The Phonetic Difference Between the Korean Stop Series /p,t,k/ and the English /b,d,g/ Based on the VOT Value

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Kang, Insun. 2003. **The Phonetic Differences Between the Korean Stop Series /p, t, k/ and the English /b, d, g/ Based on the VOT Value.** *Korean Journal of English Language and Linguistics* 3-3, 427-452.
Korean is famous for having all voiceless stop sounds. Korean does have voiced stops but they are considered to exist only as the allophones of word initial /p, t, k/. My experiment shows the English word initial stop sounds [b, d, g] and the Korean lax stop series /p, t, k/ in word initial position are similar in the range of voice onset time. If English word initial [b, d, g] sounds are posited as voiced, then Korean word initial /p, t, k/ should be classified as voiced also. Phonetically English /b, d, g/ phonemes and Korean /p, t, k/ phonemes are very similar except the word initial [p, t, k] are devoiced slightly more, but not significant enough to be classified as voiceless than English word initial [b, d, g]. If we posit /b, d, g/ as Korean phonemes, it explains why Korean /p, t, k/ series has the allophones [b, d, g] instead of fortis stops /p', t', k'/ in Korean even though /p', t', k'/ has less positive VOT value than /p, t, k/. If we posit /b, d, g/ as Korean phonemes, then it does not cause spelling or pronunciation confusion either when Koreans learn English or English speakers learn Korean.

Key Words: Korean voiceless stops, English voiced stops, voice onset time, phonetic difference

1. Introduction

Korean stop consonants are well known in phonology because they are all voiceless (Hyman 1975:15); there are no phonemic voiced stops in Korean. Korean has nine stop consonant phonemes, which are

divided into three major groups as follows. (Martin 1951):

(1) /ph, th, kh/, the aspirated voiceless stops

(2) /p, t, k/, the lax voiceless stops

(3) /p', t', k'/, the tense voiceless stops

In the intervocalic position, the lax stops /p, t, k/ have the allophones [b, d, g]. The aspirated and tense stops also occur in medial position, but with little allophonic variation as the following table 1 shows.

Table 1

(Korean stops pronunciation in isolation and between vowels)

isolation	'this+ Noun+ sbj. marker'	gloss
[pap]	[ibabi]	'rice'
[tot]	[idodi]	'sail'
[p'ang]	[ip'angi]	'bread'
[t'ang]	[it'angi]	'ground'

English has six stop consonant phonemes which are divided into two major groups voiced and voiceless.

(4) /p, t, k/, the tense voiceless stops

(5) /b, d, g/, the lax voiced stops

In word initial position, the voiceless stops /p, t, k/ have the allophones [ph, th , kh]. However, the voiced stops /b, d, g/ have no allophones.

The above classification is not satisfactory, however, mainly because the Korean lax stop series /p, t, k/ in initial position are

treated as voiceless. As a native speaker of Korean, I hear and pronounce these three sounds /p, t, k/ in initial position as the voiced sounds. In this paper, I want to compare the acoustic differences between the Korean lax stop series /p, t, k/ and the English /b, d, g/ sounds and try to figure out why Korean lax stop series [p, t, k,] are phonologically classified as voiceless stops although the speakers of Korean mentally "store"word initial [p, t, k] and medial [b, d, g] as one unit as [b, d, g] in their brains. English /p, t, k/ have allophones [ph, th, kh] and [p, t, k] and have no allophones [b, d, g]. Korean /p, t, k/ have allophones [b, d, g] and [p, t, k] and have no allophones [ph, th, kh]. This causes confusion in English spellings of Korean names; for example; city name 'Taejeon' is written as 'Taejeon' followed the above classification and pronounced as '**Th**aejeon' since English speaker automatically aspirates the word initial stop sounds and it is very different sound since the initial 't' sound is very close sound to voiced 'd'.

In phonetics, voicing is one of the most important features that distinguish stops. Lisker and Abramson (1964) found that the voice Onset Time (VOT) is an important cue for the voiced voiceless distinction in the spectrographic analysis, not only in English but in a number of other languages. However, my experimentation with the VOT value of Korean and English stops shows that Lisker and Abramson's claim about the voiced-voiceless distinction, using VOT is not uniformly applied across languages. In other words, the same VOT value is used for the phonetic classification of voiced sounds in some cases and the classification of voiceless sounds in other cases. This result necessitates the reconsideration of the phonemic classification of Korean and English stop consonants.

This study will be limited to stop consonants in initial position before vowels and to intervocalic position. Determining the acoustic characteristics of Korean and English stops is done by means of spectrographic analysis, especially VOT measure. The present study will be useful for English speakers learning Korean and for Korean

speakers learning English.

