

*Acoustic evidence for the emergence of tonal contrast in contemporary Korean**

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Acoustic evidence suggests that contemporary Seoul Korean may be developing a tonal system, which is arising in the context of a nearly completed change in how speakers use voice onset time (VOT) to mark the language's distinction among tense, lax and aspirated stops. Data from 36 native speakers of varying ages indicate that while VOT for tense stops has not changed since the 1960s, VOT differences between lax and aspirated stops have decreased, in some cases to the point of complete overlap. Concurrently, the mean F0 for words beginning with lax stops is significantly lower than the mean F0 for comparable words beginning with tense or aspirated stops. Hence the underlying contrast between lax and aspirated stops is maintained by younger speakers, but is phonetically manifested in terms of differentiated tonal melodies: laryngeally unmarked (lax) stops trigger the introduction of a default L tone, while laryngeally marked stops (aspirated and tense) introduce H, triggered by a feature specification for [stiff].

1 Introduction

Despite long-standing descriptions of standard Korean as a non-tonal and non-accentual language (Martin 1992: 60, Sohn 1999: 48, Lee & Ramsey 2000: 315), the data analysed for this study indicate that some self-identified speakers of standard (Seoul) Korean employ a speech-production strategy that includes a tonal contrast. Moreover, this tonal system has arisen in the context of a diachronic shift in Korean's three-member contrast among tense, lax and aspirated obstruents: as reported by several researchers (Jun

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1993, Kim 2000, Kim & Park 2001), many speakers of the standard language – more specifically, younger speakers (Silva 2006) – no longer mark the contrast between lax and aspirated stops in phrase-initial position with differences in voice onset time (VOT). Rather, some speakers of Korean appear to be implementing surface-level phonation-to-tone shifts akin to those reported for languages such as Tibetan (Duanmu 1992) and Kammu (Svantesson & House 2006), languages in which historical/underlying laryngeal distinctions are reinterpreted as systematic differences in fundamental frequency (F0).¹ As some younger speakers have neutralised VOT differences between lax and aspirated stop phonemes and mark this contrast tonally, formal accounts of the Korean obstruent system need revision in the direction of feature representations that adequately account for the phonetic behaviour of *all* speakers of the standard variety, young and old alike. The modification proposed here involves replacing underlying glottal aperture features (specifically [spread glottis] and [constricted glottis]) with a more abstract laryngeal ‘tensity feature’ (*à la* Kim 1965), [stiff]. This single feature has the advantage of generalisability across the speaker pool: [stiff] may be phonetically implemented in either a more traditional way, i.e. maintaining VOT distinctions between lax and aspirated stops, or a more innovative manner, i.e. backgrounding aspiration differences in favour of a tone-based strategy for marking the underlying lax *vs.* aspiration distinction.

2 Background

Korean is unusual among the major languages of East Asia in at least two ways. First, the consonant system of Korean includes a typologically rare (if not unique) distinction among three types of voiceless obstruents: lax (or plain), which Sohn (1999: 154) describes as ‘basically voiceless, with only a minor degree of aspiration and no tenseness’; tense (or reinforced, geminated), characterised by ‘building up air pressure behind the closed place of articulation’ and an unaspirated release (Sohn 1999: 154); and aspirated, produced ‘with strong aspiration lasting about 100 ms’ (Lee & Ramsey 2000: 62).² Second, most varieties of Korean do not employ F0 lexically. While both earlier stages of Korean and contemporary varieties of the language have been shown to employ pitch-based accentual systems,

¹ While it might be tempting to assume that the process described here is tonogenesis, it is perhaps best to take a cue from Svantesson & House (2006), and hold off on making such a claim. Whether standard Korean ultimately develops a purely tonal means for distinguishing lexical items currently contrasted in terms of consonantal phonation differences remains to be seen.

² In a more recent re-evaluation of the Korean consonantal system, Kim (2000) and Kim & Duanmu (2004) claim that the Korean system is, in fact, typologically unremarkable, arguing that the fundamental difference among the three stop types can be analysed in terms of the common voiced *vs.* voiceless contrast. For additional discussion on this point, see §5.

the majority of Koreans speak a variety in which F0 plays no phonologically contrastive role at the word level (Sohn 1999: 60–62, Lee & Ramsey 2000: 280, 315).

As documented in the current study, however, the phonetic implementation of the phonemic contrast among lax, tense and aspirated segments has been changing over the past two generations. According to widely cited phonetic accounts of Korean written in the 1960s and 1970s (Han & Weitzman 1965, 1967, Kim 1965, Hardcastle 1973, Kagaya 1974), a key acoustic correlate associated with each stop type is voice onset time: tense stops manifest short VOTs (in the range of 6 to 18 ms), aspirated stops manifest long VOTs (~100–115 ms), and lax stops manifest intermediate VOT values (~20–60 ms). Yet more recent acoustic studies of the language (Silva 1992, Kim 1995, Cho 1996, Han 1996, Flege *et al.* 1999) have reported noticeably different VOT values for the lax and aspirated stops; specifically, lax stops are more aspirated (~40–70 ms), while aspirated stops are less so (~85–105 ms).

The first published mention of a possible diachronic change in VOT values is a passing mention in Silva (1992: 157). Indirect evidence for such a change for VOT was presented in Silva (2002), a meta-analysis of relevant phonetic studies published between 1965 and 2000. The conclusions drawn from the meta-analysis led directly to the development of the study being reported here. Preliminary accounts of the acoustic data reported in this work first appeared in Silva *et al.* (2004), an initial description of observed age-related VOT changes for 14 female speakers in the current subject pool, which verified the existence of a robust age-related reduction of VOT values associated with the aspirated stops of the language (VOT_{asp}). Silva (2006) provides an expanded phonetic account of VOT behaviours for an additional 20 speakers, in which it is reported that an observed apparent-time decrease in VOT_{asp} , coupled with a less clear-cut rise in VOT_{lax} and a lack of any change for VOT_{tense} , points to a pattern whereby the VOT difference between lax and aspirated stops has decreased over time. Indeed, for many younger speakers, particularly those born during the 1970s and 1980s, any VOT-based distinction between lax and aspirated stops has been completely neutralised. If VOT no longer serves to distinguish lax from aspirated stops (at least for some speakers), is there evidence of a phonemic merger? As the data analysed here suggest, the answer is ‘no’: rather, contrasts previously marked primarily by differences in VOT have now been complicated by the addition of a tonal dimension, which, for some speakers, has assumed a primary role in distinguishing lax stops from their aspirated correspondents.³

