A Phonetic Characterization of Release and Nonrelease: The Case of Korean and English*

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In this paper we propose that "release" and "nonrelease" are associated neither with oral release and oral closure of oral stops nor with the presence/absence of oral burst, as usually assumed in the literature. We claim that they are associated with the presence/absence of a pulmonic egressive airstream flowing through the oral tract after the removal of oral closure. Under this new definition of "release" and "nonrelease", we can correctly describe the acoustic implementations of coda consonants in Korean and English like the following: Korean coda consonants are always unreleased, whereas English coda consonants are either released or unreleased.

1. Introduction

Usually in the literature, the terms "release" and "nonrelease" have been used to refer to oral release and closure of oral stops, respectively. For instance, Catford (1977) and Ladefoged (1993) treat "release" as the undoing, or departure from any articulatory closure, including glottal closure, and "nonrelease" as the keeping of oral closure. But they say no more than that about released and unreleased stops. When McCawley (1967) and Kim-Renaud (1974) propose the phonological feature [+/-released], claiming that Korean neutralization is a good example of unreleasing coda consonants, they implicitly refer to the feature as oral release and oral closure. However, McCawley (1967) offers no definition of "release" and "nonrelease". Kim-Renaud (1974: 111) defines unreleasing as "completely closing the air

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passage," in that, as for neutralized stops in Korean "the escape route of air is blocked, because there is no opening through the oral cavity or through the nasal cavity. Thus the articulation stops at the time of all closure and silence ensues." But this definition does not distinguish between released and unreleased stops, since both types are produced with complete closure. Selkirk (1982: 373) proposes that "a consonant is released if immediately following the articulation and not during or after the articulation of a following segment, the closure is reopened." Selkirk's definition seems more precise than Kim-Renaud's. But a consonant and a vowel in sequence are commonly observed to overlap as in the English word, *two* [t^{w}uw] and the coarticulated consonant [t^{W}] in this word must be unreleased under Selkirk's definition of "release", which is not the case.

On the other hand, Henderson and Repp (1982) and Kent & Read (1992) refer to "release" and "nonrelease" as the presence/absence of oral burst after oral closure. According to Henderson and Repp (1982: 80), a stop is unreleased if "the occlusion is maintained, as in a stop preceding a homorganic stop or in many utterance-final stops with delayed release"; and release bursts are classified into four categories (silent, inaudible, weak or strong release), depending on how audible and perceptible the bursts are. Recently Steriade (1993: 403) defines a stop release as "an audible release, audible either because accompanied by burst or because it is released with audible frication." But the presence of a burst does not necessarily make a stop audible. As reported in Henderson and Repp (1982: 79), a burst in a stop needs "acoustic events of a certain minimal duration and amplitude." Otherwise, the subjects in their perception test did not detect faint release bursts of stops.

As briefly discussed so far, it is not still clear what we mean by "release" and "nonrelease". As an attempt to clarify the terms, this paper aims to provide an aerodynamic analysis of "release" and "nonrelease", based on our phonetic data of English and Korean consonants.

2. Coda Stops in English and Korean

English stops are usually referred to as either released or unreleased in syllable- or word-final position (e.g., MacKay 1978; Ladefoged 1993). According to Ladefoged (1993), English speakers say the final voiceless obstruents of the words *rap*, *rat*, *rack* in several different ways: released with aspiration, as in (1a); unreleased with no aspiration, as in (1b); or with a glottal stop and no other final consonant, as in (1c).[1]

(1)	a.	b.	c.
rap	[ɹæʔpʰ]	[ɹæʔp˺]	[ɹæʔ]
rat	[ɹæʔtʰ]	[ɹæʔt˺]	[ɹæʔ]
rack	[ɹæʔkʰ]	[ɹæʔk˺]	[ɹæʔ]

(Ladefoged 1993: 53)

A preconsonantal stop in English is also unexploded, that is, unreleased, as in *apt* and *act* which are pronounced [æp˺t] and [æk˺t], respectively. For instance, the [p] in *apt* is "unexploded because the closure for the [t] occurs before the lips come apart" (Ladefoged 1993: 56).

However, the reference to "release" and "nonrelease" as oral release and closure is not well supported in acoustic studies. According to Henderson and Repp (1982), the first stop in i.e. alveolar-velar and labial-veolar word-medial stop sequences in English was released in 85.4% and 89.6% of all cases, respectively, showing a release burst. 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.

In contrast, Korean coda consonants are quite often referred to as unreleased in the literature (e.g., Martin 1951; Lee 1972; Kim-Renaud 1974, 1986; Chung 1980). In Korean, the three-way distinctive obstruents – plain (lax), aspirated, tense – and fricatives are neutralized into homorganic plain stops when they come in syllable- or word-final position, as shown in (2).

(2) Korean Coda Neutralization[2]

p, pʰ, (p')\]σ	→	[p˺]	e.g. /t͡sipʰ/ [t͡sip˺] 'straw'
			/t͡sipʰ + kwa/ [t͡sip˺.k'wa] 'straw and'
			/t͡sipʰ + e/ [t͡si.pʰe] 'at straw'
t, tʰ, (t')\]σ	→	[t˺]	e.g. /mitʰ/ [mit˺] 'bottom'
			/mitʰ + kwa/ [mit˺.k'wa] 'bottom and'
			/mitʰ + e/ [mi.the] 'at a bottom'

[1] A small raised mark [˺] in transcription denotes the fact that a consonant is unreleased.

