Working Papers of the Cornell Phonetics Laboratory
1994, vol. 9, pp. 137-154.

Complete neutralization of manner of articulation in Korean

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While most studies of neutralization have focused on word-final devoicing, the present study investigated a different kind of neutralization, namely that of *manner of articulation*. Korean has a rule of Coda Neutralization, whereby word-final obstruents (e.g., /t, t^h , s/) are all phonetically realized as [t]. Making use of the fact that vowels preceding fricatives are longer than when preceding oral stops, vowel and closure durations were measured to determine if the speech signal contained any acoustic cues to the underlying manner distinction. Data from four speakers suggest that neutralization of manner is phonetically complete. Moreover, complete neutralization was observed despite the fact that Korean orthography distinguishes between the different underlying consonants. Finally, 83% of all word-final stops in this study were found to be followed by a brief burst. This is of particular interest given the long tradition in Korean phonology to consider coda neutralization to yield unreleased stops.

1. Introduction

One of the most basic concepts of phonological theory is that of neutralization whereby phonemic distinctions are eliminated in a particular phonological context (e.g., Trubetzkoy 1939). The phonological approach for merging or obliterating distinctive phonemes into a single phoneme in a certain linguistic environment predicts that neutralization is phonetically manifested as complete. However, there is a lively debate in the current phonetic literature as to whether phonological neutralization is phonetically complete or incomplete (for reviews, see Dinnsen 1985; Blumstein 1991).

Almost all phonetic studies of neutralization have focused on word-final devoicing, with findings supporting either complete or incomplete neutralization. Specifically, research on languages with a phonological rule of word-final devoicing has shown that neutralization is phonetically incomplete as evidenced by vowel duration, duration of voicing into closure, and closure duration (e.g., Catalan: Dinnsen and Charles-Luce 1984; German: Port and O'Dell 1985; Charles-Luce 1985; Port and Crawford 1989; Polish: Slowiaczek and Dinnsen 1985; Russian: Pye 1986). Since in many languages vowels are longer when preceding voiced consonants relative to voiceless consonants (e.g., Chen 1970; Laeufer 1992 and references therein), incomplete voicing neutralization may be expected to manifest itself in the form of slightly longer vowels and shorter final consonant closures for those surface forms derived from stems with an underlyingly voiced final consonant.

On the other hand, there are studies which support complete neutralization (e.g.

Fourakis and Iverson 1984 for German; Jassem and Richter 1989 for Polish). These authors ascribe reports of a lack of complete neutralization to unnatural laboratory circumstances, which lead to hypercorrect productions. In particular, the results of Fourakis and Iverson (1984) and Jassem and Richter (1989) both suggest that voicing neutralization is complete if one manages to exclude orthographic information from the elicitation procedure. It should be noted, however, that Jongman, Sereno, Raaijmakers, and Lahiri (1992) found complete voicing neutralization in word-final position in Dutch even when subjects read a wordlist where the contrasting underlying forms differed in their orthography.

While most phonetic studies to date investigated the acoustic correlates of devoicing, it is not clear whether their findings would extend to other instances of neutralization. For example, Lahiri, Schriefers, and Kuijpers (1987) showed complete neutralization in their study of vowel length in Dutch. Namely, Lahiri et al. (1987) found no difference in duration between long vowels derived by an open-syllable lengthening rule and vowels that are underlyingly long. Neutralization was thus complete in that the underlying vowel length distinction was lost in the surface phonetic representation.

These results illustrate the importance of investigating many different instances of neutralization across a wide variety of languages before concluding whether or not phonological neutralization generally leads to complete phonetic neutralization. The present paper extends our knowledge of the phonetics of neutralization by examining a qualitatively different kind of neutralization, namely neutralization of manner of articulation. In particular, the present study investigates whether the underlying distinction between Korean syllable-final fricative and stop is completely neutralized on the surface.

2. Korean coda neutralization

2.1 The three types of coda neutralization

Korean distinguishes three types of Coda Neutralization: laryngeal, manner, and palatal neutralization. Korean has three types of voiceless consonants: lax (p, t, k, tʃ), aspirated (p^h, t^h , k^h, $tʃ^h$), and reinforced (p', t', k', tʃ', s'). These three types of consonants are neutralized into lax consonants in coda position (Martin 1951; Lee 1972; Kim-Renaud 1974; C-W. Kim 1979; Chung 1980). As shown in (1a), laryngeal neutralization merges all underlying laryngeal distinctions into homorganic lax stop consonants[1].

[1] In Korean, /p', t', tʃ'/ are not attested in coda position.

1a. Laryngeal neutralization

p, $p^h]_\sigma$	→	[p]	e.g.	/cip^h/	[cip]	'straw'
t, $t^h]_\sigma$	→	[t]		/mit^h/	[mit]	'bottom'
k, k^h, k'$]_\sigma$	→	[k]		/pak'/	[pak]	'outside'

Manner neutralization merges fricatives into a lax coronal stop [t], as shown in (1b).