³ A similar claim appears in Choi (2002), in which data from three speakers of the Seoul dialect are compared with those of three speakers from the Chonnam dialect. The participants in Choi’s study (which did not consider the issue of language change) are all ‘in their late twenties’ (2002: 5), squarely placing them in the younger cohort analysed in the current work.

phonation type	place of articulation		
	labial	alveolar	velar
lax (plain)	pa.nu.cil 'sewing, needlework'	ta.mo.cak 'multiple cropping'	ka.lo.tung 'streetlight'
tense (reinforced)	ppa.tu.tuk 'grinding sound'	tta.li.kwun 'flatterer'	kka.ma.tuk 'far away time/place'
aspirated	pha.na.mul 'scallion salad'	tha.ko.cang 'alien place'	kha.ni.bal 'carnival'

Table I

Target words employed in the study. All forms are given in Yale Romanisation. Orthographic syllable boundaries are indicated by a period.

3 Methodology

3.1 Materials

The materials developed for this study consist of experimentally controlled frame sentences containing nine different target forms, each of which is a three-syllable lexical item beginning with a 'C-a' sequence (Table I). The frame took the shape *i ken* __ *-i-la-ko ha-cio* 'This thing is called (a) __', where the left edge of the target corresponds to the left edge of a phonological phrase, as discussed in Silva (1992) and Yu-Cho (1990) (and roughly consistent with an accentual phrase as characterised by Jun 1993). This frame is consistent with that used in previous research (e.g. Silva 1992), particularly in that it locates the target forms in 'initial position' (a term used without further elaboration by the earliest researchers on this topic, e.g. Han & Weitzman 1965, 1967). The use of a topic-marked pronominal immediately to the left of the target form, *i ken* (< *i kes-eun* < *i* 'this', *kes* 'thing', *-eun* TOPIC), further ensures the presence of a phrasal boundary immediately before the target. As has been amply demonstrated in the literature on Korean phonetics and phonology, the prosodic position of a consonant segment plays a critical role in how that segment will be realised on the surface. In phrase-initial position, for example, the word-initial stops of the target items are expected to be realised in their strongest (i.e. least lenited) variants: tense segments should manifest noticeably long closures with very short VOTs, lax segments should manifest moderate VOTs and aspirated segments should manifest very long VOTs (Silva 1992).

Each sentence (e.g. *i ken panulcililako hacio* 'this is called needlework') was printed in Korean script on individual index cards. Subjects were instructed to read the cards in random order, along with other cards functioning as distractors (items to be used in research not related to the

current study), at a self-selected rate of speech, described as ‘normal, comfortable reading speed’. After the subject had read each of the randomly presented sentences, the cards were shuffled and the reading process repeated. For this study, data from either three or four rounds have been analysed, thereby yielding a total of 27 to 36 tokens for each subject.

3.2 Subjects

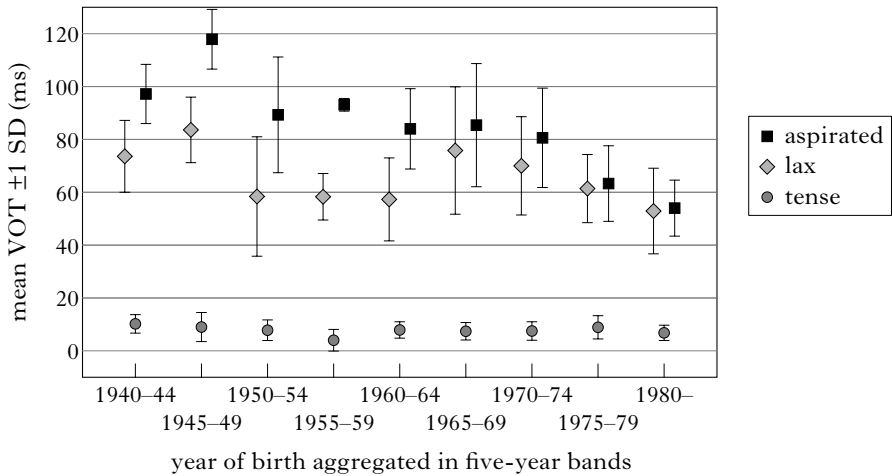
The data for this study were elicited from 36 adult native speakers of Korean residing in the area of Dallas-Fort Worth, Texas, 21 females and 15 males, born between 1943 and 1982. In response to a demographic questionnaire, all subjects reported that they were born, raised and educated in the capital region of Korea (i.e. Seoul city or Gyeonggi province), and that they speak the standard variety. All subjects entered the United States after the age of 18 and use Korean at home, speaking English as a second language (primarily for business or educational purposes). No subjects reported any difficulties in speech or hearing.⁴

Subjects were recruited through a social networking approach and invited to participate in a 20–30 minute recording session in a quiet location of the subject’s choosing. Each session was recorded by one of two female native speakers of Korean using a standard cassette audiotape and a lapel microphone. The recordings were subsequently digitised (22,050 Hz, 16 bit) for acoustic analysis in Praat (version 4.2.14).