2. Previous Studies of Korean Stops

Martin (1951) was the first to analyze Korean sounds. He found that all Korean stop phonemes were voiceless. However, he did not use spectrographic analysis. His analysis was based on his own phonetic judgment of the productions of Korean speakers. The first acoustic study of Korean stops was done by Lisker and Abramson (1964). Their study on Korean initial stop sounds gave a basis for studying Korean initial stops. They measured the average VOT of Korean initial stop sounds and the results were as follows:

1. /ph/ 91	/th/ 94	/kh/ 126
2. /p/ 18	/t/ 25	/k/ 47
3. /p'/ 7	/t'/ 11	/k'/ 19

Wondering why all Korean stops had a positive VOT value (i.e., they are all voiceless), unlike Eastern Armenian and Thai, the other two languages with three phonation contrasts that they examined, they explained the results by saying that Korean has a peculiar distribution of stops.

Korean	E. Armenian	Thai
	b	b
p	p	p
ph	ph	ph
p'		

They explain that in Korean, VOT differences adequately distinguish the aspirates from the lax and reinforced stops but do not differentiate between the latter two cases (1964: 403). Thus Lisker and Abramson conclude that Korean is a case in which some other

(unnamed) acoustic feature is necessary to distinguish the stop.

Han and Weitzman (1970), K. Kim (1975), and C. Kim (1965) also conducted experiments on Korean initial stops. (Their results are summarized in the appendix.) All of their experiments showed almost the same relative ratio results as Lisker and Abramson's concerning the VOT value, although the-absolute values of each set of results are different due to variability among spectrographic machinery. One common factor between these scholars' experimentation is that the duration of VOT is the longest for the aspirated series; the second longest for the lax stop series, and the shortest for the tense stop series: /ph, th, kh/ > /p, t , k/ > /p', t ', k'/.

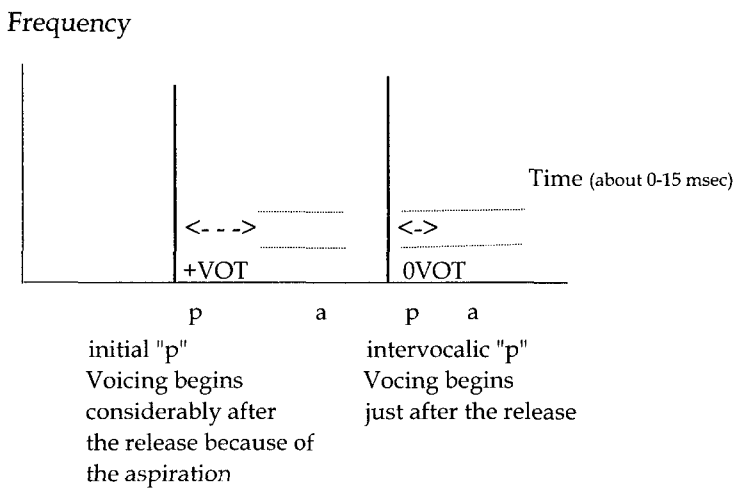
3. Voicing Onset Time as the Basic Measurement for Voicing

The differences of voicing, aspiration, and tenseness are three major phonetic dimensions which can separate the stop phonemes. Lisker and Abramson said these three dimensions of voicing, aspiration, and tenseness can be synthesized as one dimension, namely voice onset timing. The timing relationship between the release of the stop and the start of the voicing is referred to as voice onset time or VOT. The degree of voicing of stop sounds can be measured by the dimension of the time interval by which the onset of periodic pulsing either precedes or follows release. The aspiration difference is measured by the large delay in voice onset. The tenseness difference, however, is not clear in VOT. Lisker and Abramson explained this by saying that all voiceless and aspirated stops are discovered to be tense sounds, while all voiced and un-aspirated sounds are lax; therefore, tenseness is not problematic in terms of VOT. They claimed that all stops of all languages can be classified and identified in terms of VOT. The VOT measurement has been widely accepted as a powerful measurement for distinguishing stops in acoustic phonetics. In the wide-band spectrograms, if voicing begins before the release of the stop, that sound is voiced and un-aspirated. If voicing begins just after the

release, that sound is voiceless and un-aspirated. If voicing begins considerably behind the release, that sound is voiceless and aspirated. The measurements of VOT before the release are stated as negative numbers, while measurements of voice onset time after the release are stated as positive numbers. The zero point is the instant of release. If some stop sounds have a plus VOT value, it means they are voiceless sounds; if they have a minus VOT value, they are voiced sounds; if they have a zero VOT value, they are usually counted as voiceless sounds. All stop sounds are articulated by stopping the breath flow at some point in the articulatory tract, building up breath pressure, and then suddenly releasing the breath. In the wide-band spectrograms, whenever the breath flow is stopped, a similar gap or blank space will appear and the release of breath, when the lips opened suddenly, produces the irregular vertical striations. If it is a voiced stop sound, the vibration of the vocal cords produces a voice bar on the base line of the blank space. If voiceless stop have marked aspiration, the duration of silence is longer than simple voiceless stops. This is illustrated in the following English stop sounds diagram (Figure 1).