[2] The consonants in parenthesis are not attested in coda position. Syllable boundaries are indicated with dots throughout this paper. In addition, a consonant following a neutralized consonant is tensified by a language-particular rule, like [k'] in /t͡sipʰ + kwa / [t͡sip˺.k'wa] 'straw and'.

k, k^h, k'] σ	→	[$k^\urcorner$]	e.g. /pak'/ [$pak^\urcorner$] 'outside'
			/pak' + kwa/ [$pak^\urcorner$.k'wa] 'outside and'
			/pak' + e/ [pa.k'e] 'at outside'
s, s'] σ	→	[$t^\urcorner$]	e.g. /kis/ [$kit^\urcorner$] 'feather'
			/kis + kwa/ [$kit^\urcorner$.k'wa] 'feather and'
			/kis' + e/ [ki.se] 'at a feather'
h] σ	→	[$t^\urcorner$]	e.g. /$\widehat{ts}$oh/ [$\widehat{ts}ot^\urcorner$] 'to like'
			/$\widehat{ts}$oh + ko/ [tso.k^ho] 'like and'
$\widehat{ts}$, $\widehat{ts}^h$, ($\widehat{ts}$')] σ	→	[$t^\urcorner$]	e.g. /na$\widehat{ts}^h$/ [$nat^\urcorner$] 'face'
			/na$\widehat{ts}^h$ + kwa/ [$nat^\urcorner$.k'wa] 'face and'
			/na$\widehat{ts}^h$ + e/ [na.$\widehat{ts}^h$e] 'at a face'

Thus when a word is in isolation or followed by an obstruent-initial suffix like *kwa* 'and' a word-final consonant is neutralized in coda position. For example, the word-final consonant /ts^h/ in /$nats^h$/ 'face' and /$nats^h$ + kwa/ 'face + and' is neutralized into [$t^\urcorner$]. But when syllabified into an onset of a following syllable, the threefold distinction of Korean obstruents remains intact, as in /$nats^h$ + e/ → [na.ts^he] 'at a face'. According to Kim-Renaud (1974: 116), obstruent unreleasing in (2) is "a very general, obligatory process in Korean. Even in a deliberately slow and careful speech, the releasing of obstruents in syllable final position does not occur."

Under Kim-Renaud's assumption of release and nonrelease as oral release and closure, we would expect a neutralized stop to be unreleased, that is, to keep oral closure with no oral release, when followed by another stop across a syllable boundary. However, Kim (1993) and Kim & Jongman (1994, 1996) found in their acoustic experiments of Korean neutralized consonants that most of the examined word-final consonants of their test words were followed by a brief release burst. If we followed Kim-Renaud's (1974) reference to release and nonrelease, then the coda consonants accompanying a brief release burst in the acoustic studies would be considered as released.

Given that there is discrepancy between the terms "release" and "nonrelease" generally assumed in the literature and acoustic studies of English and Korean coda consonanats, the present study pursues the question of what we mean by "release" and "nonrelease" in English and Korean. For the present investigation of how we phonetically characterize "release" and "nonrelease", we conducted an experiment of English and Korean coda consonants and examined acoustic properties of coda consonants of the two languages.

3. Experiment 1: English Stops in Coda Position

3.1. Speakers

Four native speakers, two males and two females, participated in this experiment. The two male speakers were from New York state (one from up-state New York and the other from New York city) and the two female speakers were from Cambridge, M.A.. The male speaker from up-state N.Y. was in his thirties, and the other subjects were in their twenties. None of the speakers had any known speech or hearing disorders.

3.2. Materials and Procedure

Test words consisted of fourteen monosyllabic words which ended in one of the voiceless oral stops /p, t, k/, as shown in (3).

(3) tip, soup, tap, top
soot, kit, cat, pot, dot, pit
sick, cook, sock, rock

Test words were embedded in a carrier sentence, 'Say ____ carefully.' On one page, carrier sentences with the target words were randomized with two filler sentences on the top and the bottom to reduce any bias in pronunciation. Speakers were asked to read the sentences three times at different speech rates (slow, normal and fast). The total number of target words was 168 (14 words × 3 speech rates × 4 speakers).

Speakers were recorded in a sound-proofed booth in the Cornell Phonetics Laboratory, using a cardioid microphone (Electrovoice RE20) and high-quality cassette recorder (Carver TD-1700). Before recording, speakers practiced reading a few randomly chosen test sentences to familiarize themselves with the materials.

3.3. Analysis

Their recorded speech was then analyzed at the Institute of Phonetics, ILPGA, University of Paris III. All sentences were digitized at 16 kHz, and stored as files to be processed by the commercial software package UNICE. For each target word, the oral closure, oral burst and aspiration of each word-final consonant were examined on the basis of wide-band spectrograms, waveforms and LPC spectra.

3.4. Results

Our experiment of the English stops /p, t, k/ in coda position showed three kinds of acoustic manifestation: a) aspiration together with an oral burst; b) a brief, low-amplitude oral burst after silence; and c) a silence corresponding to oral closure. The frequency of occurrence of the three kinds of acoustic manifestations in our experiment is given in Table 1.

Table 1. Frequencies of Occurrence (in percent) of the Three Kinds of Acoustic Manifestations of English Coda Consonants

		a.	b.	c.
at the slow speech rate	:	89.3	7.1	3.6
at the normal speech rate	:	42.9	44.6	12.5
at the fast speech rate	:	21.4	55.4	23.2
Mean	:	51.2	35.7	13.1

a. aspiration together with an oral burst
b. a brief low-amplitude oral burst after silence
c. a silence corresponding to oral closure