3.3 Data measurement

For each target word in the corpus, seven measurements were taken: VOT of the word-initial stop, the F0 of the vowel in the first syllable at three points (onset, midpoint and offset), and the averaged F0 of the vowels in each of the target form’s three syllables. Averaged F0 values were obtained by selecting the span of the vowel in acoustic display and allowing Praat to automatically calculate the desired value. While employing this sort of summary measure obscures F0 contours that might be associated with a

⁴ Each of these selection criteria was implemented to increase the likelihood that the data elicited was maximally representative of standard Korean, despite the practical limitation imposed by the fact that the subjects under investigation are currently resident in the United States. Further assurances regarding the authenticity of the data were obtained through the on-field judgments of the two female native speakers who were contracted to recruit and record subjects for this study; these data collectors, both doctoral students in linguistics with specific training in phonetics and phonology, ascertained that each subject was a *bona fide* native speaker of Korean with no discernable second-language phonetic traits. A subsequent assessment of each subject’s authenticity was independently made in early 2006 by a third native Korean speaker, who judged all 36 subjects to be legitimate native speakers of the language. Post hoc efforts to ensure the validity of the speech data aside, of key importance is the fact that each subject entered the United States on or after the age of 18, beyond the point at which influence from American English would appreciably influence the subjects’ production of the stops under investigation. See Flege *et al.* (1995) and Flege *et al.* (2003) for further discussion of ‘Age of Arrival’ or ‘Age of Learning’ effects.

*Figure 1*

Mean VOT values and range (1 standard deviation) over time. Each marker represents the mean VOT value for speakers aggregated into five-year bands, based on year of birth.

particular vowel, it successfully captures a more general sense of the vowel's pitch in relation to (a) the other two vowels in the same target word and (b) corresponding syllables (i.e. first–second–third) in other target forms.

4 Results

4.1 VOT patterns

As predicted on the basis of previous research, while VOT values for the tense stops have remained stable over time, there are clearly discernable age-based differences in VOT values for lax and aspirated stops. In Fig. 1, which (for the sake of clarity) aggregates subjects into a series of nine five-year bands (following Labov 1994: 60ff), we find that for younger speakers the distances between mean VOT_{asp} and mean VOT_{lax} are smaller than those observed for older speakers. This apparent change in behaviour is most evident in the VOT data associated with the cohort of speakers born in 1965 and after: for each of these bands, the difference between VOT_{asp} and VOT_{lax} diminishes considerably, with corresponding overlap in the VOT data ranges (presented here as one standard deviation on either side of the mean).

The changing role of VOT as a means of distinguishing lax and aspirated stops in Korean becomes all the more evident when one disaggregates the data and calculates the mathematical difference between the mean VOT values for lax and aspirated stops for each of the 36 subjects. Since there is no natural pairing of individual tokens in the corpus, extracting VOT differences may only be done by determining the mean VOT_{lax} and mean VOT_{asp} for each speaker and then calculating 'delta-

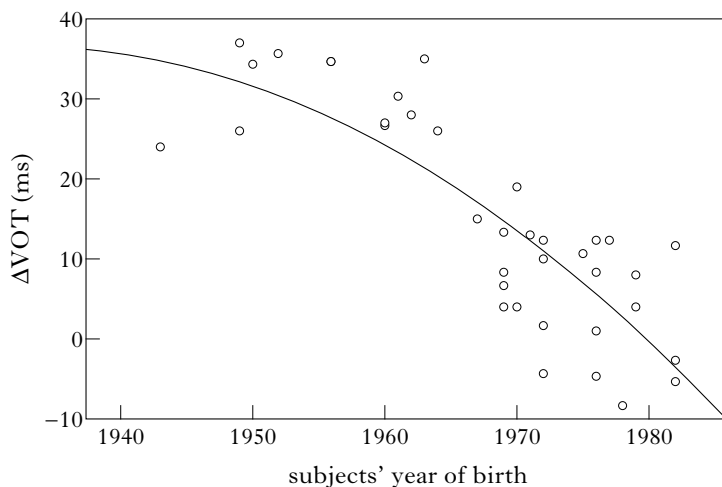


Figure 2

ΔVOT ($VOT_{asp} - VOT_{lax}$) as a function of subjects' year of birth. The best-fit curve is that representing a quadratic function ($R^2 = 0.686$).

VOT' : $\Delta VOT = \text{mean } VOT_{asp} - \text{mean } VOT_{lax}$. In calculating ΔVOT , we can better assess the relative (and putatively phonemically driven) differences in VOT employed by each speaker, while accounting for the fact that there are individual speaker differences in overall degree of aspiration (Silva *et al.* 2004). As illustrated in Fig. 2, older speakers consistently produce clear differences between mean VOT_{lax} and mean VOT_{asp} ($\Delta VOT > 0$ ms), while younger speakers produce noticeably smaller differences between mean VOT_{lax} and mean VOT_{asp} ($\Delta VOT < 20$ ms). In fitting a curve to the data, the best fit proved to be that for a quadratic equation ($R^2 = 0.686$), indicating that the relationship between ΔVOT and year of birth is non-linear (cf. the R^2 of 0.656 for a linear regression). Perhaps most surprising is the finding that for a handful of speakers ΔVOT is negative: lax stops appear to manifest longer voice onset times than aspirated stops, a finding certainly at odds with widely accepted descriptions of the language.

A repeated-measures ANOVA performed on the mean VOT values for the 36 subjects further revealed that both place of articulation ($F(2, 66) = 5.2$, $p = 0.008$) and phonation type ($F(2, 66) = 57.4$, $p < 0.001$) are significant within-speaker effects, with year of birth functioning as a significant covariate ($F(1, 33) = 10.9$, $p = 0.002$); speaker sex was not significant ($F(1, 33) = 0.0$, $p = 0.992$). Moreover, there was a single significant interaction: phonation \times year of birth ($F(2, 66) = 20.9$, $p < 0.001$).⁵

⁵ Initial assumptions regarding the data for VOT (as well as F0, discussed below) suggested that both within-speaker and between-speaker effects might play significant roles in the analysis. As such, the data were subjected to a series of repeated-measures analyses of variance, each of which included three factors initially thought to be relevant: phonation type, place of articulation and repetition

With respect to place of articulation effects, we find little new to report: as the point of articulation moves toward the posterior region of the oral cavity, VOT tends to increase (Laver 1994: 352, Ladefoged 2003: 98). Although robust for the tense and the lax stops, this pattern is confounded for the aspirated stops: while the mean VOT for /k^h/ is the longest (80.4 ms), the mean VOT for /p^h/ (79.5 ms) is greater than that for /t^h/ (73.5 ms). Scheffé post hoc tests reveal two homogeneous subsets, the first of which includes the alveolar and labial places of articulation and the second of which includes labial and velar.