Figure 1

English Wide-Band Spectrogram



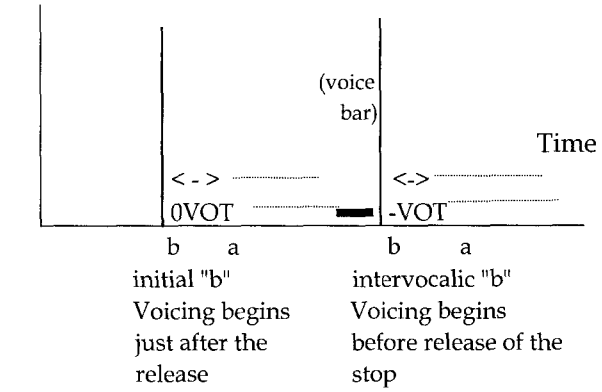


Figure 1 shows that intervocalic 'p'sound has the same VOT value with an initial 'b'sound. Lisker and Abramson and other phoneticians (e.g., Weismer 1979) classified English word initial voiced stops /b, d, g/ as voiced sounds even though they have a zero or plus VOT value (Lisker and Abramson 1964). However, this is not the case for other languages, in which sounds with a zero or plus VOT value are classified as voiceless. The VOT value is not uniformly applied across languages. This is even more evident in the following Lisker and Abramson's 1971 (Distinctive features and laryngeal control. Language 47.4,767-785) data from American English and Puerto Rican Spanish (D. Silva, 1992: 11).

Underlying Voiced			Underlying Voiceless		
b	d	g	p	t	k
(Mean VOT English)					
1	5	21	58	70	80
(Mean VOT Spanish)					
-138	-110	-108	4	9	29

*(values in milliseconds)

Here we see that the feature [voice] plays the same contrastive role

in the phonologies of both languages, it manifests itself quite differently on the surface. English "voiced stops" are for many speakers produced with vocal cords vibration that is nearly simultaneous with stop release; on the other hand, Spanish "voiced" stops are truly voiced, with vocal cord vibration preceding stop release by up to 138 milliseconds. (D. Silva, 1992: 12)

English /b, d, g/ /p, t, k/
Spanish /b, d, g/ /p, t, k/
VOT Scale<----------0---------->
+voice -voice

English "voiceless" stops are indeed voiceless but are also marked by an appreciable voicing lag; Spanish "voiceless" stops are likewise voiceless but exhibit a much smaller lag, one comparable to that of the English "voiced" segments.

In what follows, I will conduct an experiment on the VOT value of Korean and English stops by using spectrographic analysis and discuss the uniform classification of VOT value.

4. Method

The subjects for my study were five native speakers (four males and one female) and five native English speakers (three males and two females). All the Korean speakers were speaking the Seoul dialect, and all the English speakers were native New York and Pennsylvania dialect. Subjects' ages ranged from 21 to 35. English speaking subjects read 14 minimal pairs and Korean subjects read 17 minimal pairs which are contrasted with initial stop sounds. All spectrograms were made by the direct microphone input in front of the spectrograph. For Korean subjects, the text was written in Korean letters in order to lead subjects to pronounce them more naturally. A total of 60 wide-band

spectrograms were made--30 for English and 30 for Korean (refer to Appendix 1 for the subject's text). The wide-band spectrograms, employing a 500HZ filter, were made of the subject's productions, and the duration of the voice onset time of the initial stop consonants in each word was measured. Spectrographically, VOT was measured from the burst of energy, indicating the release of a stop to the onset of the vocal fold vibration marked by regularly spaced vertical striations.

5. Results and Discussion

The average durations of the initial stops in the test words are shown in Table 2.

Table 2

English			
	/ph/	/th/	/kh/
A:average	47.5	57	45
range	25-75	38-75	25-69
	/b/	/d/	/g/
B:average	-114/0	-80/0	-128/12.5
range	-150-0	-150-0	-200-12.5
Korean			
	/ph/	/th/	/kh/
C:average	61	62	72
range	25-100	31-88	31-112
	/p/	/t/	/k/
D:average	-2	15	17
range	-37.5-19	0-31	0-50
	/p'/	/t'/	/k'/

E:average	0	0	2.5
range	0-0	0-0	0-12.5

The average durations of the intervocalic /t/ sound of English and Korean are as follows:

