Durational Correlates of Prosodic Categories: The Case of Two Korean Voiceless Coronal Fricatives*

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ABSTRACT

This paper is a production study of the effects of Korean prosody on two voiceless coronal fricatives /s^h/ and /s*/. The target segments were embedded in four prosodic positions: initial to the Intonational Phrase or the Accentual Phrase, and medial to the Accentual Phrase or to the Prosodic Word. Acoustic measurements showed that the durational differences associated with the /s^h/ versus /s*/ contrast vary in magnitude in different prosodic positions, confirming the proposal that segmental properties are affected by prosodic categories. This suggests that any speech synthesizer should take into consideration prosodically conditioned durational variation.

Keywords: Korean, prosody, fricatives, duration

1. Introduction

It is well known that speech segments show variation from one position to another in a word or stress foot. In the study of allophony, many studies have focused on word-level environments, e.g. whether the target segment is word initial or medial, or whether the syllable containing the segment is stressed or not. It is true that speech segments show systematic variation relative to their word-level position and the location of stress, but as will be shown later, the range of such variation is not limited to word-level prosody.

There is increasing evidence from a number of languages that these systematic allophonic differences extend to levels higher than that of the word. Depending on their level in the prosodic hierarchy of a language, speech segments vary according to their prosodic position. Prosodic categories such as the accentual phrase in Korean have been shown to act as the domain of application of such rules as post-obstruent tensing and

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vowel shortening (Jun, 1998). Other studies have shown that segmental properties of Korean coronal stops (Cho and Keating, 2001) and fricatives (Kim, 2001) are affected by higher prosodic domains. For American English, prosodic effects have been found for segments including /h/ and glottal stop (Pierrehumbert and Talkin, 1992) and /z/ (Smith, 1997).

of the current study examines the production of the two Korean coronal fricatives /s^h/ (aspirated or lax) and /s*/ (tense or fortis) embedded in different prosodic categories. Two questions are considered: Is the role of segmental properties that distinguish one fricative from the other invariant across different prosodic positions? Do the acoustic cues that distinguish the two fricatives in isolation contribute to the same extent to the distinction of the fricatives embedded in different prosodic positions? By examining the two fricatives in different positions in Korean prosodic hierarchy, we will gain insight into how segmental properties adapt to different prosodic positions.

1.1. Prosodic hierarchy of Seoul Korean

Figure 1 is an illustration of the prosodic hierarchy of Seoul Korean. There are two tonally defined prosodic categories above the level of the prosodic word (PW) in Korean, i.e. the intonational phrase (IP) and the accentual phrase (AP) (Jun, 2000). The arrows indicate the four prosodic positions and in which the two target fricatives in the experiment were placed. Target fricative segments were embedded in (1) IP-initial, (2) AP-initial (but not IP-initial), (3) AP-medial (but PW-initial), and (4) PW-medial position.

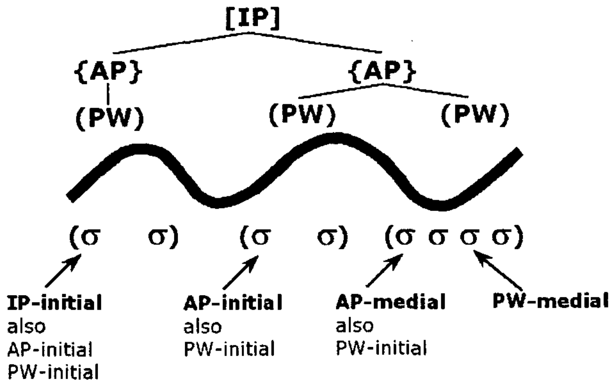

Figure 1. Prosodic hierarchy of Seoul Korean. Arrows indicate the positions where target segments were embedded in carrier conversations. The curve represents the schematized pitch contour of an utterance.

2. Methods

2.1. Stimuli

A novel approach was used to devise the carrier sentences. Rather than having the speakers repeat citation form sentences, we have created "carrier conversations" where two speakers act out a conversation. This approach produced speech that is more natural than read speech and allows the researcher to control the production of target sequences.

Two prosody-carrier conversations were devised to create situations where the desired prosody would be generated. In order to put the target segments in AP-initial versus AP-medial position, two strategies were employed to exploit predictable prosodic phrasing choices. The first involved the word *nuka*, which can be either an interrogative pronoun ('who') or an indefinite ('someone') depending on the phrasing of the pronoun-verb sequence. The second elicited contrastive narrow focus (a correction).

The first strategy used two different types of questions; a *wh*-question and a yes/no question containing the indefinite pronoun *nuka*. The first prosody-carrier conversation is given below in (1).

