PROSODIC STRENGTHENING OF /sCV/ SEQUENCES IN ENGLISH

Yoonjeong Lee

Hanyang University, Seoul, Korea
yj.cynthia.lee@gmail.com

ABSTRACT

This study examined the effects of prosodic boundary and prominence on English /sCV/ sequences. One important finding was that the domain-initial strengthening effect was not strictly confined to the first segment, but it could extend over the entire /sCV/ sequence, although it was further modulated by prominence. Another important finding was shortening of VOT for the voiceless stop in /sCV/ under prosodically strong environments, suggesting that prosodic strengthening operates on a phonological rule as a way to reinforce its phonetic outcome. Finally, we found evidence that boundary-induced strengthening and prominence-induced strengthening were separately encoded, but not in an exclusively independent way.

Keywords: domain-initial strengthening, accent, phonological rule, onset cluster, English

1. INTRODUCTION

Understanding how the prosodic structure of a spoken utterance is phonetically expressed has been one of the important goals of many prosody-phonetics interface studies, as the prosodic structure carries both linguistic and extralinguistic information. Domain-initial strengthening (DIS) has been known to be an important phonetic strategy employed by speakers to signal prosodic structure, especially by producing the initial consonant of a prosodic constituent with a longer duration and more constriction [5, 6, 8, 11]. The fine-phonetic consequences of DIS have also been found to be exploited by listeners in speech comprehension [7]. As such, understanding the exact nature of DIS has been the locus of many studies on the phonetics-prosody interface.

One of the important questions with respect to the DIS effect has been about its scope—i.e., to what extent the DIS effect can extend over the domain-initial word. Some researchers have shown that the DIS effect is strictly local to the very initial segment [6, 8, 11], while some others have reported that the effect can extend into the next vowel in CV, though it may well be too weak to be observable [2, 4, 5]. In the present study, we further explore this issue, especially focusing on the case when the initial syllable has an onset consonant cluster (/sk, sp, st/).

Examining the DIS effect with the /sC/ cluster particularly allows us to address two important questions. The first question is whether the localized DIS effect that has often been observed in the literature is indeed due to the language-specific structural constraint (i.e., the vowel is reserved for stress marking in English as Barnes [1] argued) or it is simply due to the progressively waning nature, as the segment becomes farther away from the boundary as the π-gesture theory predicts [2, 4, 5]. In their articulatory study, Byrd & Choi [3] in fact showed that the second member of the English onset clusters /sk/ or /sp/ is indeed strengthened as reflected in lengthened constriction formation, showing a quite robust DIS effect that extends over the second member of the cluster. Building on the result of this articulatory study, we further examine the DIS effect on the initial /sCV/ sequence, but this time we also examine it in connection with the prominence factor in order to understand the complex nature of the interaction between boundary-induced and prominence-induced prosodic strengthening effects [5].

The second question that we can address by examining the /sCV/ sequence is how the phonological rule (i.e., a stop becomes unaspirated after /s/ in the /s/-stop sequence) is phonetically implemented in prosodically strong environments. As a result of the rule, the stop after /s/ is associated with [-spread glottis], and it is thus produced with a shortened VOT. If prosodic strengthening operated on a phonological rule in a way to reinforce its phonetic outcome, the aspirated stop after /s/ would be produced with even more shortened VOT, so that the allophonic phonetic feature [-spread glottis] would be enhanced. Alternatively, however, if we follow the general assumption that the phonetic implementation of prosodic strengthening is closely linked with enhancement of phonemic contrast [6, 9, 10], prosodic strengthening would induce lengthening of VOT, showing an enhancement of the phonological feature [+spread glottis] to be maximally contrastive with its voiced counterpart.

Finally, testing all these effects will allow us to address a more general question about how boundary-induced strengthening differs from prominence-induced strengthening in producing /s/-stop sequences, so that we can evaluate the view that the boundary marking and the prominence marking are encoded separately in speech planning [5].