English /t/	Korean /t/ (actually [d])
F :average 19	average 62
(range -25 ~ 38)	(range -75 ~ -50)

It should be noted that I give two sets of values for English /b, d, g/. To give a single set of values would mean mixing positive and negative values of voice onset time as items of a single population. Rather, they are distributed within two discontinuous ranges. In such a case, it would be misleading to determine single average values of onset time for the /b, d, g/ set. Moreover, the instances of positive and negative values do not occur randomly in my experiment. In other words, subjects do not randomly produce stops with positive and negative values of relative onset time; rather, each speaker always produces a single kind of /b, d, g/. As seen from the above, the English word initial voiced set /b. d, g/ has a peculiar distribution in the VOT value continuum, negative as well as positive. Lisker and Abramson's experimentation also showed the negative VOT in some cases. However, the other literature on this topic does not mention the negative value, It concentrates on the positive value; therefore, I will proceed to argue on the basis of positive values for two reasons. First, the number of subjects was so few (5 in my experiment, 4 in Lisker's). Second, it is possible that some subjects consciously try to make a distinction between voiced and voiceless minimal pairs in my experimental situation. If I ignore the negative VOT value of the English word initial voiced set, this set has almost the same VOT value as the intervocalic English voiceless stop consonants; for example:

Same VOT value: baba papa

This result is the expected one and reflects the problem in distinguishing English stops in terms of VOT. Although they occur in a different environment (therefore it can be predicted), they are acoustically the same sounds. They even share the same articulatory force, namely, lax, as well as voicing. In word initial position English /b, d, g/ is pronounced as [p, t, k] phonetically and if English /p, t, k/ phonemes did not have the aspiration feature word initially, these two sets of sounds would be the same sounds acoustically. Fry said, "It has been reported in several studies that the English voiced stop sounds are often not voiced in word-initial position. In view of this observation, the presence/absence of voicing during the interval of the articulatory closure cannot be a reliable acoustic cue for the distinctions of English stop consonants." (Fry 1979) Lisker said if there is no aspiration of the /p, t, k/ series, we cannot distinguish the two sets from each other. As seen from the above, in Korean, there are three kinds of initial stop sounds, not two as in English. There is no question about classifying the /ph, th, kh/ series as voiceless aspirated stop phonemes and the /p', t', k'/ series as voiceless tense stops. However, I found from the acoustic characteristic of the Korean lax stops, /p, t, k/ have similar VOT values word initially as English word initial /b, d, g/, as shown in Table 3.

Table 3

(VOT range of my experiment)

English	Korean
Word initial /b, d, g/	Word initial /p, t, k/
0~12 .5	-2~17
Lax	Lax

Table 3 shows that English word initial [b, d, g] and Korean word initial [p. t, k] have similar positive VOT values, that is, they are the

same voiceless sounds. Korean [p, t, k] has slightly more negative VOT value , but not significant enough to be distinguished from English [b, d, g]. David Silva's paper claimed Korean speakers (1992: 185) makes judgment on 'voicing' of a stop based on the degree where 30% of the stop closure is voiced: a segment with less than 30% of the closure voicing is judged as voiceless while a segment with more than 30% closure voicing is judged as voiced. According to Kent and Read (1992), VOT ranges from about -20ms to about +20ms for the voiced stops, and it ranges from 25ms up to 100ms for the voiceless stop sounds. These values are likely to vary with speaking styles (Gay et al., 1974). In English, the stops that have a positive VOT value are classified phonetically and phonemically as voiced sounds, while, in Korean, they are voiceless. This is a contradiction. Moreover, the fact that English intervocalic [p, t, kJ sounds have almost the same VOT values as English word initial [b, d, g] supports the hypothesis that English word initial [b, d, g] and Korean word initial [p. t, k] are acoustically almost the same voiceless sounds. This can be supported by D. Silva's Spanish data which is rewritten here:

Figure 2

English /b, d, g/ /p, t, k/
Spanish /b, d, g/ /p, t, k/
VOT <----------0---------->
+voice - voice

(D. Silva, 1992: 12)

In English, because the difference between word initial [p, t, k] and intervocalic [b, d, g] can be predicted by context, the two sounds are derived from the same unit on the phonological level, that is, from the same phoneme /b, d, g/. In Korean, the phonetic differences between word initial [p, t, k] and intervocalic [b, d, g] also can be predicted by context, the two sounds are derived from the same unit on the phonological level, that is, from the same phoneme /p, t, k/. The

phonological identity of the two phonetic realizations [p, t, k] and [b, d, g] is reflected in English and Korean orthography. Korean as well as English uses the same alphabetic unit (in English "b" in Korean "ㅂ"for both sounds: [p, t, k] and [b, d, g]). The following figure shows the English and Korean phonemic and phonetic classification clearly.