1b. Manner neutralization

s, s', h$]_\sigma$	→	[t]		/kis/	[kit]	'feather'
				/is'/	[it]	'to be located'
				/tʃoh/	[tʃot]	'to like'[2]

Finally, under palatal neutralization all palatal distinctions are merged into a lax coronal [t] as well, as shown in (1c).

1c. Palatal neutralization

tʃ, tʃ$^h]_\sigma$	→	[t]	/natʃ^h/	[nat]	'face'
			/natʃ/	[nat]	'day'

When followed by a vowel-initial suffix, the coda consonant of a word is syllabified into the onset of the vowel-initial suffix, blocking Coda Neutralization from occurring as in (2a). When the consonant syllabified into the onset is lax, it gets voiced (depending on the prosodic context, see Silva 1992) in intervocalic position, as shown in (2b)[3] . In contrast, when followed by a consonant-initial suffix, the final consonant of a word is syllabified as a coda and this undergoes Coda Neutralization. As the result of Coda Neutralization, the distinctive phonation types are all merged into lax stop counterparts, as shown in (2c).

2 The merger of /h/ into [t] is limited to *word*-final position. In coda position, preceding an obstruent, /h/ will delete, with aspiration spreading to the following obstruent:

/tʃoh/ + /ta/ → [tʃot'a] 'like' + Indicative

3 This holds for stop consonants. For fricatives, /s/ remains unvoiced (1), while /h/deletes (2):

1. /kis/	'feather'	kis + i	→	[ki.ʃi]	'feather' + subj.
2. /tʃoh/	'to like'	tʃoh + a	→	[tʃo.a]	'like' + 'ing'

2a.	/tʃip^h/	'straw'	tʃip^h + i	→	[tʃi.p^{h}i]	'straw'+subj.
	/pak'/	'outside'	pak' + i	→	[pa.k'i]	'outside'+subj.
2b.	/tʃip/	'house'	tʃip + i	→	[tʃi.bi]	'house'+subj.
	/pak/	'gourd'	pak + i	→	[pa.gi]	'gourd'+subj.
2c.	/tʃip^h/	'straw'	tʃip^h + to	→	[tʃip.t'o]	'straw'+also
	/pak'/	'outside'	pak' + to	→	[pak.t'o]	'outside'+also

2.2 Neutralization of manner

Of the three types of Korean neutralization, the present study focuses on neutralization of manner of articulation. Korean has minimal contrasts, with members underlyingly ending in /t/, /t^h/, or /s/. However, these underlyingly distinctive consonants are merged on the surface in coda position, thus being phonetically (at least impressionistically) realized as [t], as shown in (3):

(3)	/mat/	'elder'	[mat]
	/mat^h/	'to smell'	[mat]
	/mas/	'taste'	[mat]

Given the presence of such contrasts, the present study examines whether or not this type of manner neutralization is phonetically complete. Specifically, this study investigates whether there are acoustic differences in a surface form such as [mat], depending on the underlying form from which it has been derived.

For the present investigation, we follow a rationale similar to that used in phonetic studies investigating voicing neutralization. It has been shown for many languages that vowels preceding fricatives are longer than vowels preceding stops (e.g., Meyer 1904 for German; Metz 1914 for Italian; Navarro Tomas 1916 for Spanish; House and Fairbanks 1953; Peterson and Lehiste 1960; Umeda 1975 for English; Delattre 1962 for French; Nooteboom and Cohen 1984 for Dutch). Since Korean fricatives never surface as fricatives in coda position, it is impossible to directly confirm this generalization for Korean. However, it seems plausible to ascribe this effect to universal mechanisms.

As Delattre (1962) states:

> "(...) stops ought to shorten the preceding vowel more than do fricatives because more closure (for the stops) requires more effort - anticipation of a greater effort shortens the vowel more." (Delattre 1962, p.1142)

Although Delattre (1962) clearly refers to a universal, automatic physiological mechanism, it is also possible that this mechanism might be auditorily motivated. For example, Kluender, Diehl, and Wright (1988) offer an auditorily-based account of vowel length differences before voiced and voiceless consonants. Kluender et al. (1988) suggest that speakers deliberately vary vowel length to auditorily enhance closure duration as a cue for the voicing of the final consonant.

There is evidence that for those cases in which comparisons between more thoroughly investigated languages and Korean can be made, Korean patterns in a similar fashion. Chen (1970) shows that Korean vowels preceding (heterosyllabic) voiceless aspirated stops are shorter than when preceding voiced stops. As for effects of manner of articulation, House and Fairbanks (1953) and Peterson and Lehiste (1960) report for English and Nooteboom and Cohen (1984) for Dutch that vowel duration in words increases as the manner of the final consonant changes from stop to fricative to nasal. Indeed, for Korean, Yang (1978) shows that vowels preceding nasals are longer than those preceding stops at the same place of articulation.

We can therefore make the following predictions about Korean manner neutralization: If Korean manner neutralization is incomplete, we would expect differences in vowel and consonant durations. Namely, that the vowel preceding underlying fricative /s/ would be longer than that preceding underlying stops /t, t^h/; or, given the general trading relation between vowel and consonant closure duration, stops derived from /t, t^h/ would be longer than those derived from /s/. Conversely, if Korean manner neutralization is complete, no differences in terms of vowel or consonant duration would be expected.