With regard to phonation effects, VOT values associated with the tense stops (/pp tt kk/) were significantly (and unsurprisingly) lower than those associated with lax /p t k/ or aspirated /p^h t^h k^h/ for all speakers in the corpus, a result is consistent with Silva's (2002) meta-analysis of the VOT literature. As concerns the mean VOT for lax and aspirated stops, however, the data revealed more complex relationships involving the speakers' year of birth. A hierarchical cluster analysis on the VOT data revealed an important divide among the subjects: speakers before 1965 belonged to one cluster, while those born in 1965 and after belonged to another. One subject, a male born in 1970, patterned with the pre-1965 group.

Among the older speakers, the 'traditionalists', the mean VOT associated with tense, lax and aspirated stops were all significantly different ($p < 0.05$), with mean VOT_{tense} ranging from 3 to 18 ms, mean VOT_{lax} ranging from 36 to 90 ms and mean VOT_{asp} ranging from 51 to 117 ms (Fig. 3).⁶ For younger speakers, the 'innovators', the mean VOT associated

number. In addition, each speaker's year of birth was taken as a covariate. During this preliminary stage of the analysis, what was systematically varied from one ANOVA to the next was a series of extralinguistic factors associated with potential between-speaker effects, including speaker sex and an array of other factors corresponding to the items included in the questionnaire, namely demographic data (self-reported educational level, occupation, father's dialect, mother's dialect, etc.) and a series of self-assessments (relative importance of clear speech, self-appraisal of speaking skill, etc.). Ideally, a single analysis including all of these variables would have provided a more statistically disciplined account of the data. Given the fact that only 36 subjects are represented in the corpus, however, such an ANOVA would have proven problematic, given the enormous ratio of variables to subjects. A less statistically sophisticated (and admittedly weaker) piecemeal approach was adopted, one yielding the aforementioned 'series' of ANOVAs. Under this strategy, the only between-speaker factors that played a significant role in any of the statistical analyses ($\alpha = 0.05$) were year of birth and sex.

⁶ It is worth mentioning that the so-called traditionalists are not even as 'traditional' as the speakers documented in the first instrumental studies of Korean. Han & Weitzman (1965: 163) report that 'in the initial position, aspiration with /p^h, t^h, k^h/ last, on the average, 14–15 centiseconds. In most cases, it lasts more than 10 centiseconds'. In the current corpus, however, VOT values for the aspirated stops are not so long, with the upper end of the range reaching only 11.4 centiseconds. Moreover, in research conducted by Lisker & Abramson (1964) and Kim (1965), we find considerable overlap in the distribution of VOT values for tense and lax stops. In the current corpus, no subject manifested such overlap, producing statistically significantly distinct distributions for VOT_{tense} and VOT_{lax} . Hence, while the general patterns of phonemic differentiation appear to be preserved by the 'traditionalists' of the current corpus, the absolute values for VOT seem to have changed.

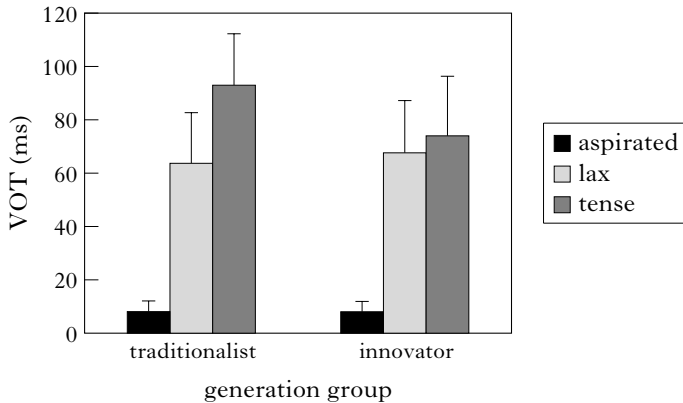


Figure 3

Mean VOT values (ms) of tense, lax and aspirated stops for traditionalists *vs.* innovators. Error bars: ± 1.00 SD.

with tense and lax stops is nearly equal to that for the traditionalists, but the mean VOT for aspirated stops is markedly lower (69.7 ms *vs.* 94.0 ms). Moreover, a repeated-measures ANOVA run only on the innovators (using place of articulation and phonation type as the independent factors and year of birth as a covariate) indicates that despite the relatively lower mean VOT_{asp} , phonation type remains a significant factor ($p < 0.001$): as a group, these younger speakers appear to use VOT differences to mark the relevant phonemic distinction, but without the same degree of separation in evidence for older speakers of the community.

In considering further the production of these younger speakers, however, one cannot help but be drawn back to the data in Fig. 2 and wonder if the story to be told is, in fact, more complicated still. For the innovator cohort alone, a correlation between year of birth and ΔVOT yields an R^2 of 0.173, indicating no meaningful age-related pattern. Moreover, there are five speakers for whom ΔVOT is negative, suggesting that for these subjects lax stops are produced with more aspiration than phonemic 'aspirated' stops, a departure from established norms. Can these speakers be differentiated from the others on extralinguistic grounds other than age? Given the current corpus, with its limited degree of social stratification, the answer at this point is a qualified 'no'. With ΔVOT as the dependent variable, a series of one-way ANOVAs for each of the demographic and self-evaluation questions posed on a survey used in the fieldwork revealed no differences in means that even approximated $\alpha = 0.05$; the smallest p-value obtained was 0.303 (for the question 'How important is good pronunciation?'). At this point in our understanding of VOT variation, then, we are left to explore elsewhere other factors that might possibly differentiate those subjects who present positive ΔVOT s from those who do not.

