to fastest talker.



5. Conclusions

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

We also have evidence suggesting that intervocalic laryngeal consonants (whether underlying or derived by germinate reinforcement) in Korean are germinates 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 germinated laryngeal (CC′) consonants but no laryngeal singletons (C″), while in initial position the inventory includes lax (C) and laryngeal (C″) consonants but no laryngeal germinates (CC″). Putative phonological process such as germinate reinforcement (CC => CC″) and laryngeal consonant germination (C″ => CC″) conspire to limit the number possible realizations of intervocalic consonant 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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