(1) (철수와 선희가, 손수 포장을 할 경우, 추가 할인을 해주는 상점으로 들어가면서)

(*Cholsoo and Sunhee enter a store that gives additional discounts for self-wrapping*)

선희: 철수야! 사/싸가는 사람들한테 할인을 해준대! IP-initial

[{č^{h}əlsuja}] [{s^{h}a/s*aka-nɨn s^{h}aramtɨl-hante}] [{harinɨl hečunte}]

č^{h}əlsu-PARTICLE buy/wrap-RELATIVE people.to give.discounts-PARTICLE

Sunhee: Cholsoo! They say they give discounts to those who buy/wrap.

(마음에 드는 물건을 보며)

(*Looking at the item that she wants to buy*)

이거 누가 사/싸가기로 되어 있나요? AP-initial

[{ikə} {nuka} {s^{h}a/s*aka-kiro twеə in-najo}]

this someone buy/wrap be.supposed.to-PARTICLE

Is someone supposed to buy/wrap this?

점원: 예. 어떤 분이 사/싸가기로 했는데요.

je. ət*ən pun-i s^{h}a/s*aka-kiro hennɨntejo

yes. certain person buy/wrap be.supposed.to-PARTICLE

Yes, a person is supposed to buy/wrap it.

선희: 아, 그래요?

a, kɨrejo?

Oh, is that so?

그럼 누가 사/싸가기로 되어 있나요? AP-medial
[{kɨrəm} {nuka $\underline{s^ha/s^*a}$ka-kiro tweə in-najo}]
then who buy/wrap be.supposed.to-PARTICLE
Then, who is supposed to buy/wrap it?
혹시, 영미라는 분 아닌가요?
hoksi, jəŋmi-ranɨn pun ani-nkajo
by.any.chance, a jəŋmi person not-PARTICLE
Is s/he by any chance a Youngmee?

(과자를 파는 코너로 가서, 이것 저것 살펴보다가)
(Approaching to a bakery section and browsing through it)
선희: 근데, 이 과자 포장지에 '바삭/바싹'이라고 왜 써있죠? PW-medial
[{kɨnte}] [{i} {kwača p^hočaŋčie}] [{pa$\underline{s^ha}$k/pa$\underline{s^*a}$k-irako} {we s*əič*o}]
by.the.way, this cookie wrapper.on crisp/parched-PARTICLE why written-question
By the way, why is 'crisp/parched' written on this cookie wrapping paper?
점원: 글쎄요. 모르겠는데요.
kɨls*ejo. morɨkennɨntejo
well. don't.know-particle
Well, I don't know.

Jun and Oh (1996) established that speakers use different phrasing to disambiguate the two types of sentences, putting an AP boundary after *nuka* for yes/no questions but grouping following material into the same AP as *nuka* for the other type of question. Thus a string such as *nuka oni*? can be either a *wh*-question ('who's coming?') or a yes/no question ('Is anyone coming?'). As shown in (2), speakers use different phrasing to disambiguate the two types of sentence, putting an AP boundary after *nuka* for the yes/no question in (2a) but grouping following material into the same AP as *nuka* for the *wh*-question in (2b).

(2) (*Looking at the item that she wants to buy*)
이거 누가 사/싸가기로 되어 있나요?
$[\{ikə\}_{AP}$ $\{nuka\}_{AP}$ $\{\underline{s^ha/s^*a}$ka-kiro tweə in-najo$\}_{AP}]_{IP}$
this someone buy/wrap be.supposed.to-PARTICLE
Is someone supposed to buy/wrap this?

그럼 누가 사/싸가기로 되어 있나요?
[{kirəm}$_{AP}$ {nuka s^{h}a/s*aka-kiro tweə in-najo}$_{AP}$]$_{IP}$
then who buy/wrap be.supposed.to-PARTICLE
Then, who is supposed to buy/wrap it?

Two example pitch tracks from the first prosody-carrier conversation in Figure 3 shows that the speaker produced an AP-initial and an AP-medial utterance as intended. In the upper panel of Figure 3, as the arrow indicates, the target segment /s^{h}/ starts a new AP, thus occupying an AP-initial position, whereas in the lower panel, the target segment (arrow) is in the middle of an AP.

The second strategy, adapted from (Jun *et al.*, 1997), involves a short conversation, designed to elicit contrastive narrow focus. An excerpt from this conversation is shown in (3). Square brackets indicate intonational phrases (IP) and curly braces accentual phrases (AP). Target segments and following vowels are underlined.

(3) (엄마를 따라 시장에 나온 딸에게, 해물을 파는 가게 앞에서)
(*A mom and her daughter at a seafood market*)

엄마: 민희야! 사가/싸가는 방법은 알지? IP-initial
[{minhija}] {s^{h}aka/s*aka-nin} {paŋpəb-in} {alči}]
minhee-particle buy/wrap-relative method-topic know-question
Minhee! You know how to buy/wrap, don't you?