3. Acoustic Study

3.1 Methods

Four Korean subjects, two males (1, 2) and two females (3, 4), participated in this experiment. They were recruited from the Cornell student population. They had been in the U.S. for at most four years, and conducted most of their interactions outside the classroom in Korean. None of the speakers had any known speech or hearing disorders.

3.2 Materials and Procedure

Test words consisted of 17 minimal wordpairs. As shown in the Appendix, of these 17 pairs, nine exemplify the neutralization of underlying /t, s/ into [t], while eight pairs exemplify the neutralization of underlying /t^h, s/ into [t]. Three underlying forms, /mis/, /mas/, and /kəs/, served a dual purpose as they were contrasted with underlying forms ending in both /t/ and /t^h/. Five repetitions of the stimuli were randomized and embedded in the carrier phrase [əsə ____ kwa sap malhasejo] ('Please say ____ and a shovel'). As discussed above, when followed by the consonant-initial suffix /kwa/ 'and', the coda consonant of the CVC target word is expected to be neutralized. The sentences, interspersed with unrelated filler sentences, were presented in lists in Korean orthography. Korean orthography distinguishes the three underlying consonants /t, t^h, s/. The total number of target words was 620 (31 words x 5 repetitions x 4 speakers).

The four Korean speakers were recorded in a sound-proofed booth in the Cornell Phonetics Laboratory, using a cardioid microphone (Electrovoice RE20) and high-quality cassette recorder (Marantz PMD 222). Before recording, speakers practiced reading a few randomly chosen test sentences to familiarize themselves with the materials. All materials were read at a comfortable speed throughout the recording session.

3.3 Analysis

All sentences were digitized onto a Sun Sparcstation 2 at a sampling rate of 11 kHz with 16-bit resolution, and stored as files to be processed by the commercial software package WAVES+/ESPS. Each sentence was stored under a numeric code which contained no information about the underlying form of the target word in order to avoid any biased measurements. For each target word, vowel duration and closure duration of the coda consonant were measured on the basis of both wideband spectrograms and waveforms. A representative segmented word is shown in Figure 1. Vowel onset was considered to be the onset of the first formant, which corresponded with the onset of periodicity in the waveform. Vowel offset was taken as the offset of the second formant. Closure duration was defined as the interval between vowel offset and burst release.

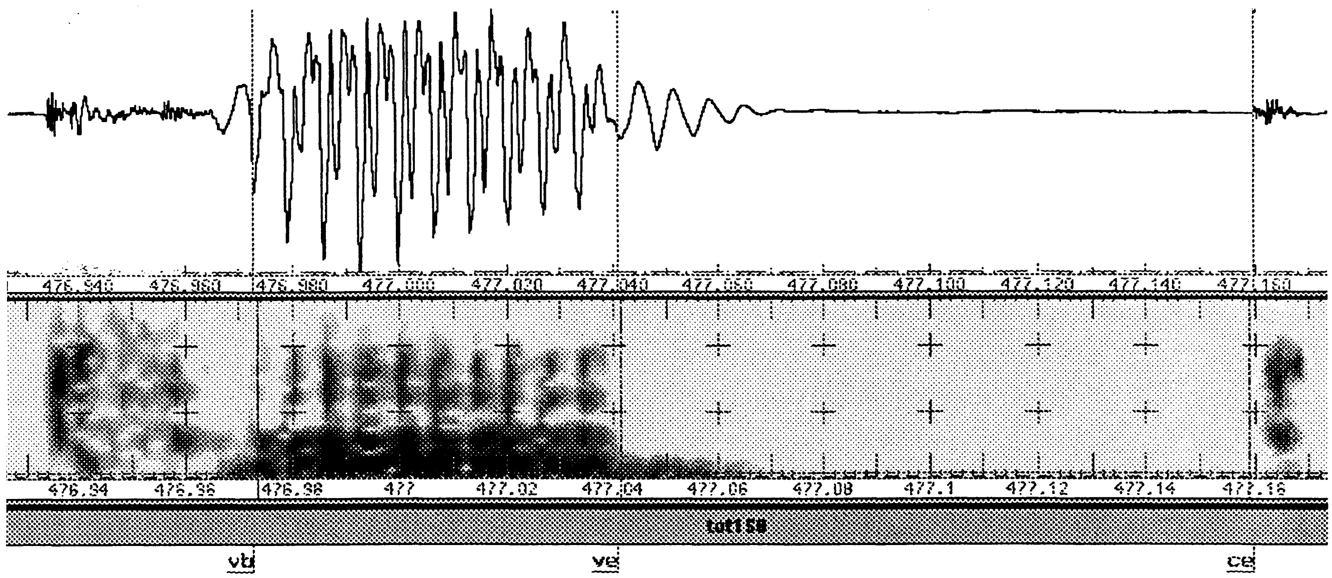

Figure 1. Segmented and labeled waveform and wide-band spectrogram of the word /kot/ as produced by Speaker 2. Vb marks the beginning of the vowel, ve marks the end of the vowel and the onset of closure, while ce marks the end of closure.