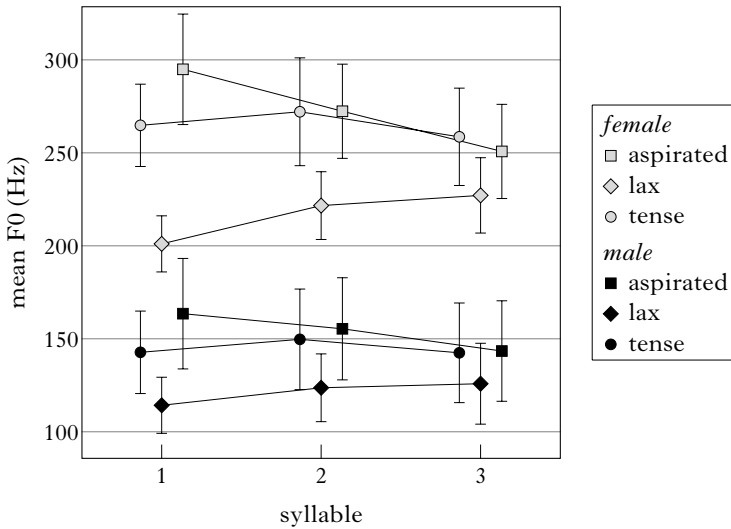


Figure 4

Comparison of averaged tonal melodies of male *vs.* female speakers. The phonation types indicated refer to the first C in each target word. The bars represent 1 SD above and below the mean value.

The need for more carefully constructed and socially informed sociolinguistic inquiry notwithstanding, a fundamental phonological question remains to be addressed: if it is true that at least some of the younger speakers in the community no longer use VOT to differentiate lax and aspirated stops, how do they signal the underlying contrast? A potential answer lies in an analysis of the corresponding F0 patterns.

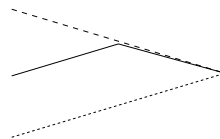
4.2 Tonal melodies

Across the corpus, independent of a speaker's age or sex, F0 patterns for the target items are consistent: for words beginning with a lax stop, the F0 of the vowel in the first syllable is consistently lower than both (a) the second and third syllables of the same target word and (b) the first syllable of analogous words beginning with either a tense or aspirated stop (Fig. 4). The robustness of these patterns is confirmed by a repeated-measures ANOVA in which the dependent variable was the mean F0 for the vowel in each syllable of the trisyllabic target forms. In this analysis, three independent variables were found to be statistically significant: phonation type of the word-initial stop ($F(2, 33) = 121.5, p < 0.001$), location of the vowel in the target word (first, second or third) ($F(2, 33) = 11.2, p < 0.001$) and speaker's sex ($F(1, 34) = 260.0, p < 0.001$). In addition, three interactions proved significant (each at $p \leq 0.001$): Phonation \times Sex, Phonation \times Syllable and Phonation \times Syllable \times Sex. Two factors not significant in the analysis ($p > 0.05$) were the place of articulation of the word-initial stop

and the speaker's year of birth. These findings suggesting that unlike the VOT behaviours reported above, F0 behaviours are different in two critical ways: place of articulation for the word-initial stop has no bearing on the rate of vocal fold vibration of the targeted vowels, and there are no clearly discernable diachronic effects on the same. This latter point is particularly noteworthy, as it suggests that the tonal patterns presented in Fig. 4 have been stable over time.

While one might expect phonation effects on the F0 values for the vowels appearing in the target words' initial syllables (Han & Weitzman 1965, Silva 1998), differences among F0 values are also statistically significant across syllables 2 and 3, but only with respect to a distinction between lax and non-lax word-initial stops. In words beginning with aspirated and tense stops, mean F0 values are not statistically significantly different in either syllable 2 ($p = 0.318$) or syllable 3 ($p = 0.059$). Further probing by means of Scheffé post hoc tests reveals that words beginning with a lax stop exhibit a sequence of progressively higher-pitched syllables, words beginning with an aspirated stops exhibit a sequence of progressively lower-pitched syllables, and words beginning with a tense stop exhibit a pattern whereby the F0 of syllable 2 is higher than those of syllables 1 and 3, but the F0s of syllables 1 and 3 are not significantly different from each other. These patterns are schematised using Chao numbers in (1):

(1)			σ_1	σ_2	σ_3
	aspirated	5-4-3	5		
			4		
	tense	3-4-3	3		
			2		
	lax	1-2-3	1		



5 Discussion

5.1 Variation and language change

The results of the acoustic study point to a change in how some Korean speakers signal differences between lax and aspirated stops. The clearest indicator of such a change is the presence of age-related shifts in VOT values: as shown in Figs 1 and 2, older speakers are more likely to maintain clear VOT distinctions between lax and aspirated stops, while younger speakers tend to minimise (or neutralise) such differences. The non-linear pattern suggested by the data in Fig. 2 is arguably the first and second components of a so-called *s-* (or *z-*) shaped curve, a pattern widely documented in the sociolinguistic literature as representative of a language change in apparent time (Labov 1972, 1994, Bailey *et al.* 1991, *inter alia*). As Guy writes, 'although such data actually constitute a synchronic snapshot of a single point in time, the progress of the change is reflected in the differential use by age' (2003: 384–385). In the specific case of the

VOT data under analysis here, we can see the shift from a wide, statistically significant differentiation between the VOTs of lax and aspirated stops among older speakers, via a narrower (but still statistically significant) differentiation of the same among middle-aged speakers, to the apparent neutralisation of the VOT distinction for some of the youngest members of the subject pool. As noted above, this younger cohort of speakers does not appear to present a consistent set of behaviours, with some subjects producing statistically significant differences in VOT for lax *vs.* aspirated word-initial stops and other subjects appearing to neutralise VOT differences for these two phoneme types. How this situation plays out for a larger pool of increasingly younger subjects remains to be documented. The distribution of Δ VOT in Fig. 2, coupled with the fact that the best-fit curve is a quadratic (and not a linear) relationship, provides support for the claim that the sound change evidenced here has recently concluded. As such, it is predicted that VOT data collected from speakers born after 1982 will yield an extension of points hugging the X-axis of the graph in Fig. 2 (i.e. Δ VOT = 0), thereby providing more a clearly discernible (reversed) *s*-shaped curve.