딸: 그럼 내가 사가/싸가라구? AP-initial
[{kirəm} {neka} {s^{h}aka/s*aka-raku}]
then I buy/wrap-question
Then, you want me to buy/wrap it?

엄마: 아니, 내가 사간/싸간다니까. AP-medial
[{ani}] [{neka s^{h}akan/s*akan-tanik*a}]
No, I buy/wrap-particle
No, 'I' am going to buy/wrap it.
방법을 알고 있는지 그냥 물어본거야.
paŋpəb-il alko inninči kinjaŋ murəponkəja
method-accusative know-conjunctive just ask-particle
I just asked if you know how to do it.

딸: 근데, 이 해물 포장지에 바삭/바싹이라고 왜 써있지? PW-medial
[{kinte}] [{i} {hemul počaŋčie} {pas^{h}ak/pas*ak-irako} {we s*əič*i}]
by.the.way this seafood.wrapper.on crisp/parched-particle why written-question

By the way, why is 'crisp/parched' written on this seafood wrapping paper?

2.2. Procedures

Six native speakers of Seoul Korean (three men and three women) participated in the recording. Three groups, each consisting of two speakers, enacted the two prosody-carrier conversations until each pair produced ten (five for each member of the group) clear repetitions of each sentence. The total number of tokens was 480 (6 (subjects) x 2 (prosody-carrier conversations) x 2 (fricatives) x 4 (prosodic positions) x 5 (repetitions) = 480). Analyses

The labeled utterances were inspected to confirm that participants had produced the predicted prosodic phrasings. Indeed, for the two types of conversations, participants always produced the target segments in the expected prosodic positions. The success of this prosodic phrasing manipulation is illustrated in Figure 2. There is a phrase break after *nuka* in Figure 2a, indicating that the pronoun was used as an indefinite, but not in Figure 2b, indicating that the pronoun-verb sequence belongs to the same phrasing. The underlined target segments /s^h/ and /s*/ were thus embedded AP-initially in Figure 2a and AP-medially in Figure 2b.

2.3. Measurements

Durations were measured for the following sections of the target segment and adjacent vowels: fricative, aspiration noise segment, preceding vowel segment, and following vowel segment.

All segment onsets and offsets were labeled. For most segmentation decisions, standard criteria were used. The most difficult segmentation point, the boundary between the fricative noise and aspiration noise, was determined as follows. In order to achieve this segmentation, I wrote a Praat (Boersma and Weenink, 2002) script to repeat what a trained phonetician would do for a set of spectrograms from a particular speaker. The script performed the following steps.First, spectra were made every 5 ms with a 5 ms-Hamming window from the start of fricative to the vowel onset. Each spectrum was divided into a high frequency band and a low frequency band across a variable frequency value that was pre-determined by examining many spectra for each speaker (a value which, once determined, was consistent for each speaker). In most cases, the frequency value corresponded to the lower cutoff frequency of the fricative segment.

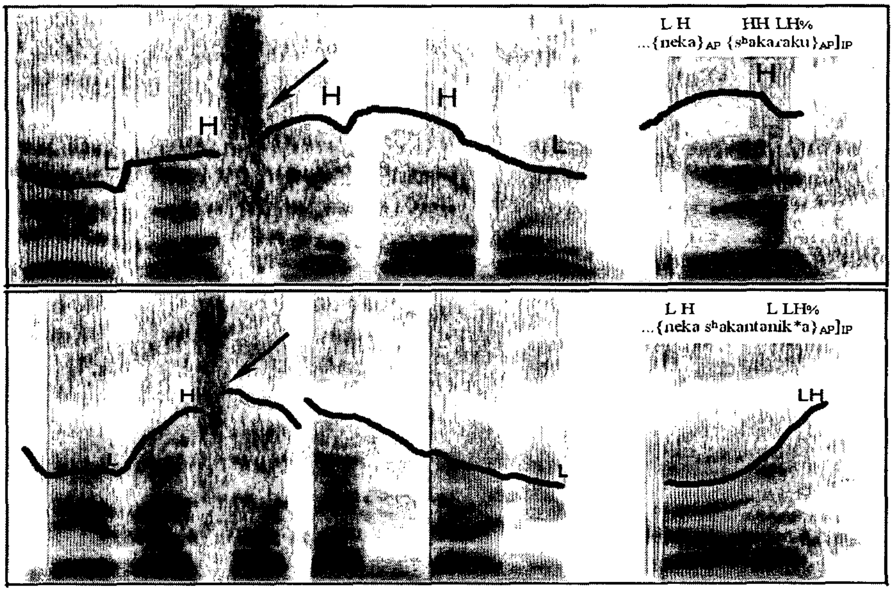

Figure 2. AP-initial and AP-medial utterance from the first prosody-carrier conversation (see excerpt in (2)) where the target segment /sʰ/ (arrow) is embedded either in AP-initial position (a) or in AP-medial position (b)}