For words without bursts (17%), only vowel duration was measured since the closure duration for those words could not be measured. Vowel and consonant durations were first measured by the first author. In order to evaluate the consistency of these measurements, a subset of the stimuli (34 stimuli per speaker, distributed across the different underlying forms) was measured by the second author. The correlation between the two sets of measurements was high (Pearson's $r = .9809$, $p < .0001$), suggesting that there was a high degree of consistency in the application of segmentation criteria.

4. Results

Vowel duration measurements and consonant duration measurements for each speaker are shown in Figures 2-5. Figures 2 and 3 show vowel and consonant duration, respectively, for minimal pair members ending in underlying /t/ and /s/.

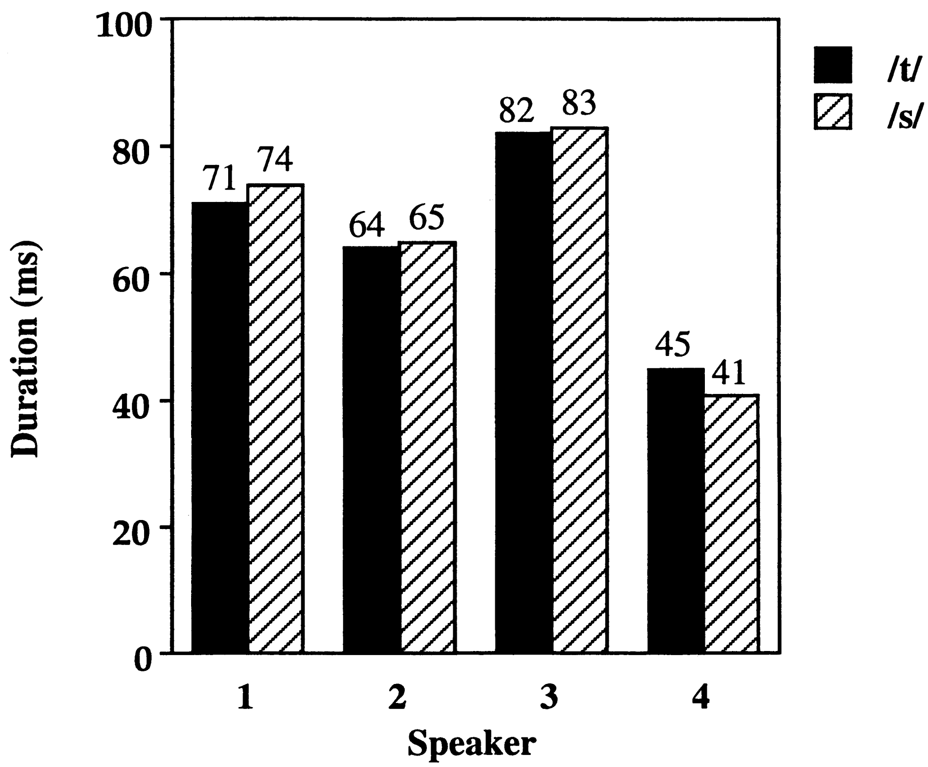

Figure 2. Mean vowel duration (in ms) for each speaker, for minimal pair members underlyingly ending in /t/ and /s/.

Across speakers, mean vowel duration preceding /t/ was 66 ms, preceding /s/ 66 ms.