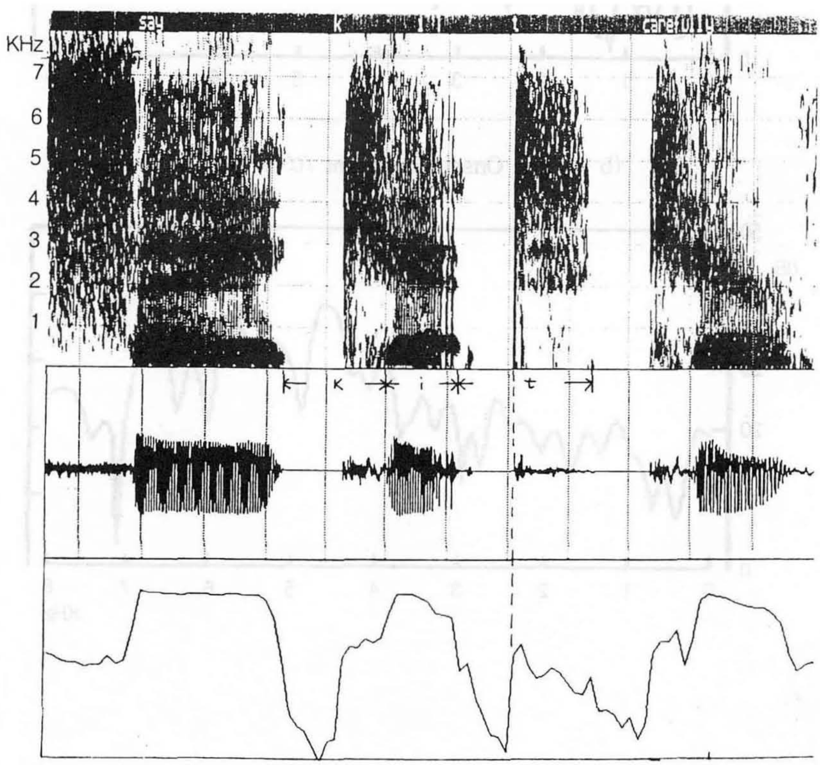
Table 1 shows that the faster speech rate is, the less aspiration and the more oral burst or silence occurs. Looking at the means in the bottom row, we see that, overall, 51.2% of stops had aspiration with an oral burst, 35.7% just an oral burst after closure, and 13.1% only oral closure with no oral burst.

As representative examples from our acoustic data, Figures 1, 2, and 3 (a) demonstrate the three types of transitions between a coda consonant /t/ and a following onset consonant /k/. Figure 1 (a) is a wide-band spectrogram of the word *kit* uttered by one of our female speakers at the slow speech rate. The coda consonant /t/ in Figure 1 (a) illustrates a case where a coda consonant accompanies aspiration after oral burst. The energy shape of the coda consonant /t/ has a rapid rise with a slightly tilted plateau, as indicated by the dashed line under the waveform. The LPC spectrum of the coda consonant /t/ has a diffuse-rising shape with its highest spectral energy at around 6 kHz, as shown in Figure 1 (b i).[3] This spectrum shape

[3] When the peaks in an LPC spectrum fairly spread out or diffuse, and when there is greater spectral energy in the higher frequencies, the spectrum shape is described as diffuse-rising (e.g., Jakobson, Fant & Halle 1963).

looks similar to that of a released onset consonant /t/ in the word *tip*, which also has a diffuse-rising shape, though its highest spectral energy is in the frequency of 4625 Hz, as shown in Figure 1 (b ii). But the spectrum shape of the coda consonant /t/ in Figure 1 (b i) is different from that of the onset consonant /k/ in the word *kit* shown in Figure 1 (b iii), where the LPC spectrum is compact with a strong concentration of energy in the frequency of 3312 Hz.[4]

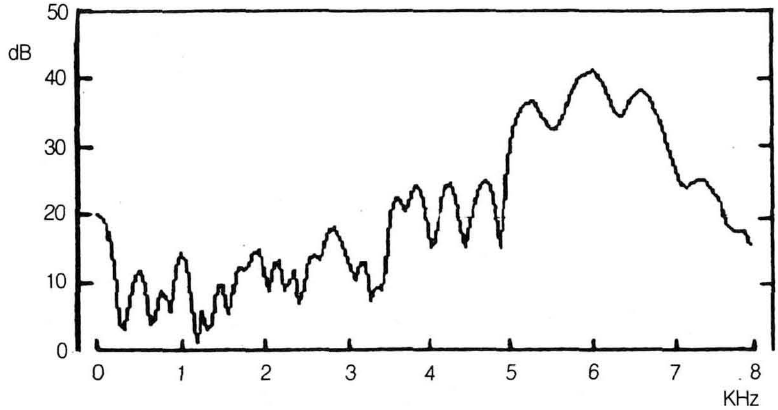
(a) The Wide-band Spectrogram, Waveform and Energy Shape of *kit*



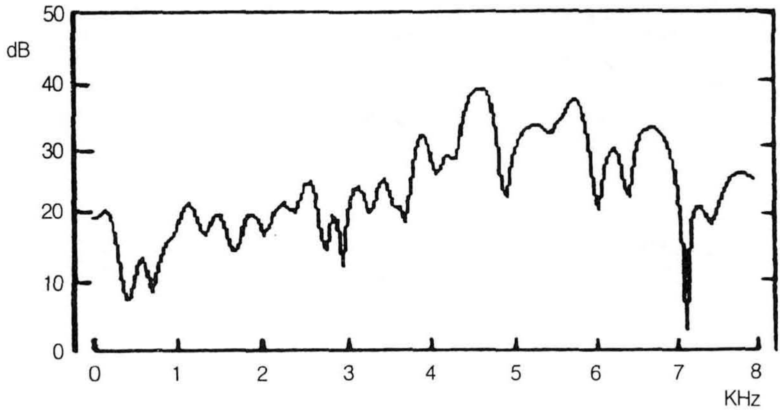
The comparison of the LPC spectra of coda and onset consonants /t/ and onset consonant /k/ at the time of the removal of oral closure.

[4] When there is one spectral peak dominating the entire spectrum or with less high spectral peak(s) close to it, the spectrum shape is described as compact.