Table 4

English	Korean
1./p, t, k/--a. [ph, th, kh]/#-	3. /ph, th, kh/
--b.[p, t, k] / v-v	4. /p', t', k'/
2. /b, d, g/--c.[p, t, k] / #-	5. /p, t, k,/
--d. [b, d, g] /v-v	--e. [p, t, k] /#-
	--f. [b, d, g] / v-v

In English the phonemes /b, d, g/ have the allophones [p. t, k] in word initial position. Allophones are by definition, variants of phonemes that are predictable from a given environment. In this case English has a devoicing rule in word initially: [b, d, g] -> [p, t, k]/#_. Phoneticians want to avoid calling English initial /b, d, g/ voiceless stops; they say that initial [b. d, g] sounds are devoiced voiced stops. Han and Weitzman (1965) write that the voicing of the lax stops is "automatically conditioned by the environment, in the medial position between voiced sounds, the weak stops /p, t, k/ are usually manifested by voiced allophones [b, d, g]." However, devoiced voiced stops are exactly the same sounds as the voiceless unaspirated stops. In other words, the above "b." and "c." are the similar sounds and should be described the same way in phonetic transcriptions. In that case, the English phonemes /b, d, g/ and /p, t, k/ are in partial overlapping word initially. Partial overlap means one phone can be assigned sometimes to one phoneme and at other times to another phoneme depending on the context. The phones [p, t, k] are assigned to the phonemes /p, t, k/ inter-vocalically; however, they are

assigned to /b, d, g/ word initially.

In Korean, the lax stop series /p, t, k/ have the same phones in the same environment as English /b, d, g/ (see Table 4 "2"and "5"). Establishing phonemes can be done in many possible ways and these different solutions are not correct or incorrect, but may be regarded only as being good or bad for various purposes. In English, the phones [b, d, g] are contrasted with the phones [p, t, k] word medially; therefore, it is reasonable to establish the phonemes /b. d, g/. In Korean, the phones [p, t, k] and [b, d, g] never contrast with each other and they are in complementary distribution. Therefore, it is arbitrary to posit the phoneme /p, t, k/ or /b, d, g/ for phones [p, t, k] and [b, d, g], since Korean has no contrastive minimal pairs between them. However, since Koreans mentally "store" word initial [p, t, k] and medial [b, d, g] as one unit in their brains as [b, d, g] is the rather reasonable factor to posit /b, d, g/ as the representative phonemes for [p, t, k] and [b, d, g]. This can explain also why the /p, t, k/ series has the allophones /b, d, g/ instead of /p', t', k'/ in Korean although /p', t', k'/ has the shorter VOT duration time than /p, t, k/. According to Chin-Woo Kim (1968), the reason why /p, t, k/ have allophones instead of /p', t', k'/ (although /p', t', k'/ have shorter VOT values than /p, t, k/; therefore, /p', t', k'/ are closer to the voiced sounds /b, d, g/ than /p, t, k/ in terms of VOT value) is that, in Korean stops, tenseness is the primary feature that occupies the higher node in the phonological hierarchy of stops, and VOT is the secondary feature. This is rather arbitrary argument since tenseness cannot be a primary factor to distinguish stops above voicing in any other world languages. Lisker and Abramson stated Korean has s a peculiar distribution of consonants because all consonants are voiced. If we posit /b, d, g/ as the representative phoneme for Korean [p, t, k] and [b, d, g], it is more natural consonant system where voiced-voiceless distinction exist and it does accommodate with the phoneme definition "the phoneme is a mental reality, as the intention

of the speaker or the impression of the hearer, or both"(Twaddell, 1935:56). Since each time a speaker pronounces the sound [p] it is acoustically never quite the same as the last [p], the speaker must have internalized an image or idealized picture of the sound, a target which he tries to approximate." (Hyman, 1975:72). Korean speakers try to pronounce [b, d, g] word initially and slightly more devoiced than English or any other western language [b, d, g] and sounds like [p, t, k] to western ears. Koreans use the same alphabet to 'ㅂ'for word initial [p, t, k] and medial [b, d, g] show their mental perception of these sounds.