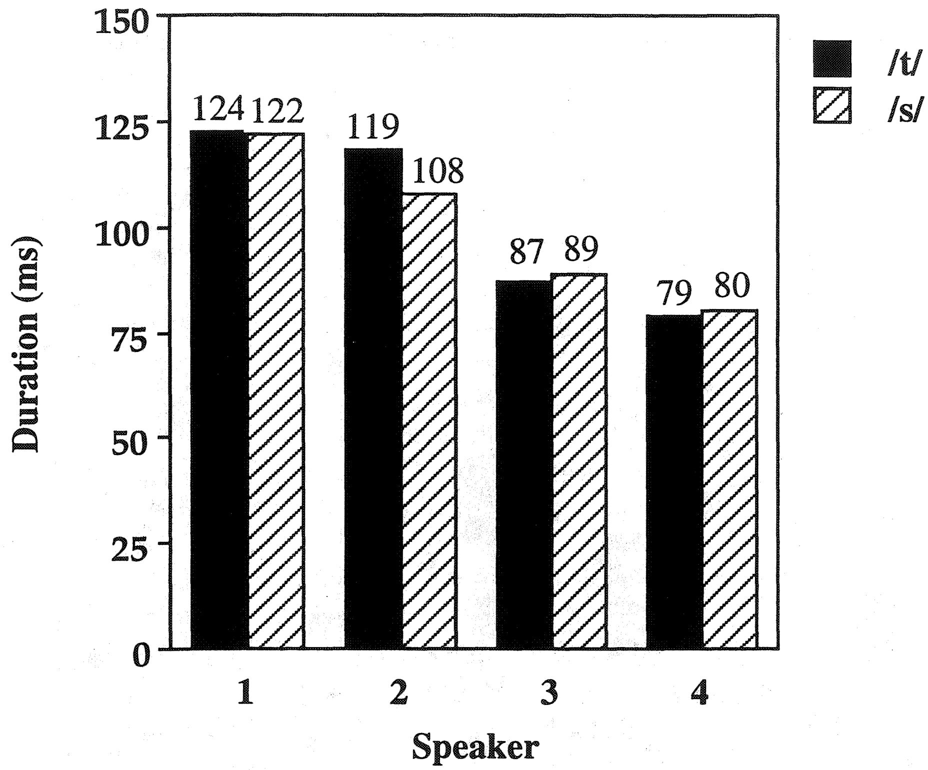

Figure 3. Mean closure duration (in ms) for each speaker, for minimal pair members underlyingly ending in /t/ and /s/.

Across speakers, mean closure duration of /t/ was 102 ms, and of /s/ 100 ms.

Separate pairwise two-tailed t-tests for vowel duration and closure duration, using subject means for each word (averaged across the 5 tokens), revealed that none of the relevant comparisons was significant, with one exception: speaker 2's closure duration was significantly shorter for underlying /s/ (108 ms) relative to underlying /t/ (119 ms) [$t(8)=-2.48$, $p<.04$]. This difference was thus in the expected direction.

Pooling the data for all four speakers, one-way ANOVAs with Underlying Consonant as the within factor and Speaker as the between factor were conducted separately for vowel and closure duration. For vowel duration, this analysis revealed a significant effect for Speaker [$F(3, 32) = 10.91$, $p <.0001$], indicating that speakers differed in terms of their average vowel durations. More importantly, there was no effect for Underlying Consonant [$F(1, 32) = 2.93$, $p>.1$]. Finally, there was no significant Underlying Consonant x

Speaker interaction [$F(3, 32) = 1.49$, $p > .24$]. For closure duration, the ANOVA revealed a significant effect for Speaker [$F(3, 32) = 23.22$, $p < .0001$], indicating that speakers differed in terms of their average closure durations. However, there was no effect for Underlying Consonant [$F(1, 32) = 1.65$, $p > .21$] and no significant Underlying Consonant x Speaker interaction [$F(3, 32) = 1.94$, $p > .14$].

Figures 4 and 5 show vowel and closure duration, respectively, for minimal pair members ending in underlying /t^h/ and /s/.

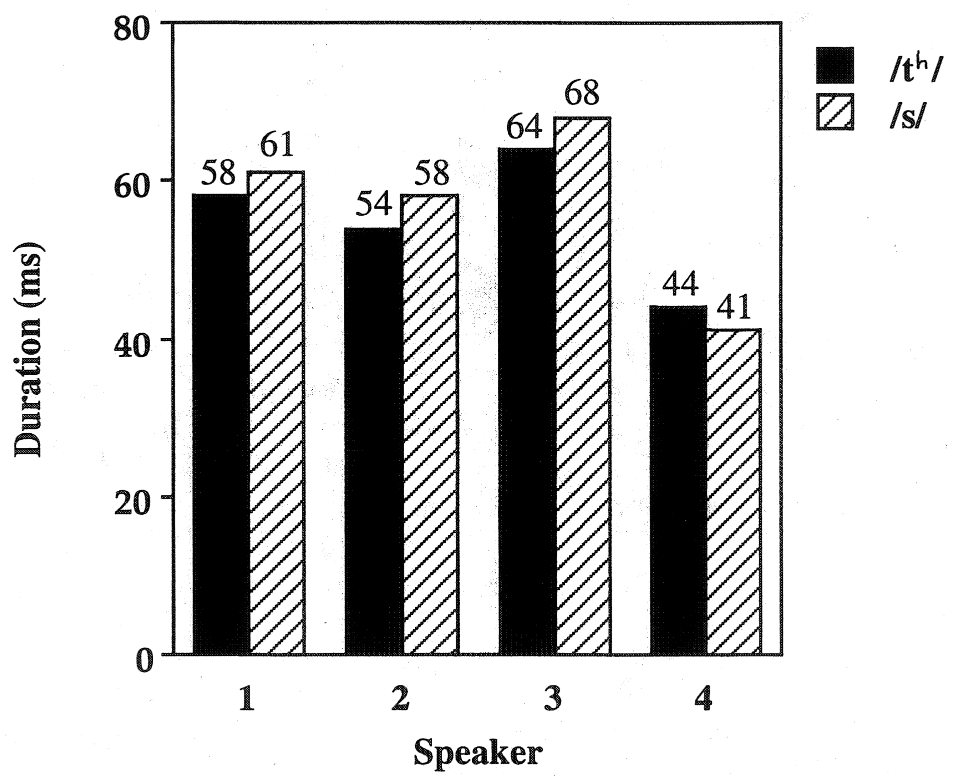

Figure 4. Mean vowel duration (in ms) for each speaker, for minimal pair members underlyingly ending in /t^h/ and /s/.

Across speakers, mean vowel duration preceding /t^h/ was 55 ms, preceding /s/ 57 ms.