\label{fig:pitch1}

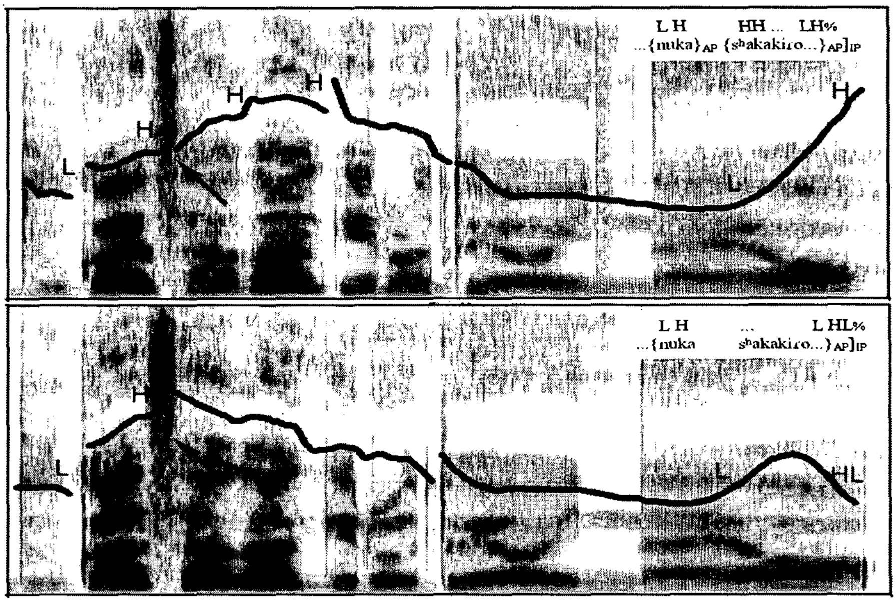

Figure 3. AP-initial and AP-medial utterance from the second prosody-carrier conversation where the target segment /sʰ/ (arrow) is embedded in AP-initial position (a) and in AP-medial position (b).

The amplitude values within each of the two bands were summed. The ratio of high-frequency band to low-frequency band, $\Sigma E_H/\Sigma E_L$, was used as an indicator of the relative ratio of the turbulence energy generated by air passing through the coronal constriction to the energy generated by air passing through the open glottis. This ratio was examined for each successive spectrum starting at the beginning of the fricative noise until the point at which the ratio fell below the criterion value (See Figure 4). This point was interpreted to reflect the point at which there was a shift in the location of the noise source; that is, the end of frication and the start of aspiration. This is illustrated in Figure 4 for a sample token by Speaker f1.

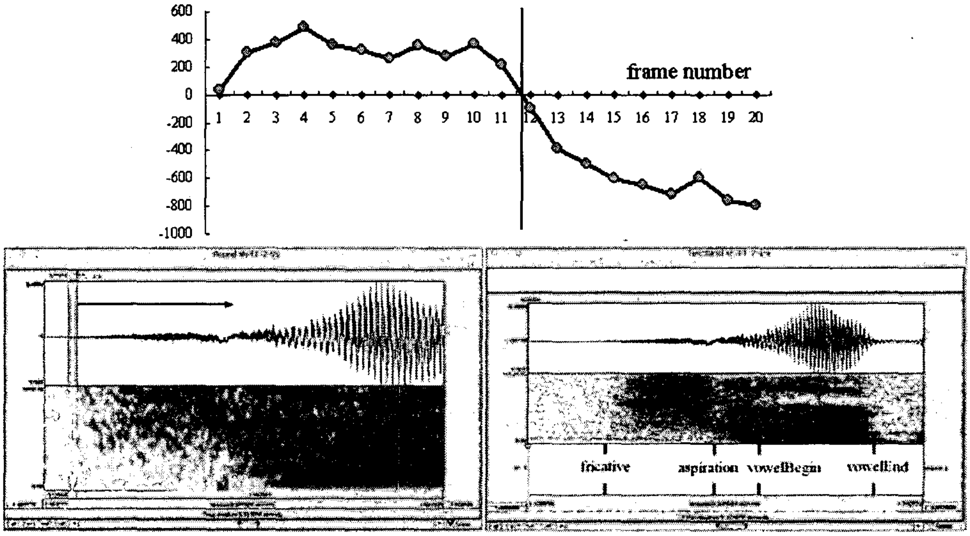

Figure 4. (Top panel) Plot of $\Sigma E_H/\Sigma E_L$ change for successive frames of spectra. The vertical line indicates the point where $\Sigma E_H/\Sigma E_L$ crosses the criterion value, whose x intercept was taken as the end of fricative and start of aspiration. (Bottom left panel) A slice was selected for spectral analysis. A series of spectra were made in the direction of the arrow. (Bottom right panel) After a series of comparison of the ratio, a dividing line (the second vertical line in the bottom tier) was drawn.