(b i) The Coda Consonant /t/ in *kit*



(b ii) The Onset Consonant /t/ in *tip*



(b iii) The Onset Consonant /k/ in *kit*

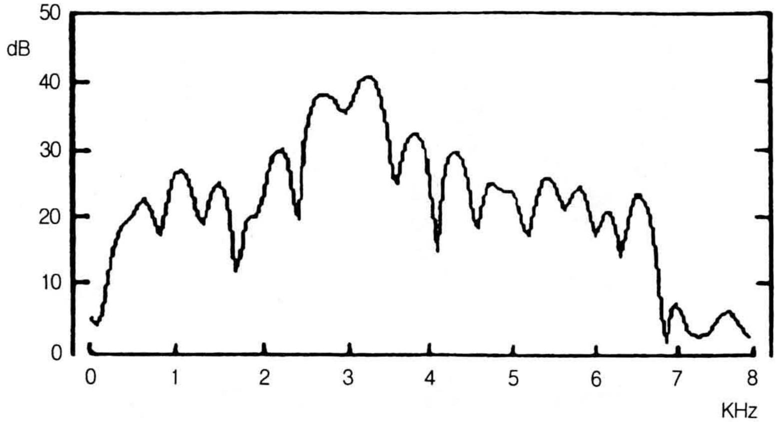
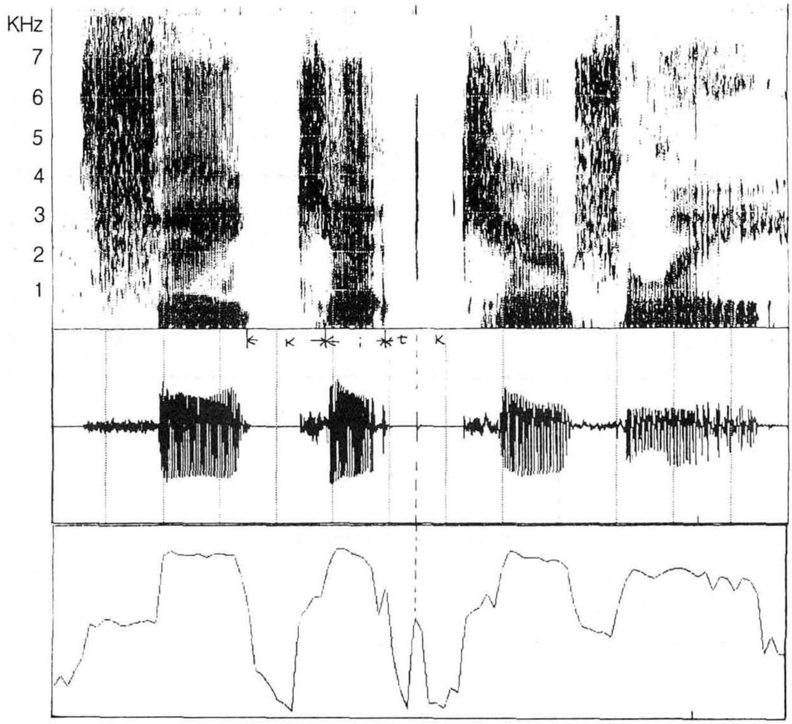


Figure 1.

As a case of a coda consonant accompanying only an oral burst with no aspiration, Figure 2 (a) shows a wide-band spectrogram of the same target word *kit*, spoken by the same female speaker at the fast speech rate. The coda consonant /t/ of the target word *kit* only has a burst spike in the same frame sentence. The LPC spectrum of the burst spike in Figure 2 (b) has a diffuse-rising shape with a spectral peak above 4 kHz, as in Figure 1 (b i, ii), and thus it indicates that the burst spike belongs to the coda consonant /t/ rather than a following stop /k/. Compared to the coda consonant /t/ in Figure 1 (a), the coda consonant in Figure 2 (a) reveals a different energy shape: the energy shape corresponding to the burst spike is as steep as the coda consonant /t/ in Figure 1 (a), but there is no sustained energy plateau after the rapid change of energy. Instead, the energy drops drastically after the rapid rise.

Figure 3 (a) shows a case of a coda consonant having oral closure alone with no oral burst. The target word *pot* in Figure 3 (a) is spoken by the other female subject at the fast speech rate. There is no energy, only silence, between the coda consonant /t/ of *pot* and the word-initial consonant /k/ of *carefully*. The LPC spectrum of the consonant /k/ after the silence shown in Figure 3 (b) is not diffuse-rising, as in Figure 1 (b i, ii), but compact, as in Figure 1 (b iii). Its highest spectral peak is in the frequency of 2937 Hz, which is less than the highest spectral peaks in Figure 1 (b iii).