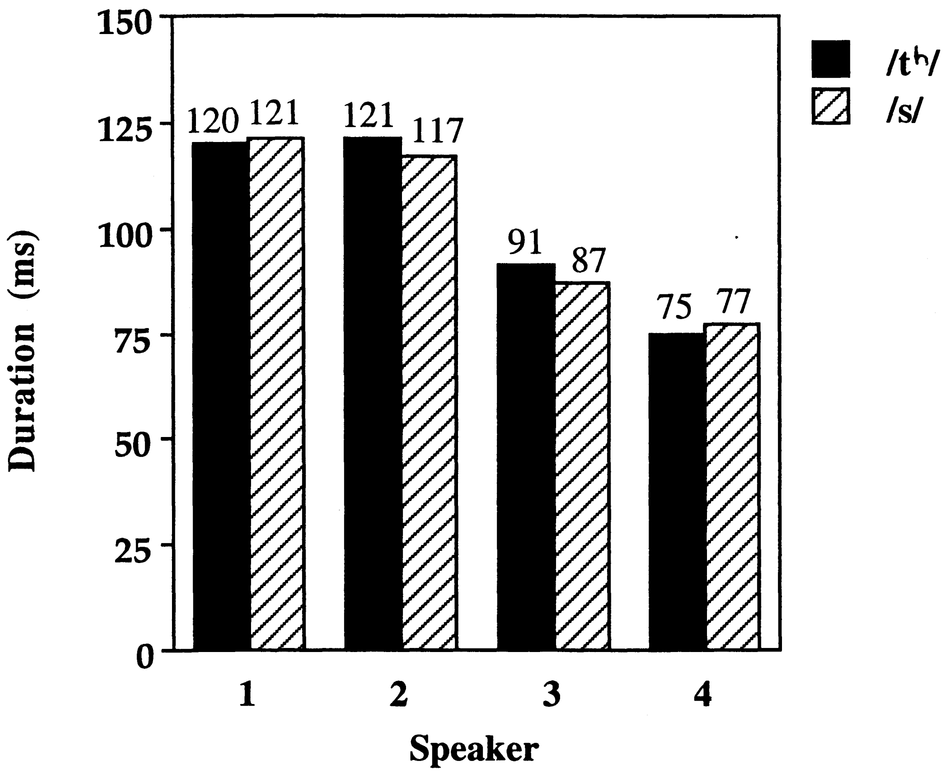

Figure 5. Mean closure duration (in ms) for each speaker, for minimal pair members underlyingly ending in /tʰ/ and /s/.

Across speakers, mean closure duration of /tʰ/ was 101 ms, and of /s/ 101 ms. Pairwise two-tailed t-tests revealed that none of the relevant comparisons was significant.

Pooling the data for all four speakers, one-way ANOVAs were conducted separately for vowel and closure duration. For vowel duration, this analysis revealed no significant effects (Speaker: [$F(3, 28) = 1.61$, $p > .21$]; Underlying Consonant: [$F(1, 28) = 2.53$, $p > .12$]; Underlying Consonant x Speaker: [$F(3, 28) = 1.45$, $p > .25$]. For closure duration, the ANOVA revealed a significant effect for Speaker [$F(3, 28) = 16.82$, $p < .0001$], again indicating that speakers differed in terms of their average closure durations. However, there was no effect for Underlying Consonant [$F(1, 28) = .00$, $p > .96$] and no significant Underlying Consonant x Speaker interaction [$F(3, 28) = 1.03$, $p > .39$].
These results clearly show that neither vowel nor closure duration differed significantly as a function of the underlying manner of the coda consonants /t, tʰ, s/.

The testwords also contained three minimal triplets ([mit, kət, mat]) which allowed us to directly evaluate neutralization of underlying /t, t^h, s/. Figures 6 and 7 show vowel and closure duration, respectively, for minimal triplet members ending in underlying /t/, /t^h/, and /s/.