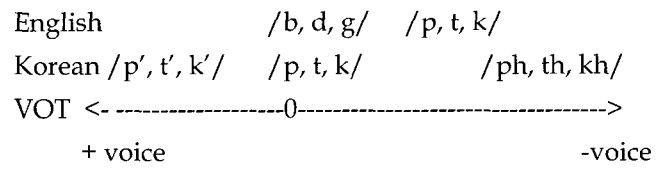
Probably acoustically /p, t, k/ is more correct, but from the perceptual standpoint of the native speaker, /b, d, g/ seems to be more correct. If we posit /b, d, g/ as representative phonemes, it reduces confusion when a Korean learns English. One of the reasons that Korean lax stops are represented as he phoneme /p, t, k/ instead of /b, d, g/ is the influence of Martin's analysis of Korean phonemes. His analysis was derived not from experimental phonetic evidence, but from an auditory and impressionistic test. To English speakers' ears, the Korean lax stop series gives the auditory impression that they are voiceless sounds because Korean /p, t, k/ sounds have slightly more positive VOT value than the English /b. d, g/ sounds word initially. Conversely, to Korean ears, English word initial /b. d, g/ sounds are perceived as voiced ones because English /b, d, g/ sounds have less positive VOT value than Korean /p, t, k/ sounds.

6. Conclusion

Phonetically, Lisker and Abramson's criterion of classifying stops in cross-world language lacks uniformity. This is the case of Korean too. My experiment has proven the necessity of reconsideration of phonemic classification of the Korean lax stop series /p, t, k/ in word initial position. My experimentation has established that the English word initial stop sounds [b. d, g] and the Korean lax stop series /p, t,

k/ in word initial position are similar in the range of voice onset time. This has been supported by other scholars too. Fry said "it has been reported in several studies that the English voiced stop sounds are often not voiced in word-initial position." (Fry 1979) These findings are summarized in the following diagram.

Figure 3



English word initial /b, d, g/ sounds as voiced, then Korean word initial /p, t, k/ are should be classified as voiced also. It would be better to classify English word initial /b, d, g/ as voice-less /p, t, k/ instead of /b, d, g/, because, in English, word medial /p, t, k/, which has the same VOT as word initial /b, d, g/, is classified as voiceless /p, t, k/. Phonemically, English /b, d, g/ phonemes have the allophones [p, t, k] word initially and these allophones are phonetically the same as the allophones of the phonemes /p, t, k/ in intervocalic position. Therefore, the English stop phonemes /p, t, k/ and /b, d, g/ are in partial overlap.

The Korean lax stops /p, t, k/ have the same allophones as English /b, d, g/ in the same environment. Phonetically English /b, d, g/ phonemes and Korean /p,t, k/ phonemes are very similar except the word initial [p, t, k] are devoiced slightly more than English word initial [b, d, g]; however, the Korean [p, t, k] and [b, d, g] phones never contrast with each other as in English. In other words, there is nothing in Korean phonology that determines whether these are [+voiced] or [-voiced]. Therefore, it is arbitrary to posit these phonemes for the Korean [p, t, k] and [b, d, g] phones. If we posit the /p, t, k/ phonemes, it is probably more consistent with VOT measures;

however, it causes confusion when Korean speakers learn English sounds because mentally Korean speakers store [p, t, k] and [b, d, g] as the same sound since Koreans use the same alphabet 'ㅂ' for word initial [p, t, k] and medial [b, d, g]. It also explains why the /p, t, k/ series has the allophones /b, d, g/ instead of /p', t', k'/ in Korean although /p', t', k'/ has less positive VOT value than /p, t, k/. Present classification makes English /p, t, k/ and Korean /p, t, k/ are really different sounds. If we posit /b, d, g/ as Korean phonemes, then it does not cause spelling or pronunciation confusion when Koreans learn English or English speakers learn Korean. Thus 'Daejeon' will be the correct spelling for 'Taejeon' and pronunciation-wise it is more native like pronunciation. The phoneme is regarded as a convenient fictitious unit whose reality is yet to be proven. Establishing phonemes can be done in many possible ways and we cannot say which way is correct or incorrect; we can only say whether it is good or bad. Positing /p, t, k/ based on phonetic evidence or /b, d, g/ based on native speakers' psychological reality is a matter of convention. I believe it should be done based on native speakers' mental reality and naturalness of consonant systems. It is true that phonological representations are not identical to phonetic descriptions and there is a gap between phonemic and phonetic levels; however, the two levels are related to each other. The more phonology narrows the gap between the two levels, the more phonology effectively represents the natural language.

References

Ahn, H. 1999. *Post Release Phonatory Processes in English and Korean: Acoustic Correlates and Implications for Korean Phonology*. Ph.D. Dissertation. The University of Texas at Austin.

Dart, S. N. 1987. An aerodynamic study of Korean stop consonants: measurements and modeling. *Journal of the Acoustical Society of America* 81, 138-147.

Fry, D. B. 1979. *The Physics of Speech*. Cambridge: Cambridge University Press.

Fujimura, O., H. J. Hacchi, and L. A. Streeter. 1978. Perception of stop

consonants with conflicting transitional cues: A cross-Linguistic study. *Language and Speech* 21, 337-346.

Gleason, M. A. 1961. *An Introduction to Descriptive Linguistics.* New York: Holt, Rinehart, & Winston.