(a) The Wide-band Spectrogram, Waveform and Energy Shape of *kit*



(b) The LPC Spectrum of the Burst Spike in the Consonant /t/

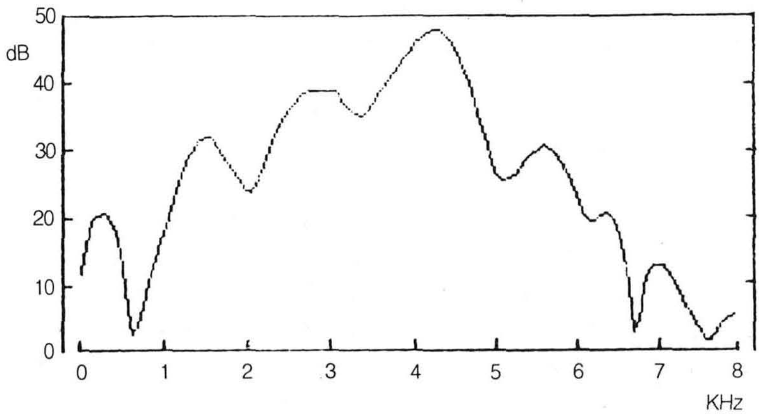
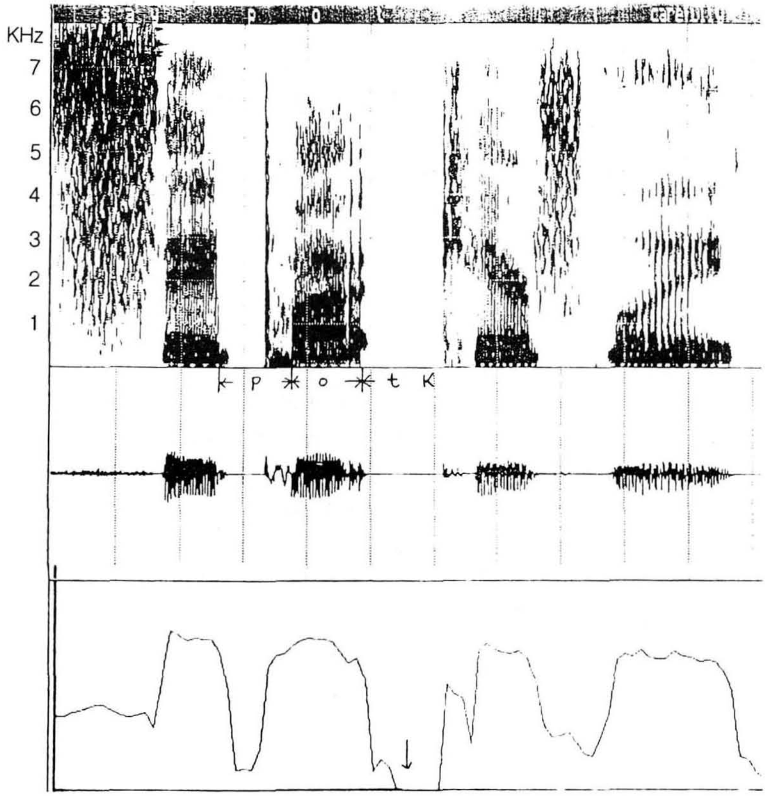


Figure 2.

(a) The Wide-band Spectrogram, Waveform and Energy Shape of *pot*



(b) The LPC Spectrum of the Consonant /k/ in *carefully*

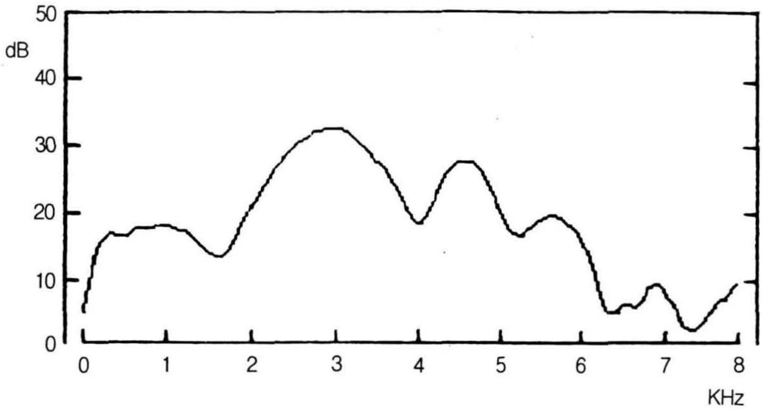


Figure 3.

4. Experiment 2: Coda Consonants in Korean

4.1. Speakers

Four Korean speakers, two males and two females, 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.

4.2. Materials and Procedure

Test words consisted of 17 minimal word pairs. As shown in 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/. Therefore, there were six /t, s/ minimal pairs, five /t^h, s/ minimal pairs, and three /t, t^h, s/ minimal triplets. Five repetitions of the stimuli were randomized and embedded in the carrier phrase [əsə ______ kwa sap malhasejo] ('Please say ____ and a shovel'). When followed by the consonant-initial suffix /kwa/ 'and' the coda consonant of the CVC target word is expected to be neutralized into [t]. 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 × 5 repetitions × 4 speakers). The subjects were asked to read at their normal speeds, and were recorded in the sound-proof room of the phonetics lab of Cornell University. Recording procedures were the same as those described for Experiment 1.

4.3. Analysis

All sentences were digitized onto a Sun Sparcstation 2 at a sampling rate of 16 kHz with 16-bit resolution, and stored as files to be processed by the commercial software package WAVES+/ESPS. For each target word, the oral closure, oral burst and aspiration of each word-final consonant were examined on the basis of wideband spectrograms, waveforms and LPC spectra.

4.4. Results

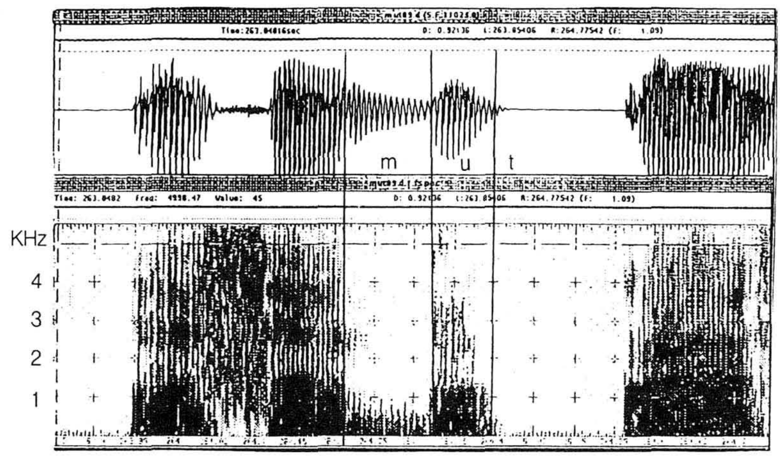
The Korean coda neutralized consonants in our acoustic data were found as manifested either with a burst spike after a silence or with complete silence corresponding to oral closure. As shown in Table 2, among the 620 target words, only 102 words (17% of the words) had a complete silence with no burst in coda consonants, and the rest (83% of the words) had a burst spike after silence. However, aspiration was not found at all.