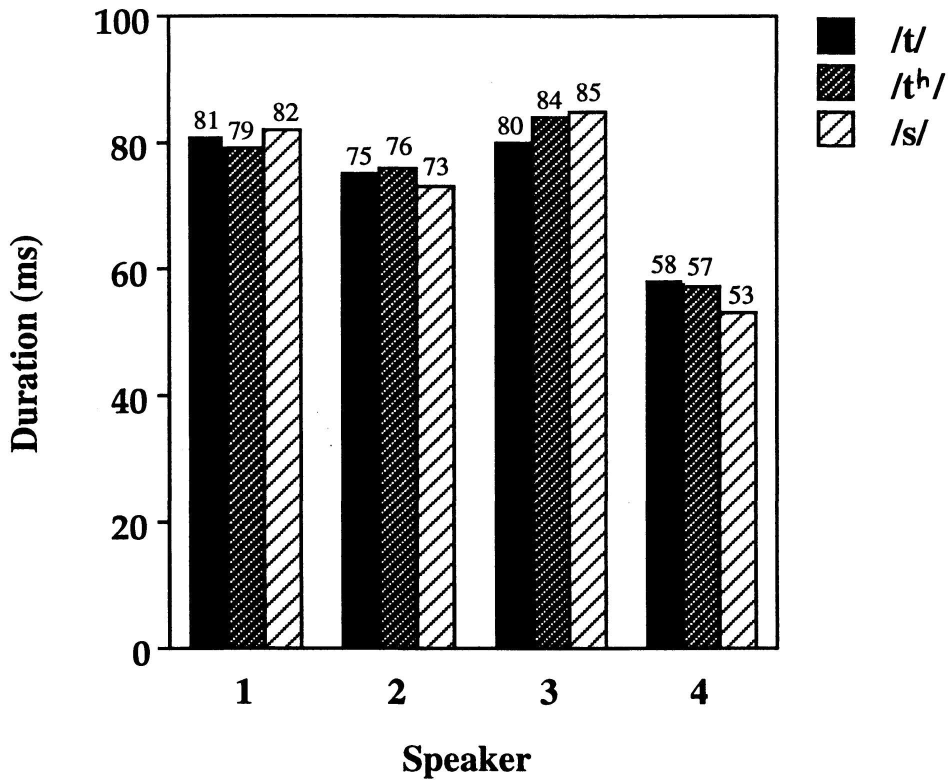

Figure 6. Mean vowel duration (in ms) for each speaker, for minimal triplet members underlyingly ending in /t/, /t^h/, and /s/.

Across speakers, mean vowel duration preceding /t/ was 74 ms, preceding /t^h/ 74 ms, and preceding /s/ 73 ms.

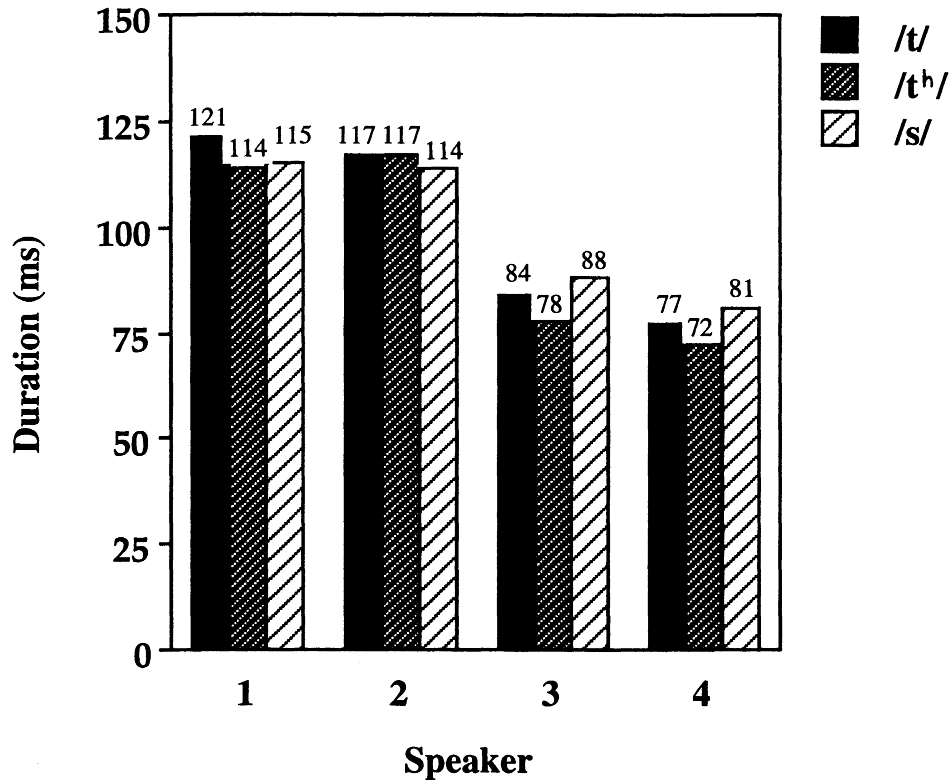

Figure 7. Mean closure duration (in ms) for each speaker, for minimal triplet members underlyingly ending in /t/, /tʰ/, and /s/.

Across speakers, mean closure duration of /t/ was 100 ms, of /tʰ/ 94 ms, and of /s/ 99 ms.

Separate ANOVAs were conducted for vowel duration and closure duration. For vowel duration, a one-way ANOVA with Underlying Consonant as the within factor and Speaker as the between factor, revealed no significant effects (Speaker: [$F(3, 8) = 1.03$, $p > .43$]; Underlying Consonant: [$F(2, 16) = .05$, $p > .95$]; Underlying Consonant x Speaker: [$F(6, 16) = .31$, $p > .92$]. Similarly, for closure duration, the ANOVA revealed no significant effects (Speaker:[$F(3, 8) = 3.74$, $p > .06$]; Underlying Consonant: [$F(2, 16) = 1.54$, $p > .24$]; Underlying Consonant x Speaker: [$F(6, 16) = .63$, $p > .71$]. In sum, there were no significant differences between triplet members, either in terms of vowel or consonant duration.

As mentioned before, stimuli in which the final [t] was not released were not included in our closure duration analysis, since it was impossible to measure closure duration for these tokens. Overall, 17% of all tokens were excluded for this reason. It is conceivable that the frequency of release in itself could be a cue to the consonant's underlying manner of articulation. Table I shows the frequency of released and unreleased instances of [t] as a function of their underlying final consonant.

