Effects of prosodic structure on voice quality associated with Korean three-way stop contrast

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Korean has a three-way voiceless stop contrast between aspirated, fortis, and lenis stops [1]. While VOT was regarded as the primary cue which distinguished the three stop categories, recent studies have suggested that Korean is undergoing a tonogenetic sound change, showing that the VOT distinction between the aspirated and lenis stop is merging and that the contrast is now distinguished by F0 (higher F0 for aspirated and lower F0 for the lenis) in younger Koreans' speech [2]. Traditionally, however, the three-way stop contrast in Korean has also been known to be phonetically characterized by the difference in voice quality of the following vowel, such that the breathiness of the vowel is greatest after the lenis, intermediate after the aspirated, and least after the fortis [1]. The purpose of this study is to examine the voice quality differences associated with the three-way contrastive stops, and to explore to what extent these differences contribute to the three-way stop contrast and how the effect may be conditioned by two prosodic-structural factors.

Regarding the effect of prosodic strengthening on the voice quality of the three stops, it is possible to hypothesize that the strengthening would be phonetically manifested by increased glottalization across the board as sounds are known to be glottalized (or become creakier) in prosodic strengthening environments [3,4]. The prosodic strengthening effect may thus increase the laryngeal muscular tension, which in turn would augment the degree of glottalization. If the three-way contrastive stops are produced with an increase in laryngeal muscular tension, the breathiness of the following vowel across the three stop categories would be reduced. However, studies on prosodic strengthening have also indicated that prosodic strengthening is not a mere low-level phonetic effect, but it refers to the phonological system of a given language, often enhancing the phonological contrast [5]. This leads to an alternative hypothesis that prosodic strengthening would increase the breathiness of the vowel only after the lenis stop while the creakiness of the vowel is reinforced after the fortis stop, enhancing the three-way stop contrast. This alternative hypothesis may not be borne out, however, if VOT and F0 are the only primary phonetic cues of phonological contrast in Korean, as has been argued in conjunction of a recent development of the tonogenetic sound change among young speakers [2]. To explore these possibilities, this study investigates whether the three-way phonological contrast of word-initial stops manifest itself in the voice quality of the following vowel in Korean in prosodic strengthening contexts.

Twelve native Seoul Korean speakers participated. Example sentences are given in Table 1. Two measurements of breathiness, H1*-H2* and H1*-A1*, were taken as acoustic indexes of the voice quality [4], obtained by VoiceSauce [7] at the 25% and 50% points of the vowel.

Results are summarized in Fig. 1. One of the basic findings of the present study is that the difference in voice quality of the following vowel, as indicated by breathiness measures (H1*-H2* and H1*-A1*), makes a three-way phonetic distinction among the (Seoul) Korean stop series produced by young speakers. The amount of breathiness is largest for the lenis stop, intermediate for the aspirated stop, and smallest for the fortis stop. The three-way laryngeal distinction is consistent with what was reported 16 years ago [1], indicating that the voice quality difference has continued to underlie the three-way stop contrast. Another important finding of the study is that the three-way distinction in voice quality is further conditioned by prosodic strengthening factors: focus-induced prominence and boundary. The results showed that the three-way stop contrast is indeed enhanced under focus, with the stops being substantially dispersed along the breathy-creaky phonetic continuum. The voice quality difference as a function of stop categories has also been found to be influenced by prosodic boundary (IP-initial vs. IP-medial). The dispersion effect was observed in both H1*-H2* and H1*-A1*. The converging enhancement pattern under prosodic

strengthening is that vowels become more breathy (less creaky) after the lenis stop, but less breathy (more creaky) after the fortis stop, contributing to the enhancement of the phonological contrast. Interestingly, the voice quality associated with the aspirated stop falls somewhere in between, which may be understood as an effort to retain the contrast by maintaining its intermediate position.

The results imply that variation in the voice quality difference as a function of prosodic strengthening is not a mere low-level phonetic effect that would otherwise have applied to all three stops in a collective way, but is an outcome of the phonetic-prosody interface in reference to the phonological contrast in the language. The results also suggest that understanding the nature of laryngeal (voicing) contrast that occurs in Korean as well as in other languages requires multidimensional approaches to explore the phonetic realization of both the primary and other non-primary phonetic features [e.g., 8]. It remains to be seen to what extent the voice quality difference is exploited by the listeners and how the voice quality cues may interact with F0 and VOT [cf. 8].

Table 1. Example sentences with the target word *pak* in different prosodic context. Focused words are in bold.

IP-initial	Foc	[ani]. IP [**pak**satʃʰin twi]. IP [twɛssʌ]? "No. To the right of the picture of **pak**. Got it?" (as an answer to "This time, do I place the word (card) to the right of the picture of **mak**?")
	Unfoc	[ani]. IP [paksatʃʰin **twi**]. IP [twɛssʌ]? "No. To the **right** to the picture of pak. Got it?" (as an answer to "This time, do I place the word (card) to the **left** of the picture of pak?")
IP-medial	Foc	[ani]. IP [aˑpa **pak**satʃʰin twi]. IP [twɛssʌ]? "No. To the right of dad's picture of **pak**. Got it?" (as an answer to "This time, do I place the word (card) to the right of dad's picture of **mak**?")
	Unfoc	[ani]. IP [aˑpa paksatʃʰin **twi**]. IP [twɛssʌ]? "No. To the **right** of dad's picture of pak. Got it?" (as an answer to "This time, do I place the word (card) to the **left** of dad's picture of pak?")

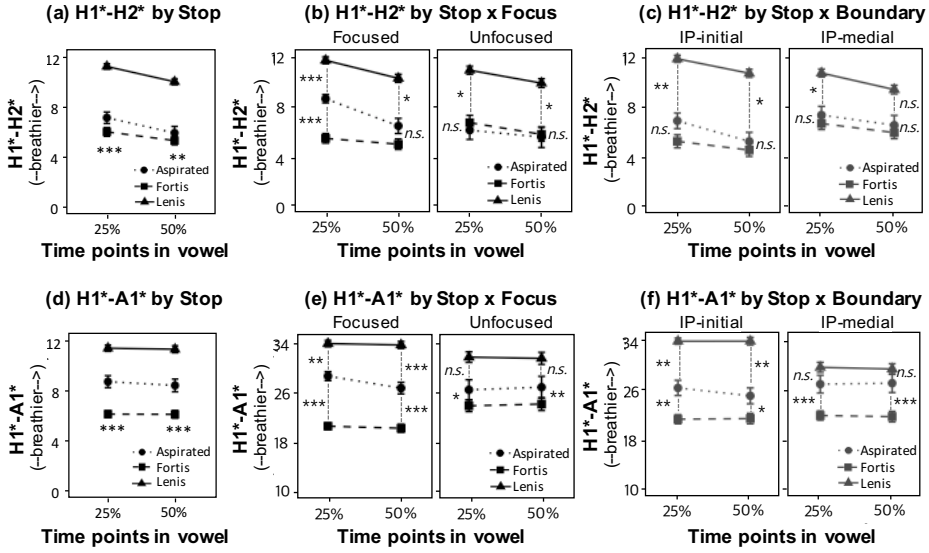

Fig.1 Effects of Stop and its interaction with prosodic factors (focus and boundary) on H1*-H2* (a-c) and on H1*-A1* (d-f). '*', '**', '***', '*tr.*', '*n.s.*' refers to $p<.05$, $p<.01$, $p<.001$, $.05<p<.06$, $p>.09$ respectively.

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