Table 2. Frequencies of Occurrence (in percent) of the Two Kinds of Acoustic Manifestations of Korean Coda Consonants

a. aspiration together with an oral burst	: 0
b. a brief low-amplitude oral burst after silence	: 83
c. a silence corresponding to oral closure	: 17

As respresentative examples, Figure 4 illustrates the two kinds of acoustic manifestations of the coda consonant /s/ in the target word /mus/ ([mut]) 'many', spoken by one of our male speakers. In Figure 4 (a), there is only silence between the neutralized consonant [t] of the target word and the following suffix-initial consonant /k/: no acoustic manifestation for the removal of the oral closure of the stop [t] during or before the oral closure of the suffix-initial consonant /k/. In Figure 4 (b), there is a burst spike between the same consonant sequence, as indicated by arrows in the wave-form and the spectrogram.

(a)



(b)

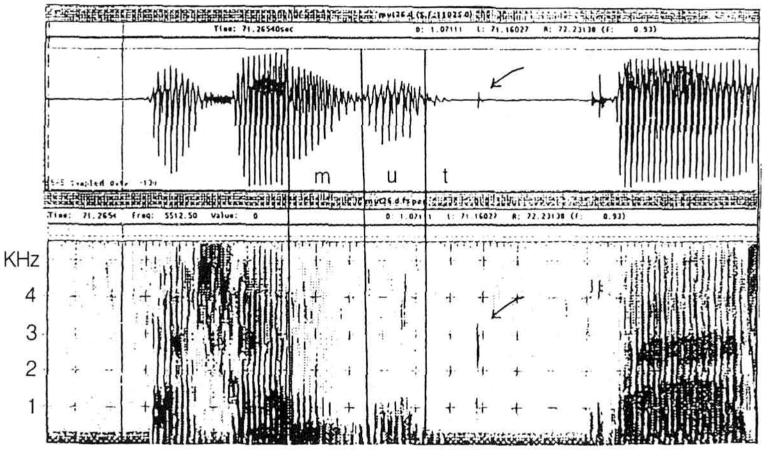
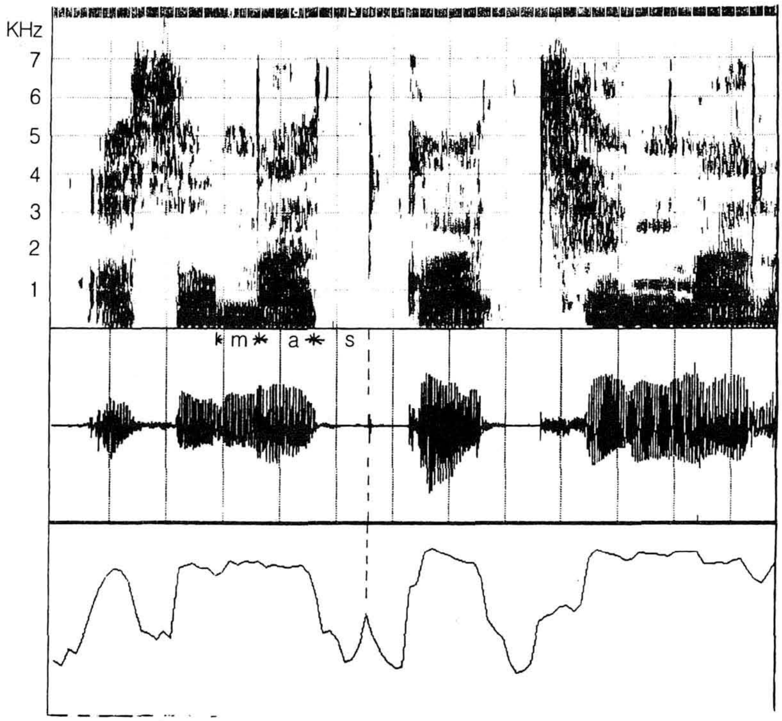


Figure 4. The Two Kinds of Acoustic Manifestations of the Neutralized Consonant [t] in /mus/ ([mut]) 'many'

In order to allow comparison with the English data which was analyzed at the Institute of Phonetics, University of Paris III, some Korean target words were recorded in the same carrier sentence, and then analyzed on the same software program. Figure 5 (a) is the wide-band spectrogram, wave-form and corresponding energy curve of the target word /mas/ ([mat]) 'taste'. The neutralized consonant [t] only has a burst spike with a rapid rise of energy but with no plateau, as indicated by the dashed line under the waveform. At the time of the burst, the LPC spectrum of the coda consonant has a diffuse-rising shape with the highest spectral peak at 4250 Hz, as shown in Figure 5 (b), indicating that the burst spike belongs to the coda consonant. The acoustic features of the neutralized consonant [t] are the same as in the English coda consonant /t/ in Figure 2 (a).