As shown in Figure 4, after scanning through the spectra, the script inserted a dividing line into a labeling tier. The criterion value had to be determined by trial and error. If a certain criterion value drew an inappropriate line between the two noise segments, the value was adjusted until the dividing line was drawn at the place one would choose manually.

3. Results

The average durations in the first prosody-carrier conversation of Speaker f3 are given in Figure 5. For the set of /s^h/'s in the four prosodic positions, it appears that the fricative and aspiration noise duration tend to decrease as the strength of the prosodic boundary decreases (IP-initial, AP-initial, AP-medial, PW-medial). For this speaker, the fricative noise duration roughly divides IP-initial /s^h/ from the rest of /s^h/'s. Taking the aspiration noise duration and following vowel duration into account, the three /s^h/'s in positions other than the one in IP-initial position can also be divided into two groups, AP tokens versus PW-medial token. Following vowel duration is shorter for AP tokens than for PW-medial tokens.

For /s*/ tokens in the four prosodic positions, the fricative noise duration was longest for PW-medial token. This is consistent with the results of a previous study (Oh and Johnson, 1997), which analyzed tense stops as geminate. Mira found that, among "degeminated" positions, fricative duration was longest in IP-initial position. Given this, one way of characterizing the biggest effect of prosodic position would be to posit thattense fricatives are geminate PW-medially and aspirated fricatives are more aspirated IP-initially.

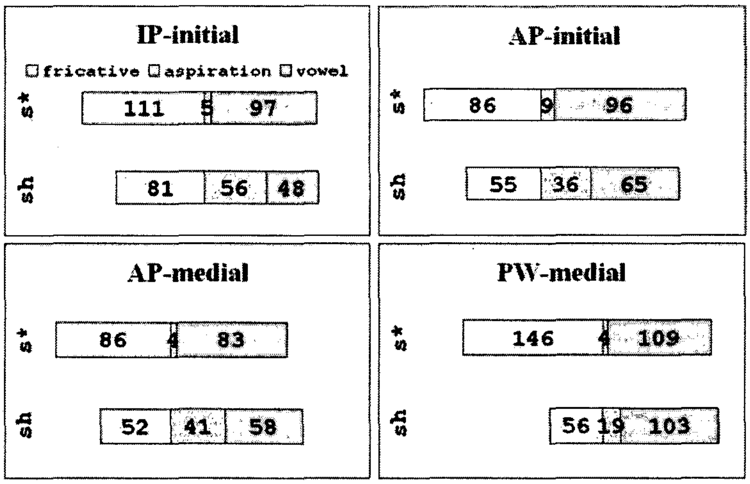

Figure 5. Average duration of fricative, aspiration, and vowel segment of five repetitions of target utterances in the first prosody-carrier conversation for Speaker f3. Segments are arranged in reference to the aspiration noise onset.

If we look at the two fricatives /s^h/ and /s*/ in each prosodic position, the fricative and aspiration noise duration seem to play an important role. The difference in fricative noise duration becomes the largest in PW-medial position. Here the /s^h/ versus /s*/ contrast appears to be mainly a function of fricative noise duration.

It seems as if the decrease in the aspiration noise duration of the /s^h/ in the PW-medial position was compensated for by the increase in the fricative noise duration of /s*/ in that same position. In addition, the decrease of fricative noise duration in the /s^h/ in the PW-medial position ends up augmenting the long fricative noise duration of /s*/ in PW-medial position, a possible 'dual' action, making the difference in fricative noise duration a more convincing acoustic parameter for the contrast in PW-medial position.

Overall, the differentiation of the two fricatives is maintained throughout the four prosodic positions despite changes in the acoustic parameters involved.

Therefore we can tentatively hypothesize that while a primary cue is the amount of aspiration noise for the distinction of /s^h/ and /s*/ in IP-initial position, confirming my earlier study (Yoon, 2002), a better differentiated cue for the distinction between the /s^h/ and /s*/ in PW-medial position is fricative noise duration.