	Underlying Final Consonant		
	/t/	/t^h/	/s/
Released	88%	80%	81%
Unreleased	12%	20%	19%

Table I. Frequency of occurrence (in percents) of released and unreleased [t], as a function of underlying manner of articulation (/t, t^h, s/).

A Chi-square test was conducted to establish whether frequency of release and manner of articulation of the underlying final consonant were independent. This test was not significant [$\chi^2 = 5.35$, ns], indicating that the two variables, frequency of release and underlying manner, are indeed independent. Thus, the fact that a final [t] is or is not released does not provide any cue to underlying manner of articulation.

5. Conclusions

This study investigated the acoustic correlates of neutralization of manner of articulation in Korean. In coda position, underlying /t, t^h, s/ are all neutralized to [t]. Examination of the vowel and consonant durations of minimal wordpairs produced by four speakers of Korean revealed no acoustic differences as a function of the manner of articulation of the underlying consonant. The present results suggest that the manner neutralization of /t, t^h, s/ offers an instance of complete neutralization. Coda neutralization of coronal consonants in Korean is phonetically complete regardless of their underlying manner of articulation. These results support the standard phonological treatment of neutralization: since the distinction of underlying segments is removed at the phonological level by means of phonological neutralization, neutralized segments do not show any phonetic differences.

It is also of interest to note that the present study provides an instance of complete neutralization despite potential cues in the orthography. Fourakis and Iverson (1984) argued that incomplete neutralization resulted from hypercorrect pronunciation as a result of differences between minimal pair members in terms of orthography. Korean does differentiate the minimal pair members in terms of orthography. Nevertheless, complete neutralization was obtained.

The fact that 83% of all word-final stop consonants were followed by a brief release burst is particularly interesting in view of the long tradition in the phonological literature on Korean to consider coda neutralization to yield unreleased stops (e.g., Martin 1951; Lee 1972; Kim-Renaud 1974; Chung 1980). The consonants in the present study are alveolar stops in stem-final position, followed by the velar stop /k/. It is important to note that many textbooks of English phonetics similarly claim that the first stop consonant in a sequence of two stops is unreleased (e.g., MacKay 1978; Ladefoged 1993). However, Henderson and Repp (1982) have shown that while in such sequences the release burst is often difficult to detect auditorily, it clearly shows up in acoustic analyses. Henderson and Repp (1982) found that in English clusters where the first stop is an alveolar and the second is a velar, the alveolar was released in 85% of all cases. This is very comparable to the 83% release rate in the present study for similar clusters. Regarding the issue of release vs. nonrelease, H. Kim (1994) proposes, based on acoustic analyses of Korean and English, that the terms release and nonrelease are to be associated with the airstream mechanism, rather than with oral closure and release as is usually assumed in the literature. Thus, under this account, release is assumed to be the removal of oral closure followed by a pulmonic egressive airstream before or during the articulation of a following segment.

In conclusion, while most of the debate regarding neutralization has focused on the voicing distinction, the present results show that Korean neutralization of manner is phonetically complete in terms of duration. Although duration was selected as the most likely parameter to show any differences as a function of underlying manner of articulation, it is possible that other parameters (e.g., burst amplitude, formant transitions into the coda consonant) might reveal such differences. In order to investigate this possibility, perception experiments are planned, which will reveal whether or not there are additional cues which enable listeners to distinguish minimal pair members. The present study indicates that a wider range of neutralization phenomena should be investigated to begin to resolve the issue of whether or not phonological neutralization is complete, and to assess the role of language-specific differences.

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Appendix. Surface and underlying representations of the minimal pairs used in this study.

surface	underlying /t/	/s/	surface	underlying /tʰ/	/s/
[pat]	/pat/ 'to receive'	/pas/ 'to break'	[mut]	/mutʰ/ 'land'	/mus/ 'many'
[pət]	/pət/ 'to spread'	/pəs/ 'friend'	[put]	/putʰ/ 'to paste'	/pus/ 'to pour'
[tat]	/tat/ 'to close'	/tas/ 'five'	[sat]	/satʰ/ 'inside'	/sas/ 'straw hat'
[tot]	/tot/ 'to sprout'	/tos/ 'straw'	[sut]	/sutʰ/ 'thickness'	/sus/ 'pure'
[kot]	/kot/ 'soon'	/kos/ 'place'	[kat]	/katʰ/ 'to be the same'	/kas/ 'straw hat'
[kut]	/kut/ 'to harden'	/kus/ 'exorcism'			
[kət]	/kət/ 'to collect'	/kəs/ 'thing'	[kət]	/kətʰ/ 'outside'	/kəs/ 'thing'
[mit]	/mit/ 'to trust'	/mis/ 'tasteless'	[mit]	/mitʰ/ 'underneath'	/mis/ 'tasteless'
[mat]	/mat/ 'first'	/mas/ 'taste'	[mat]	/matʰ/ 'to smell'	/mas/ 'taste'