(a) The Wide-band Spectrogram, Waveform and Energy Shape of /mas/([mat]) 'taste'



(b) The LPC Spectrum of the Neutralized Consonant [t] in /mas/([mat]) 'taste'

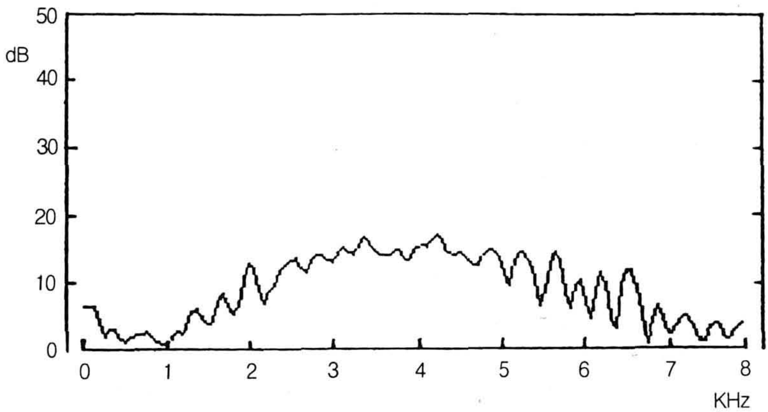


Figure 5.

5. Discussion

As shown above, Experiment 1 established that English stops in coda position are acoustically manifested as aspiration together with an oral burst, a brief low-amplitude oral burst after silence, or a silence corresponding to oral closure, regardless of speech rate. Experiment 2 examined whether neutralized stops in Korean are always manifested as a silence without oral burst, as usually assumed in the literature. 83% of the examined word-final neutralized consonants were found with a brief low-amplitude oral burst after silence, whereas the rest were found with silence only.

Under the terms "release" and "nonrelease" generally assumed in the literature, English and Korean stops, which were acoustically manifested with a brief low-amplitude oral burst after silence in our data, would be referred to as released due to the removal of oral closure. This would mean that Korean neutralized coda stops were either released or unreleased just like English coda stops. But if Korean neutralized coda stops were released or unreleased just like English coda stops, then we could not account for the different acoustic manifestation between English and Korean coda stops: Korean coda stops are never acoustically manifested as aspiration together with an oral burst like English ones, as shown in our data. Thus, the present results suggest that the terms "release" and "nonrelease" generally assumed in the literature are not adequate to cover acoustic manifestations of released and unreleased stops in Korean and English.

Based on our acoustic data of English and Korean coda consonants, we propose that "release" does not simply involve the removal of oral closure, or the presence of oral burst, as usually assumed in the literature. We claim that "release" is associated with the presence of a pulmonic egressive airstream which flows through the oral tract after the removal of the oral closure, before or during the articulation of a following segment. The definitions of "release" and "nonrelease" which we propose are given in (4):

(4) a. Release:

Release is the removal of oral closure followed by a pulmonic egressive airstream flowing through the oral tract.

b. Nonrelease:

A stop which does not meet this condition is unreleased.

In our proposal of "release" and "nonrelease" in (4), the presence of a pulmonic airstream is crucial for an orally released stop. Thus "release" as proposed in (4), is acoustically-manifested as a sharp rise in the energy curve, followed by a high-energy plateau. This can be characterized by aspiration, a short voicing lag or full voicing, usually in prevocalic position, as shown in Figure 6. The wide-band spectrogram, waveform, and corresponding energy curve presented in Figure 6 are for each of the English words *cat*, *sky*, and *dot* at the slow speech rate of one of our male speakers from New York city.

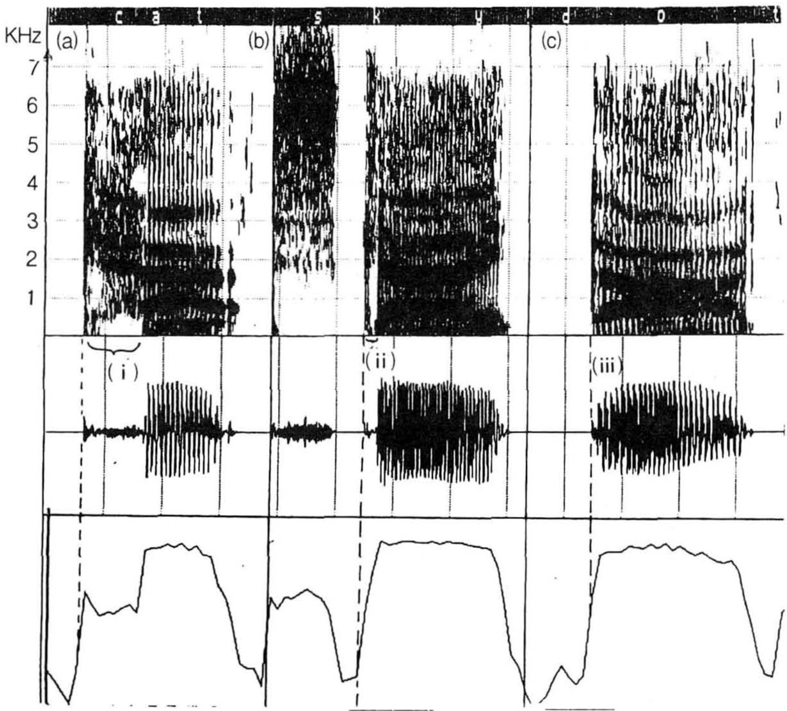


Figure 6. The Wide-band Spectrograms, Waveforms and Energy Shapes of *cat* (a), *sky* (b), and *dot* (c).

The onset consonants of the three words in Figure 6 have the oral burst accompanying a short periord of frication noise and a long period of aspiration, as marked by (i) in (a); the short period of frication noise and an immediately following short aspirated voicing lag, as marked by (ii) in (b); and voicing, that is, the phonation of a following vowel, as marked by

(iii) in (c). In each example, the corresponding energy at the time of oral burst has an almost 90° rise, as indicated by the dashed line under the waveform aligned with the beginning of the burst, and the energy is sustained along a plateau. An acoustic manifestation similar to that in Figure 6 (a) is also found in post-vocalic position in English, as in Figure 1 (a): oral burst followed by a plateau of sustained energy, though the energy is weaker than that in Figure 6 (a). Such a plateau-like sustained energy shape in Figures 1 (a) and 6 is directly associated with the explosion of compressed air when oral closure is removed, that is, with a pulmonic egressive airstream flowing through the oral tract after oral release.