Han, J.-I. 1996. *The Phonetics and Phonology of "Tense" and "Plain" Consonants in Korean.* Ph.D. Dissertation. Cornell University

Han, M. S. and R. S. Weitzman. 1970. Acoustic features of Korean /P, T, K/, /p, t, k/ and /p', t', k'/. *Phonetica* 22, 112-128.

Hardcastle, W. J. 1973. Some observations on the tense-lax distinction in initial stops in Korean. *Journal of Phonetics* 1, 263-272.

Hyman, L. H. 1975. *Phonology Theory and Analysis.* New York: Holt.

Kagaya, R. 1974. A fiberscopic and acoustic study of the Korean stops, affricates and fricatives. *Journal of Phonetics* 2, 161-80.

Kent, R. and C. Read. 1992. *The Acoustic Analysis of Speech.* San Diego: Singular Publishing.

Kim, C. W. 1965. On the autonomy of the tensity feature in stop classification. *Word* 21, 339-359.

Kim, K.-O. 1975. The nature of temporal relationship between adjacent segments in spoken Korean. *Phonetica* 31, 259-273.

Lisker, L. 1957. Closure and the intervocalic voiced-voiceless distinction in English. *Language* 33, 42-29.

Lisker, L. 1978. In qualified defence of VOT. *Language and Speech* 21, 375-383.

Lisker, L. and Abramson. 1964. A cross-language study of voicing in initial stops: Acoustical measurement. *Word* 20, 384-422.

Lisker, L. and Abramson. 1971. Distinctive features and laryngeal control. *Status Report on Speech Research* 27, 133-153. Haskins Laboratories.

Lisker, L. 1967. Some effects of context on voice onset time in English stops. *Language and Speech* 10, 1-28.

Lisker, L., A. M. Liberman, D. M. Erickson, D. Dechovitz, and R. Mandler. 1977. On pushing the voice-onset-time boundary about. *Language and Speech* 20, 209-216.

Martin, S. E. 1951. Korean phonemics. *Language* 27, 519-533.

Martin, S. E. 1956. Korean morphophonemics. *Language* 32, 314-319.

Silva, D. J. 1992. *The Phonetics and Phonology of Stop Lenition in Korean.* Ph.D. Dissertation. Cornell University.

Sloat, C., S. H. Taylor, and J. E. Hoard. 1978. *Introduction to Phonology.* New Jersey: Prentice Hall Inc.

Tyun, C. E. 1931. The Korean alphabet and its approximate Korean equivalents. *Indiana Univ. Studies* 18, 87.

Twaddell, W. F. 1935/57. On defining the phoneme. *Language Monograph* 16. Baltimore. Reprinted in Joos, 1957, 55-80.

Weismer, G. 1979. Sensitivity of voicing onset time measures to certain segmental features in speech production. *Journal of Phonetics* 7, 197-204.

Wemyss, S. 1950. *The Languages of the World.* New York: Wehman Bros.

Wolf, C. C. 1960. Voicing cues in English final stops. *Language and*

Speech 3, 71-77.

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received: May 28, 2003
accepted: August 28, 2003

Appendix 1

English Text

1. /dada/	/tata/	
2. /deda/	/teda/	
3. /beda/	/peda/	
4. /geda/	/keda/	
5. /be/	/de/	/ge/
6. /pe/	/te/	/ke/

Korean Text

1. 다다 [tata]	타타 [thatha]	따따 [t'at'a]
2. 대다 [teda]	태다 [theda]	때다 [t'eda]
3. 배다 [peda]	패다 [pheda]	빼다 [p'eda]
4. 개다 [keda]	캐다 [kheda]	깨다 [k'eda]
5. 배 [pe]	대 [te]	개 [ke]
6. 패 [phe]	태 [the]	캐 [khe]

Appendix 2

Voice Onset Time of English in Miliseconds

Informant 1 (male)

/ph/	/th/	/kh/
AV 56.3	50	33
RA 50~62.5	37.5~62.5	25~40

/b/	/d/	/g/
AV -112	-58	-85
RA -112~112	25~ -112	-31~ -138

Intervocalic /t/: -25

Informant 2 (male)

/ph/	/th/	/kh/
AV 47	48	33
RA 37.5-56	37.5~56	28-37.5

/b/	/d/	/g/
AV-77	-100	+37.5
RA -100~100	-81~ -150	-100~ -100

Intervocalic /t/: +37.5

Informant 3 (male)

/ph/	/th/	/kh/
AV 25	50	60
RA 25~25	37.5~75	50~68.8

/b/	/d/	/g/
AV -131	-150	-200
RA -112~150	-150	-200

Intervocalic /t/: +19

Informant 4 (female)