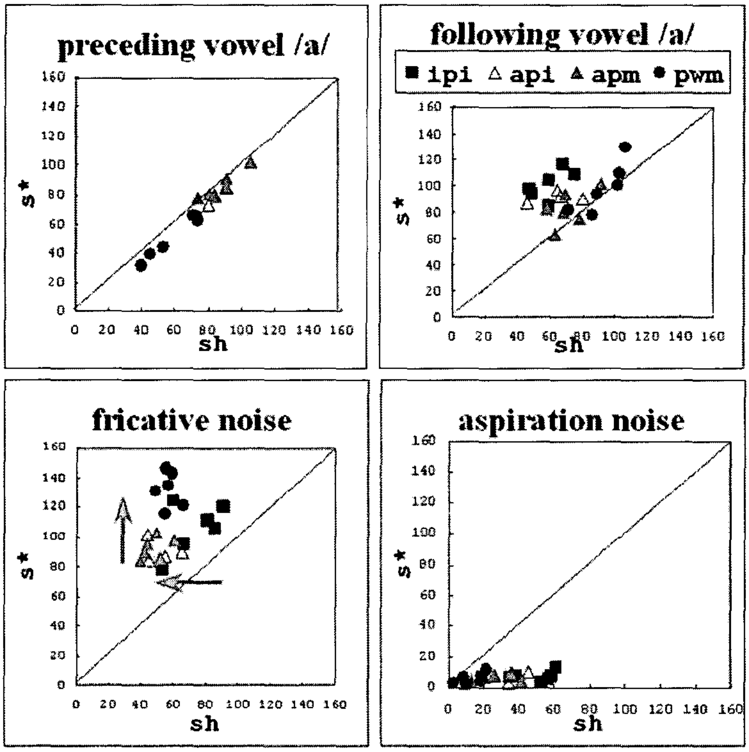

Figure 6. Scatterplots of duration for all subjects in the first prosody-carrier conversation.

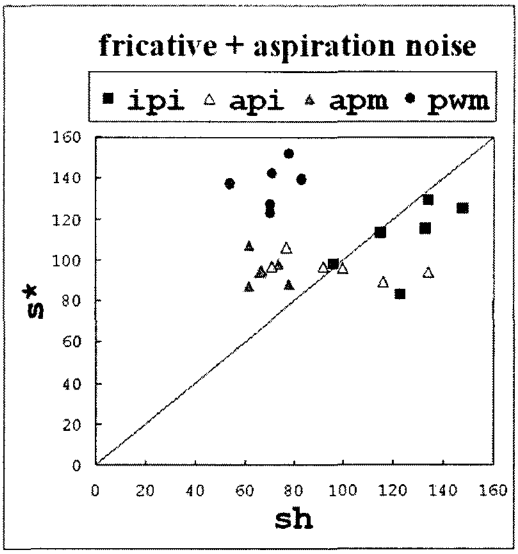

Figure 7. Scatterplot of entire noise duration (fricative + aspiration duration) for all subjects.

The scatterplot of durations for all speakers in the first prosody-carrier conversation is given in Figure 6. Each data point is a plot of the average of a pair of five repetitions of /s^h/ token (x-axis) and /s*/ token (y-axis). As can be seen from the groupings of data points, at least three groups of data points (IP-initial, AP, and PW-medial) are distinct from each other, that is, /s^h/ versus /s*/ contrast in the three prosodic positions is maintained for all tokens from the first conversation.

Even if we look at each fricative across different prosodic positions, duration alone can signal prosodic positions in most cases. The scatterplots for the second prosody-carrier conversation show roughly the same pattern as the first prosody-carrier conversation. Overall, the scatterplots for all tokens showed us that the durational parameter can be effective both in signaling prosodic positions of either /s^h/ or /s*/ tokens, and in contrasting the two fricatives in different prosodic positions.

The duration of the entire noise portion (the fricative portion plus the aspiration portion) is plotted in Figure 7. In IP-initial position (filled squares), the noise duration for /s^h/ is greater than that for /s*/, while in PW-medial position (filled circles), the duration for /s*/ is longer. The noise duration for AP-initial and AP-medial lies somewhere in between. Thus the relative duration of the entire noise portion thus appears to be effective in signalling prosodic positions.

Statistical analyses were performed based on two factor ANOVAs (by fricative type and prosodic position). As Table 1 shows, the fricative duration, aspiration duration, whole noise duration, and following vowel duration all seem to be effective cues in signaling the contrast between the two fricatives.

The interaction of the two factors on the fricative and aspiration duration evident in the table results from the fact that the two fricatives show the opposite pattern (Figure 8). That is, in the IP-initial position, the fricative durational difference becomes smaller while in PW-medial position, the aspiration durational difference becomes smaller. For the following vowel duration, the interaction stems from the decreasing durational difference toward the PW-medial position. Lastly, the interaction on the noise duration results from the fact that toward the IP-initial position, /s^h/ has longer noise than /s*/ whereas toward the PW-medial position, the noise for /s*/ is longer.

Table 1. Two factor, fricative type (I) x prosodic position (II), ANOVA with the significance level of $p < 0.001$.