Evidence further supporting the existence of a recent change lies in the quasi-longitudinal data brought to bear in Silva (2002). Here we find that speakers in their twenties during the 1960s and 1970s produced 'traditional' VOT patterns, i.e. clear differences in the mean VOTs of lax *vs.* aspirated stops. Moreover, as Han & Weitzman report in their 1970 perception experiment, systematically manipulated differences in VOT yielded responses that reflected a divide between the phonemic categories of lax (shorter VOTs) and aspirated (longer VOTs). In contrast, speakers in their twenties some 40 years later produce more 'innovative' VOT patterns, i.e. Δ VOT < 20 ms, often approximating 0. Were the data from these two time periods representative of some other sociolinguistic phenomenon (e.g. age-grading), there should have been more consistency in the behaviour of subjects of similar ages. This is not the case.

5.2 Phonological implications

Despite this change in VOT patterns, the underlying contrast between lax and aspirated stops in Korean is still preserved in the speech of younger speakers, apparently manifested in terms of differentiated F0 patterns: lax stops are associated with a melody that begins with a low pitch and then rises through the target word, while aspirated stops are associated with a melody that begins with a relatively higher pitch followed by a falling F0 contour.

Although phonation-associated F0 behaviours are not new to Korean (Han & Weitzman 1965, Silva 1998), they have typically been relegated to secondary status: while VOT values were taken as primary markers of phonation type, F0 values were viewed as redundant.⁷ Moreover,

⁷ Systematic consonant effects on the F0 trajectory of /a/ following word-initial target stops could not be discerned in this corpus, either within or across subjects. This

long-distance tonal associations correlated with lax *vs.* non-lax phonation types have been documented in other varieties of Korean (e.g. Jun 1993); but in these cases, F0 melodies have coexisted with robust VOT differences (Kim 2000). The current study, however, presents a new situation: for younger speakers of the standard variety, VOT differences have been neutralised and F0 appears to have assumed a *primary* role in marking the lax *vs.* aspirated distinction.

These acoustic data corroborate a perception study by Kim *et al.* (2002), who claim that their native Korean listeners made a critical distinction in how they processed vocalic information edited from source stimuli originally drawn from CV sequences containing lax, tense and aspirated onsets. When presented with only the vowel portions of the source syllables, subjects were consistently able to identify those source syllables beginning with lax onsets: 'for both vowel-only stimuli and cross-spliced stimuli with conflicting consonant and vowel portions, listeners heard lax initial stops if and only if the vowel had an L tone' (2002: 97). Vowel portions from syllables with tense and aspirated onsets, however, were not so readily differentiated. Indeed, vowels drawn from syllables with both tense and aspirated onsets were largely identified as coming from tense stops; F0 cues were not sufficiently robust differentiators between the two stops types. It was only when significant periods of aspiration noise were included in the stimuli that subjects included aspirated onsets in their reactions. Thus we find perceptual evidence in support of the acoustic study reported here: that underlying phonation types for consonants are correlated with the fundamental frequency characteristics of the immediately following vowel. The present study further generalises this claim by arguing that these C-to-V correlations not only local, but may be broader in scope. Given that the presence of a word-initial lax stop yields a trisyllabic tonal melody significantly lower than that associated with forms beginning with either an aspirated or tense stop, we have reason to believe that among these speakers of Korean, word-initial consonantal effects are not restricted to the initial syllable, but extend into the higher prosodic domain of the phonological word.

This shift in the relative weighting of phonetic events – from the CV transition (most critically, the post-release aspirated region) to the F0 of the following vowel(s) – provides evidence that standard Korean has undergone a sound change analogous to that reported for various languages, including Vietnamese (Haudricourt 1954, Thurgood 2002, among others), Zaiwa (Wannemacher 1996) and Tibetan (Duanmu 1992). In Tibetan, for example, historical differences between aspirated and unaspirated stops

finding is consistent with Han & Weitzman's assessment of the issue: 'there is mutual overlapping between the onset values of fundamental frequency following all three stops. This extreme overlapping suggests that the onset value of fundamental frequency cannot be too significant a cue in the distinction of stop consonants' (1967: 22). It is surprising, however, given the local phonation effects reported in Silva (1998). This lack of local effects neither undermines nor diminishes the more global melodic patterns reported here.

have been neutralised and replaced by differences in tone in the contemporary Lhasa variety.

(2) *historical Lhasa*

kho	khó (H level)	'he'
go	khõ (L rising)	'hear'

Svantesson & House (2006) make a similar case in their comparison of two varieties of Kammu (Laos). Where Eastern Kammu presents a voiced *vs.* voiceless contrast (e.g. *buuc* 'wine' *vs.* *puuc* 'to undress'), Northern Kammu manifests a corresponding L *vs.* H contrast, with no voicing distinction (*pùuc* 'wine' *vs.* *púuc* 'to undress'). Svantesson & House argue that Northern Kammu is not truly tonal, despite the phonetic evidence. Rather, they argue that the Eastern and Northern varieties share a common set of underlying representations, which are phonetically specified in dialect-specific ways: speakers of Eastern Kammu realise the underlying voicing contrast in initial consonants as such phonetically, while speakers of Northern Kammu realise the same underlying contrast on the syllable rhyme (i.e. higher *vs.* lower F0).

An analogous set of arguments has, in fact, been advanced for Korean by Kim & Duanmu (2004). In their account, underlying lax stops are argued to bear the features of a voiced obstruent ([+voiced, -aspirated]), while the tense series is treated simply as voiceless ([-voiced, -aspirated]) and the aspirated series is assigned the features [-voiced, +aspirated]. Moreover, they write that 'in this analysis, the main phonetic difference in words pairs such as [t*al] 'daughter' and [tal] 'moon' [with tense and lax initial stops, respectively] does not lie in the stops themselves but in the tone of the vowel ([tál] *vs.* [dál/tál])' (2004: 96). In phrase-initial position, lax stops are devoiced, thereby leaving only tonal information to differentiate them from their tense counterparts. Under this analysis, one further presumes that in word-initial position, the lax ~ aspirated contrast is maintained by the opposition between [-aspirated] and [+aspirated].