/ph/	/th/	/kh/
AV 44	62	45
RA 37.5~50	50~75	31.5~56.5

/b/	/d/	/g/
AV 0	0	12.5
RA 0	0	12.5

Intervocalic /t/: + 37.5

Informant 5 (female)

/ph/	/th/	/kh/
AV 65	66	53
RA 56~75	56~62.5	44~62.5

/b/	/d/	/g/
AV 0	0	6.3 RA 0
	0	0~12.5

Intervocalic /t/:+25

Voice onset time of Korean in milliseconds

Informant 1 (female)

/ph/	/th/	/kh/
AV 62.5	45	84
RA 60~75	37.5~66	81.3-87.5

/p/	/t/	/k/
AV 9.4	6.3	9.3
RA 0~18.8	0~ 12.5	0~ 18.7

Intervocalic /t/: -75

/p'/	/t'/	/k'/
AV 0	0	0
RA 0	0	0

Informant 2 (male)

/ph/	/th/	/kh/
AV 60	73	95
RA 31.3~100	62.5~87.5	87.5-100

/p/	/t/	/k/
AV _	31	38
RA _	31	25~50

Intervocalic /t/: _

/p'/	/t'/	/k'/
AV 0	0	0
RA 0	0	0

Informant 3 (male)

/ph/	/th/	/kh/
AV 73	68.7	94
RA 68.7~75	56~75	87.5~100

/p/	/t/	/k/
AV 0	25	0
RA 0	18.7~ 31	0

Intervocalic /t/: -50

/p'/	/t'/	/k'/
AV 0	0	0
RA 0	0	0

Informant 4 (male)

/ph/	/th/	/kh/
AV 36.5	40	31
RA 25~48.8	31~50	31

/p/	/t/	/k/
AV -19	0	19
RA 0~37.5	0	0~ 37.5

Intervocalic /t/: -63

/p'/	/t'/	/k'/
AV 0	0	
RA 0	0	

Informant 5 (male)

/ph/	/th/	/kh/
AV 63	75	94
RA 50~75	68.8~82	75~112

/p/	/t/	/k/
AV 0	12.5	19
RA 0	12.5	19

Intervocalic /t/: _

/p'/	/t'/	/k'/
AV 0	0	0
RA 0	0	0

Chin-W Kim: Voice Onset Time of Korean

	/p'/	/t'/	/k'/
AV 12	9	15	13

	/p/	/t/	/k/
AV 35	23	38	45

	/ph/	/th/	/kh/
AV 93	98	92	90

Leigh Lisker: Voice Onset Time in Miliseconds : Korean (1 speaker)

	/p/ /k/	/p'/ /k'/	/ph/ /kh/	/t/	/t'/	/th/
AV	7 19	18 47	91 126	11	25	94
R.	0:15 0:35	10:35 30:65	65:115 85:200	0:25	15:40	75:105
M.	15 16	30 34	21 12	16	24	12

Leigh Lisker: Voice Onset Time in Miliseconds : English (4 speakers)

	/b/ /t/	/p/ /g/	/d/ /k/
AV	1/-101 70	58 21/-88	5/-102 80
R.	0:5/-130:-20 30:105	20:120 0:35/-150:-60	0:25/-155:-40 50:135
M.	51/17 116	102 53/13	63/13 84

M.S. Han and R.S. Weitzman: Acoustic Features of Korean: VOT in Centiseconds

Informant 1

	/ph/	/p/	/p′/
AV	12.90	2.70	0.53
Min	8.00	1.50	0.00
Max	18.50	4.50	1.50

	/th/	/t/	/t′/
AV	13.30	3.30	1.20
Min	8.50	1.50	0.50
Max	19.00	8.00	2.50

	/kh/	/k/	/k′/
AV	14.80	6.20	2.04
Min	9.50	1.00	1.25
Max	20.50	10.00	3.50

Informant 2

	/ph/	/p/	/p′/
AV	10.50	1.96	0.18
Min	7.50	0.75	0.00
Max	14.00	4.00	1.00

	/th/	/t/	/t′/
AV	10.70	2.29	0.75
Min	7.50	1.25	0.25
Max	17.00	3.00	1.50

	/kh/	/k/	/k'/
AV	13.60	4.24	2.71
Min	11.00	1.50	1.25
Max	17.50	7.25	5.25

Informant 3

	/ph/	/p/	/p'/
AV	6.60	1.68	0.48
Min	2.00	0.50	0.00
Max	9.50	3.25	1.00

	/th/	/t/	/t'/
AV	7.30	2.10	0.57
Min	4.50	1.00	0.25
Max	13.00	4.00	1.50

	/kh/	/k/	/k'/
AV	7.10	4.00	11.00
Min	2.72	1.50	5.00
Max	1.52	0.75	2.75