On the other hand, in proposal (4), when a stop lacks a pulmonic airstream, it is regarded as unreleased, regardless of an oral burst. For instance, the shape of energy corresponding to the brief low-amplitude burst in Figures 2 (a) and 5 (a) is as steep as in a released consonant (e.g., Figures 1 (a) and 6, but the energy drops drastically after a rapid rise with no sustained energy plateau. We speculate that such a pattern comes not from a pulmonic egressive airstream but from an ingressive velaric airstream. That is, when the tongue gestures for /t/ and /k/ are overlapped, air is formed between the two tongue gestures. When the tongue tip is removed first with the tongue back blocking the velum, air comes in from outside, and then the inside air is in negative pressure, producing a burst spike with some energy. Thus, we can say that such a burst in Figures 2 (a) and 5 (a) is a click sound (e.g., Marchal 1987; Ladefoged 1993).

Our interpretation of the burst spike as the manifestation of a click is supported by the aerodynamic study of Korean intervocalic consonants in Silverman & Jun (1994). In Figure 7, which is taken from Silverman & Jun (1994: 213), a brief low-amplitude burst occurs in the sequence of a coda consonant /p/ and an onset consonant /k/, in the waveform of a nonsense word /ipku/ spoken by Jun, the Korean author. When the burst occurs, the oral pressure drops sharply to a negative value, as indicated by arrows. This negative air pressure clearly indicates that air flows into the mouth from outside, producing a click sound, when the oral burst of /p/ occurs. Therefore, the oral burst which we saw in Figure 4 (b) as well as in Figure 2 (a) can be plausibly interpreted as a click with an ingressive airstream.[5]

[5] In his articulatory data (electropalatography), Marchal (1987) shows that in the sequence of /t/ and /k/ in French air flows into the oral cavity.

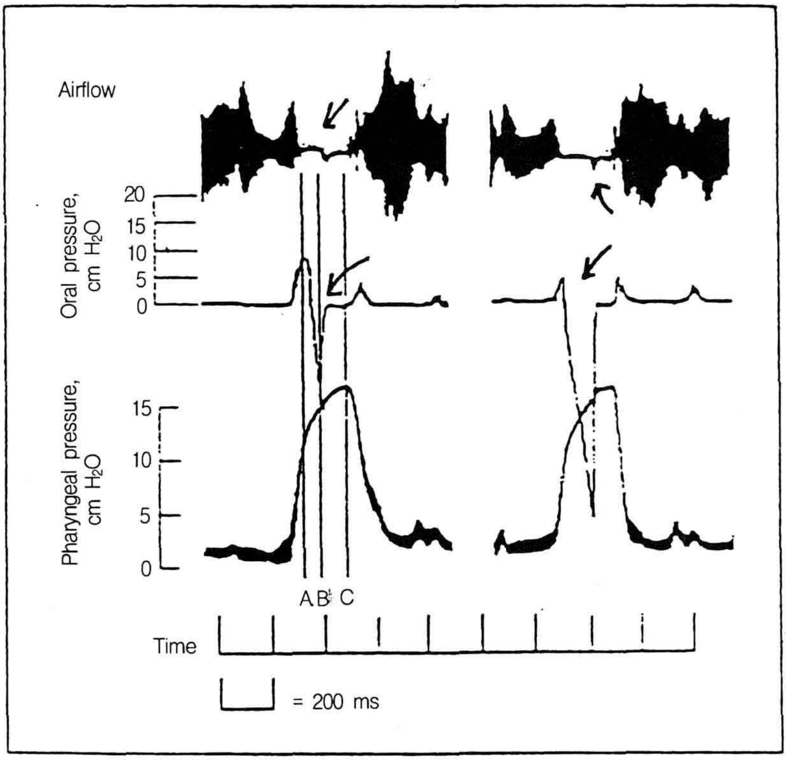


Figure 7. The Waveform and Airflow of a Nonsense Word /ipku/ (Silverman & Jun 1994: 213)

As for the absence of an oral burst in Figures 3 and 4 (a), we can attribute it to the articulatory overlap of tongue tip and tongue body (e.g., Catford 1977; Ladefoged 1993). When the occlusions made by tongue tip and tongue body are removed simultaneously, compressed air behind the tongue body rushes out of the oral tract, resulting in an oral burst followed by breathy noise. The removal of oral closure at the alveolar in this case is an automatic consequence of the removal of oral closure at the velar.

To sum up, in our proposal of "release" and "nonrelease" in (4), a released stop is associated with a pulmonic egressive airstream, thus acoustically manifested as a sharp rise in the energy curve, followed by a high-energy plateau after oral burst. An unreleased stop is realized either as the absence of an oral burst (that is, just oral closure) with no pulmonic egressive airstream, as in Figures 3 and 4 (a), or as a low-amplitude burst involving an ingressive airstream, as in Figures 2 (a) and 4 (b). In other words, burst spikes alone don't count as releases.

6. Conclusion

This study investigated a phonetic characterization of "release" and "nonrelease", based on acoustic data of English and Korean consonants. We have proposed a new definition of the terms "release" and "nonrelease" based on the phonetic experiments of both Korean and English coda consonants: "release" and "nonrelease" are associated neither with oral release and oral closure of oral stops nor with the presence/absence of an oral burst, but with the presence/absence of a pulmonic egressive airstream. Under such an aerodynamic characterization of "release" and "nonrelease", burst spikes alone don't count as releases. As a result, in our proposal we can adequately describe the acoustic implemetations of Korean and English consonants with respect to "release" and "nonrelease": Korean coda consonants are always unreleased, while English coda consonants are either released or unreleased.

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Appendix

Minimal Pairs Used in Experiment 2

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

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