Aside from the critical insight that phonation and tone should be phonologically integrated in Korean, Kim & Duanmu's accounting evokes both empirical and theoretical concerns. Empirically, their analysis provides no clear accounting for the phonetic facts presented in §4 above: it is not clear how they would capture the innovation manifested by younger speakers, whereby lax and aspirated stops are no longer distinguished by differential VOT values. Theoretically, their account raises two questions of considerable import. First, it renders the tense series as the least marked in the phonological system, as they are reanalysed as voiceless unaspirated segments. Second, it suggests that in Korean, intervocalic position is the primary locus for faithfulness (at least with respect to the feature [+voiced]), an implication at odds with widely accepted accounts that give primacy to domain-initial positions and prosodic heads in assessing featural faithfulness (Beckman 1998).

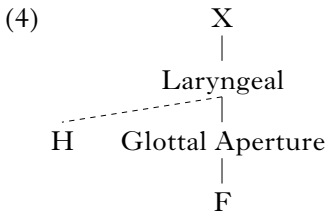
5.3 Toward a revised model of Korean stop phonology

In this section, we propose a theoretical explanation that accounts for the ‘traditional’ and ‘innovative’ patterns reported above without the need to introduce radical changes to our existing understanding of the Korean feature inventory. The analysis advanced draws substantially from that proposed by Ahn & Iverson (2004), which was predicated on a fully ‘traditional’ understanding of the phonetic facts.

We begin by returning to the Tibetan and Kammu situations, noting that when they are compared to more traditional treatments of Korean, a key difference emerges: in Korean, there is no underlying voicing contrast in play. As would be predicted, both Tibetan and Kammu voiced stops are associated with a low tone on the following vowel, a relatively common ‘depressor effect’ triggered by the voicing, high sonorance or nasality of an immediately preceding syllable onset (Goldsmith 1990, Koehler 1995). In Korean, however, standard accounts of the consonantal system deny a contrastive role for the feature [voiced], under the general redundancy statement that links sonorance with voicing: $[\alpha \text{sonorant}] \rightarrow [\alpha \text{voiced}]$ (see Kim 1965, Kim-Renaud 1974, Lee & Ramsey 2000, Sohn 1999). This is no problem, however, as support for an aspirated segment taking precedence over a corresponding unaspirated segment when it comes to tone raising (the issue of voicing *per se* aside) can be found as far back as the 1970s, when researchers such as Hyman & Schuh (1974) advanced the following hierarchy of consonant-induced tonal effects (reported in Lee 1978: 218):

(3) <i>tone raising</i>	implosive
↑	voiceless aspirated
↕	voiceless unaspirated
↓	sonorant
<i>tone lowering</i>	voiced obstruent
	breathy voiced

With the hierarchy in (3) as background, the absence of phonemic voicing in Korean poses little theoretical problem for the analysis advanced here, which rests primarily on the fact that in most languages (including Korean) voiceless unaspirated segments are the least marked elements in the consonant inventory. Interpreting markedness in a structural sense, the current account treats the presence of a privative feature [spread glottis] (or an analogous feature marking aspiration) as the driving force behind the shift from aspiration to tone to mark the underlying lax *vs.* aspirated distinction. More specifically, the ‘innovators’ in the subject pool employ a redundancy rule whereby a laryngeal node dominating any content is interpreted not on the segmental plane but tonally, formalised in (4) (inspired by Yip 1995).



Under the analysis in (4), aspirated stops, by virtue of their underlying marking for [spread glottis], acquire a tonal value of H; similarly, tense stops, with their surface-level marking for [constricted glottis], likewise acquire an H tone.⁸ In contrast, lax stops do not receive any tonal marking, leaving them to be realised by a default L tone. Appealing to a default L is consistent with tonal analyses of other languages, e.g. Geman, Haya, Kimatuumbi, Luganda and Somali (X-Tone 2005), as well as Lee's (1987: 104) account of Gyeongsang Korean (but may be at odds with Kim's 1997 account of the Northern Gyeongsang variety).

What, then, might motivate this association of a H tone with a non-null Laryngeal node? To address this question, let us turn to the theory of glottal features originally advocated in Halle & Stevens (1971). We begin by assuming that underlying lax stops are represented by a single laryngeally unspecified C. Additionally, phonemic tense stops are represented as geminated Cs (linked to a single syllable node), which are subsequently modified by the introduction of a phonetic-level laryngeal specification [constricted glottis] (Han 1996: 191, Silva 1992: 63–67). In the current account, however, the element interpolated to the C-C structure is a more abstract 'tensity feature', privative [stiff] (Halle & Stevens 1971, Bao 1990). Here we adopt Kim's (1965) perspective on the notion that tense and aspirated stops do, in fact, form a natural class of tense (or fortis) segments, a view later adopted by Kim-Renaud in her underlying feature specification of tense and aspirated phonemes as [+tense] (1974: 5). Finally, under this account, aspirated segments are laryngeally marked in underlying representation, the relevant feature again being privative [stiff]; they are the only segments that bear any laryngeal specification in the lexicon.

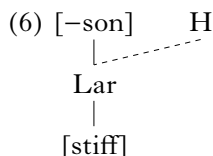
As consonantal representations are interpreted by the phonetic component of the grammar, C nodes marked by the tensity feature (i.e. tense and aspirated) are realised with H tone – the primary reflex of the stiff vocal folds. At the same time, any non-sonorant singleton consonant (i.e. non-geminate and aspirated) in phrase-initial position is realised with aspiration, indicated by the insertion of the feature [spread]. Such an account, with its explicit reference to prosodic constituency, is a reflection

⁸ This account operates independently of any assumptions regarding the underlying status of the tense stops in Korean, be they phonemically geminates (which ultimately receive a language-specific marking for [constricted glottis]) or singletons (marked for [constricted glottis] from the outset).

of what Kim-Renaud refers to as a ‘boundary-sensitive strengthening phenomenon[on]’ (1974: 3).