Main effect of two factors on	**P<0.001**	**Factor I** / Factor II	**Significant interaction**
Fricative duration	Yes	F[1,472] = 1286.88	Yes
		F[3,472] = 100.89	
Aspiration duration	Yes	F[1,472] = 590.48	Yes
		F[3,472] = 98.09	
Noise duration (fricative + aspiration)	Yes	F[1,472] = 190.91	Yes
		F[3,472] = 102.03	
Following vowel duration	Yes	F[1,472] = 170.02	Yes
		F[3,472] = 53.70	
Perceding vowel duration	No		No
	Yes	F[2,61] = 19.03	

4. Discussion

In all prosodic positions, /s^h/ had a shorter fricative noise interval but a longer period of aspiration than /s*/. For /s^h/ and /s*/, the difference in aspiration noise duration was larger in IP-initial position, whereas PW-medial /s^h/ was hardly aspirated at all. The difference in fricative noise duration was largest in PW-medial position, whereas IP-initial /s*/ is nearly as short as /s^h/.

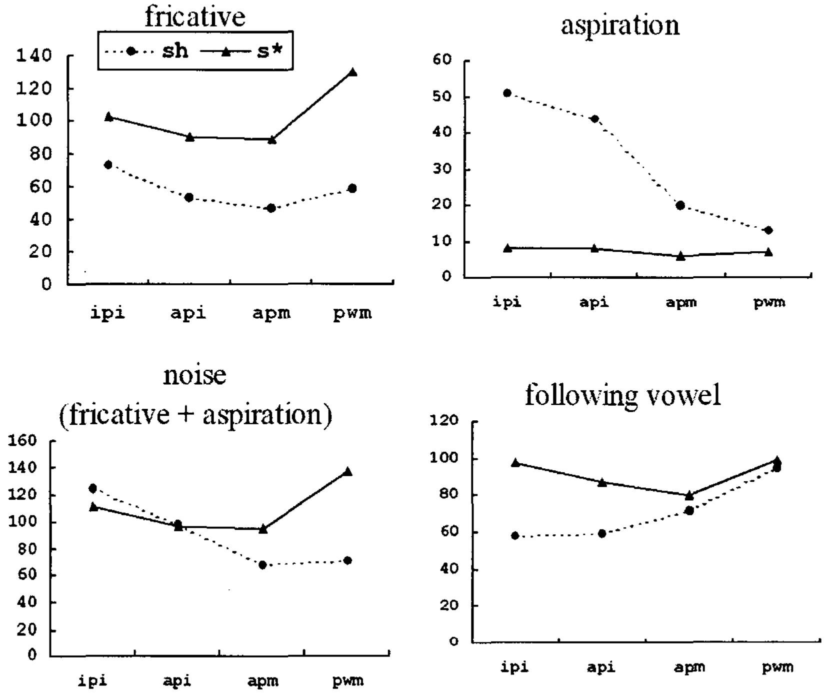

Figure 8. Average duration for all subjects.

In terms of "intra-segmental" differences, the same fricative in different prosodic positions displayed characteristics that appear to signal its prosodic location by means of durational differences. For /s*/, fricative noise duration was longest for PW-medial position and shortest for AP positions, with IP-initial position lying in between, whereas aspiration noise duration was nearly the same for all positions. For /s^h/, however, both fricative and aspiration noise duration seem to play a role in signaling prosodic positions, i.e. both noise segments (fricative noise and aspiration noise) were longest for IP-initial position, whereas for the rest of the positions, fricative noise duration was about the same while aspiration noise duration was slightly longer for AP positions than for PW-medial position. Recently Cho *et al.* (2002) showed that the /s^h/ in Korean is likely to be voiced intervocalically. They report that about 47% of the tokens had fully voiced /s^h/ and about another 40% of the tokens were voiced over more than half of the frication period. Their finding that the intervocalic voicing may contribute more to the contrast in (intervocalic) PW-medial position cannot be fully verified in the current study. Only 23% of our tokens were voiced over more than half the fricative noise interval. Among these, only one token had fully voiced /s^h/. In addition, 54% of the tokens were voiced for about quarter of the frication period, and the rest of them (27%) were not voiced at all.

For "inter-segmental" differences, the two fricatives in the same prosodic position contained sufficient acoustic information to distinguish one from the other. In IP-initial position, the two fricatives are distinct in the duration of their aspiration noise portion and the duration of theirfricative noise portion. As suggested earlier (Yoon, 2002), the aspiration noise durational difference seems to be most pronounced in IP-initial position. The /s^h/ and /s*/ in AP positions (initial and medial) display differences in noise segment durations as well. Here we see that although the overall fricative noise duration is smaller than in IP-initial position, its difference is about the same, probably distinguishing the fricatives in these positions from those in IP-initial position. For /s^h/ and /s*/ in PW-medial position, the difference is most dramatic. The duration of preceding vowels also seems to signal prosodic positions, getting progressively shorter toward PW-medial position.