2. METHOD

Ten native speakers of American English (5 females, 5 males) participated in the experiment.

The test consonant cluster was a /s/-stop sequence (/sk, sp, st/) embedded in a two-word sequence, in which /s/ and the following stop formed a complex onset of the second word (e.g., ‘eye scan’). For each /s/-stop sequence, two items were included (i.e., for /sk/, ‘eye scan’ and ‘rye scone’; for /sp/, ‘dye spot’ and ‘lay spin’; for /st/, ‘pea stacks’ and ‘bay stone’). The two-word sequences then appeared in carrier sentences in which the two critical factors, Boundary (IP-initial vs. IP-medial) and Accent (Accented vs. Unaccented) were manipulated. (Note that the lexical stress factor was controlled in the present study, as we used all monosyllabic words.)

In the experiment, the subjects were presented with test sentences on a computer screen and asked to read the sentences aloud. Each experimental trial was composed of two sentences to induce desired renditions of the various conditions. In order to induce the accented condition, the subjects were asked to make contrast between the two sentences in which only two pairs of words are contrastive. The items that are contrastive were printed in bold uppercase. Two different sentence types were used for different boundary conditions (see Table 1).

In total, 720 tokens were collected and analyzed in the present study (6 items x 2 boundaries x 2 accent conditions x 10 speakers x 3 randomized repetitions).

Acoustic measurements included /s/ duration, the spectral center of gravity (COG) and RMS spectral energy for /s/, the closure duration and VOT for the following stop, vowel duration, and vowel intensity peak.

Table 1: An example set of test sentences containing /sk/.

(1) IP-initial /sk/: Accented After **THEY** say ‘eye’, ‘**SPAN**’ again will be the next phrase to say. But after **WE** say ‘eye’, ‘**SCAN**’ again will be the next phrase to say.
(2) IP-initial /sk/: Unaccented After **THEY** say ‘eye’, ‘scan’ again will be the **NEXT** phrase to say. But after **WE** say ‘eye’, ‘scan’ again will be the **FINAL** phrase to say.
(3) IP-medial /sk/: Accented To say ‘eye **SPAN**’ again with me is going to be **DIFFICULT**. But to say ‘eye **SCAN**’ again with me is going to be **EASY**.
(4) IP-medial /sk/: Unaccented To say ‘eye scan’ again with **JOHN** is going to be **DIFFICULT**. But to say ‘eye scan’ again with **ME** is going to be **EASY**.

3. RESULTS

In the present study, statistical evaluation of the systematic influence of prosodic factors was made based on repeated measures Analyses of Variance (RM ANOVAs). For further analyses of within-factor effects, posthoc pairwise comparisons with the method of Bonferroni/Dunn were conducted. The results of RM ANOVAs will be summarized in Tables 2-4 for /s/, the following stop, and the vowel, respectively. The reader is asked to refer to the tables for detailed numerical reports of statistical analyses.

3.1. /s/

/s/ duration. There were main effects of Boundary and Accent on /s/ duration—i.e., it was longer in IP-initial position than in IP-medial position, and when accented than when unaccented. There was a significant Boundary by Accent interaction, which was attributable to a more robust boundary-induced lengthening in the unaccented (p=0.001, eta^2=0.72) than in the accented condition (p<0.05, eta^2=0.48).

COG. There was a significant main effect of Accent on COG with no Boundary effect. A higher centroid frequency of /s/ was found when accented than when unaccented. However, Boundary interacted with Accent. The interaction was in part due to the fact that the accent effect was significant only in IP-initial position (p<0.005, eta^2=0.67), not in IP-medial position.

RMS spectral energy. There were main effects of Boundary and Accent on RMS energy for /s/. The spectral energy was smaller in IP-initial than IP-medial position, but greater in the accented than in the unaccented condition. As was the case with

COG measure, Boundary interacted with Accent, showing a more robust accent effect in prosodically strong, IP-initial, position ($p<0.001$, $eta^2=0.79$) than prosodically weak, IP-medial, position ($p<0.05$, $eta^2=0.5$).