(5)	<i>lexical representation</i>	<i>after redundancy rules</i>	<i>phonetic realisation</i>
a. <i>lax</i>	X [+cons, -son]	X [+cons, -son] Lar [spread]	aspirated, L tone
b. <i>aspirated</i>	X [+cons, -son] Lar [stiff]	X [+cons, -son] Lar / \ [stiff] [spread]	aspirated, H tone
c. <i>tense</i>	X X \ / [+cons, -son]	X X \ / [+cons, -son] Lar [stiff]	unaspirated, H tone

Under this analysis, the degree of aspiration associated with these phrase-initial singleton Cs is assumed to be consistent, regardless of the consonant’s marking for the tensivity feature: [stiff] and [spread] is no more aspirated than just [spread]. What is different about [stiff] and [spread] is the fact that the stiffness leads to a higher F₀ on the following vowel than a structure marked by [spread] alone. This transfer of laryngeal characteristics from C to V is formally accomplished by following Ahn & Iverson (2004), who invoke the principle of ‘bipositionality’:



Applying the principle in (6) to the structures in (5), we can begin to account for the tonal patterns schematised in (1). What remains to be accounted for is the apparent long-distance nature of the C-to-V spreading.

It is suggested here that no further phonological spreading is required to account for the observed tonal melodies; rather, phonetic interpolation working across a higher prosodic domain, such as the minor phrase (Silva 1992) or the accentual phrase (Jun 1993), gives rise to the observed upward trajectory for the lax/L items and the downward trajectory for the non-lax/H items.

When compared to more traditional accounts of the lax ~ aspirated ~ tense contrast in Korean, the analysis above differs in several ways. First, it suggests that for Korean language innovators, the aspiration feature (here [spread]) no longer functions phonemically; rather, it is now a prosodically conditioned redundant property. More specifically, the insertion of [spread] occurs only in phrase-initial position, an example of a prosodically driven strengthening process. In word-internal intervocalic position, by contrast, lax stops remain unmarked for laryngeal features, thereby allowing for the phonetic interpolation of voicing (Silva 1992: 142). Aspirated stops in word-internal position also fail to acquire any new features; their underlying marking for [stiff] prevents intervocalic voicing (be the process a matter of phonological feature spreading or one of phonetic interpolation), leaving these segments voiceless in this position. The extent to which the presence of a word-internal instance of [stiff] yields a raised F₀ on the following vowel is a matter left for future research.

Second, the current analysis assumes that the spreading effects attributed to bipositionality can be – if not must be – more than simply local. In the spirit of Pierrehumbert & Beckman (1988), we argue that this phonologically spread instantiation of [stiff] functions as an anchor for subsequent F₀ interpolation across tonally unspecified syllables across a larger prosodic unit (most likely a phonological word, but perhaps even a phrasal constituent), thereby yielding the F₀ patterns displayed in Fig. 4. Further consideration of [stiff] as a more general manifestation of tonal ‘prominence’ will likely dictate whether the developing tonal contrast might eventually be characterised as a pitch-accent system. Such an account would certainly place contemporary Seoul Korean in a familiar context, given the existence of other pitch-accented dialects. All the same, it would be foolhardy to assume that the phenomenon under discussion here is unequivocally pitch-accentual, solely on the basis of what has been claimed in other varieties of the language. In the absence of the necessary corroborating data, no position is taken on the matter.

Finally, this account takes the explicit position that the relationship between phonation type and the fundamental frequency of the following vowel(s) is by-and-large ‘automatic’, as opposed to ‘controlled’. In contrast to the position put forth by Kingston & Diehl (1994: 423), the current analysis claims that the phonological feature [stiff] actually serves to predict phonetic behaviour, as opposed to simply limiting it. Moreover, it is implied that this relationship predates the onset of the sound change whereby VOT differences between lax and aspirated stops have become neutralised, suggesting further that relevant relationship is not one between glottal aperture and F₀ (as argued by Kingston & Diehl, who focus their

discussion on the feature [voice]), but rather one between glottal tension and F0.

6 Conclusions

As the data from this study indicate, the obstruent system of Korean appears to have undergone a process of sound change: while the underlying tripartite distinction among tense, lax and aspirated stops persists, the basic phonetic manifestation of the latter two stop types has shifted from one of a clear voice onset time distinction to one whereby fundamental frequency plays the primary role. While other researchers have documented this sort of relationship between phonation type and F0 in speech of contemporary Korean speakers (Jun 1993, Kim 2000, Kim & Park 2001), the current study makes clear the diachronic status of this situation, namely, that the change appears to be in its final stages, if not actually completed. This type of shift is much like the voicing-to-tone changes attested in other languages (such as Tibetan), thereby providing further support for a phonological theory that allows for unified functionality of the laryngeal mechanism, a single set of features that account for both tonal and phonation events; the relevant feature here is [stiff], analogous to Kim's (1965) 'tensity' feature. The acoustic results of the current research further corroborate perceptual experiments conducted by Kim *et al.* (2002), by supplementing their observations and analysis of related data with a larger-scale, age-differentiated acoustic study. Indeed, the Kim *et al.* methodology merits replication with a larger pool of listeners, one that includes subjects older than the twelve 26–32 years old 'phonetically untrained native speakers of the Seoul dialect of Korean' (2002: 84). If the acoustic data reported here have any bearing on the outcome of such a perception experiment, we might expect that the responses of older speakers (i.e. those born before 1965) would differ from those of their younger counterparts, with older speaker perhaps less likely to consistently differentiate among all three stop types solely on the basis of F0 information. In addition, adding sonorant- and zero-initial three-syllable words to the corpus (e.g. *mapali* 'packhorse', *nameci* 'remainder', *ladio* 'radio', *apeji* 'father') will reveal the extent to which sonorance and/or voicing influence the tonal melody of the entire word.

Finally, this study suggests that standard Korean is coming into alignment with other varieties of the language (most of which employ either lexical or phrasal pitch accent), as well as with other East Asian languages, which use F0 in phonemically relevant ways.

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