From these observations, we can say that for /s*/, it is the fricative noise duration that appears to be primarily responsible for both "intra-segmental" (e.g. /s*/ in each of the four prosodic positions) and "inter-segmental" (e.g. distinction of /s^h/ and /s*/ in all prosodic positions) differences whereas for /s^h/ it is the aspiration noise duration and to a lesser degree, the fricative noise duration. In a different perspective, one can say that if a prosodic position (e.g. PW-medial position) is not favorable for a certain acoustic cue (e.g. aspiration noise duration), one of the other cues (e.g. fricative noise duration) comes into play and maintains the segmental distinction. The reasons for which a prosodic position may not be favorable for a certain acoustic cue is beyond the scope of this paper. To give an example, however, for (intervocalic) PW-medial position, one might hypothesize that in terms of articulation, aspiration noise is hard to maintain because of target undershoot, and that in terms of perception, a difference in fricative noise duration is easier to perceive.

Our finding of durational differences in different prosodic positions for Korean /s^h/ vs. /s*/ supports the idea that a linguistic contrast is not conveyed by a single acoustic cue.. What appeared to be a major cue to /s^h/ vs. /s*/ contrast in isolated words, i.e. aspiration noise duration (Yoon, 2002), turned out to be only one of multiple cues, including the fricative noise duration. If we take into consideration other cues, e.g. harmonic ratios, which are known to contribute to the distinction, we have many more acoustic parameters that play important roles in the distinction.

In this perspective, we may be able to say that a particular cue in a given prosodic position is nothing but a single cue from a "cue package", borrowing the term from Steriade (1997). There may well be other cues that this study has not examined that play a supportive role to the /s^h/ vs. /s*/ contrast. In a sense, we can say that the acoustic parameters comprising a linguistic contrast can be said to be not one-dimensional, but multi-dimensional. This phenomenon is not limited to word-level allophony, but ranges across prosodic levels higher than than word.

As the English /z/ and /s/ voicing distinction can be accounted for by employing several acoustic parameters (VOT, fricative noise duration, preceding vowel duration, etc.) at levels higher than word, so the Korean /s^h/ and /s*/ contrast also appears to employ several acoustic paramters (noise duration of fricative and aspiration segment, duration of preceding and following duration, harmonic ratio of following vowel). To a greater or lesser degree, these acoustic parameters tell us not only the identity of a particular segment, but also the identity of the prosodic position in which the segment appears. Since all natural segments are produced in a prosodic context, it is crucial that one examine the properties of a segment or the contrast of a set of segments with regard to prosody.

Moreover, this study confirms the well-known fact that any natural-sounding speech synthesizer must take into consideration the prosodic position each speech segment occupies before proceeding to of the step of actual synthesis. Specifically, the result of this sduty has implications for duration modeling in concatenative speech synthesis. Although duration appears to be one of the parameters that cue different prosodic positions, variations in subsegmental duration were not uniform. Take, for example, the durations of /s^h/ in IP-initial and PW-medial positions in Figure 5. The durations of the fricative and aspiration intervals of a PW-medial segment are 69% and 34% of the durations of the corresponding intervals of an IP-initial segment. Uniform stretching or shrinking of /s^h/ based on one or the other would result in distortion of the modified sound in concatenative synthesis. The situation would be the same even if we regarded the aspiration interval as part of the following vowel. The dynamic property of the fricative spectrum as reflected in the high-to-low frequency band ratio in Figure 4 is another indication that a simple durational model is inappropriate to model the dynamic variation of the turbulence energy in the fricatives considered. All of these factors suggest that a simple segment-based durational approach has much to overcome in modeling the effects of prosody on segment.

In a different perspective, prosodic effects on segmental properties are one way in which prosody manifests itself segmentally. Prosody is better-known to manifest itself tonally. This study has implications in the sense that it added one more case to the increasing body of evidence that prosody has segmental correlates as well as tonal correlates. If tonal correlates contribute to the parsing of prosody (Beckman, 1996), the segmental correlates may also help listeners parse the overall prosody of an utterance.

5. Conclusion

This study examined segmental properties such as the duration of fricative and aspiration noise, and the duration of preceding and following vowel of the two Korean voiceless coronal fricatives /s^h/ and /s*/ embedded in four prosodic positions, IP-initial, AP-initial, AP-medial, and PW-medial.

Results show that segmental properties are indeed affected by prosodic positions. There was not a single cue, but multiple cues to the distinction. Prosody did have effects on the segmental realization of each fricative in different prosodic positions. Despite these effects, the /s^h/ versus /s*/ contrast is preserved because when the contrast for one measure was lessened to make it a less effective cue to the fricative type, some other measure was more differentiated. For example, difference in aspiration noise duration was more consistently pronounced for IP-initial position than for PW-medial position, where the difference in fricative noise duration was largest. In other words, different properties can dominate as cues to preserve the segmental contrast in the face of the prosodically conditioned variation. Finally, it was suggested that variation in segmental properties may help listeners parse the prosody of an utterance.

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