Table 2: ANOVAs for /s/. * = p<0.05; ** = p<0.01.

	Boundary	Accent
/s/ duration (ms)	IPi > IPm F[1,9]=16.74**	Acc > Una F[1,9]=127.56**
	Boundary x Accent: F[1,9]=14.24**	
COG (Hz)	IPi = IPm $F[1,9]=3.81^{n.s.}$	Acc > Una F[1,9]=10.02*
	Boundary x Accent: F[1,9]=13.46**	
RMS energy (dB)	IPi < IPm F[1,9]=44.32**	Acc > Una F[1,9]=22.01**
	Boundary x Accent: F[1,9]=20.52**	

3.2. Stop

Stop closure duration. Both Boundary and Accent showed main effects on stop closure duration—i.e., it was longer in the prosodically strong, IP-initial and accented, conditions than in weak conditions. There was a significant interaction between Boundary and Accent, which stemmed from the fact that boundary-induced lengthening was significant only in the unaccented condition ($p=0.001$, $eta^2=0.75$).

VOT. There was a significant main effect of Accent on VOT with no Boundary effect. VOT was *shorter* in the accented than in the unaccented condition. There was, however, a significant interaction effect between Boundary and Accent, which was attributable to the fact that a significant Boundary effect was found only in the unaccented condition ($p<0.05$, $eta^2=0.48$), showing *shorter* VOT IP-initially than IP-medially.

Table 3: ANOVAs for stop. * = p<0.05; ** = p<0.01.

	Boundary	Accent
closure duration (ms)	IPi > IPm F[1,9]=10*	Acc > Una F[1,9]=40.62**
	Boundary x Accent: F[1,9]=18.56**	
VOT (ms)	IPi = IPm $F[1,9]=2.41^{n.s.}$	Acc < Una F[1,9]=30.47**
	Boundary x Accent: F[1,9]=24.5**	

3.3. Vowel in #/sCV/

Vowel duration. There was a significant main effect of Accent with no Boundary effect. The vowel was longer when accented than when unaccented. Boundary, however, interacted with Accent. This interaction was attributable to the following facts: accent-induced lengthening was reinforced in the prosodically strong, IP-initial, condition ($p<0.001$, $eta^2=0.92$); boundary-induced lengthening effect on the initial vowel was observed only in the unaccented condition ($p<0.05$, $eta^2=0.39$).

Vowel intensity. Both Boundary and Accent showed a significant main effect on the vowel intensity peak. The vowel was produced with greater energy in the prosodically strong, IP-initial and accented, conditions. No interaction between factors was found.

Table 4: ANOVAs for vowel. * = p<0.05; ** = p<0.01.

	Boundary	Accent
vowel duration (ms)	IPi = IPm $F[1,9]=0.34^{n.s.}$	Acc > Una F[1,9]=104.04**
	Boundary x Accent: F[1,9]=5.3*	
vowel intensity (ms)	IPi > IPm F[1,9]=8.86*	Acc > Una F[1,9]=84.37**
	Boundary x Accent: $F[1,9]<1^{n.s.}$	

4. SUMMARY AND DISCUSSION

In the present study, we have examined how the /sCV/ sequence is acoustic-phonetically realized in the domain-initial strengthening (DIS) environment, and how the DIS effect interacts with accent. In what follows, we will summarize the results and discuss them in light of research questions and hypotheses discussed at the outset of the paper.

One of the important findings of the present study was that both the first and the second member of the /sC/ cluster showed DIS effects. /s/ was produced with longer frication duration and lower RMS energy (indicating a greater oral constriction [6]) in IP-initial position. The voiceless stop as the second member also showed a DIS effect by lengthening the stop closure duration, which is comparable to the effect found in Byrd & Choi [3]. These results therefore confirm that the DIS effect is not strictly local to the first segment, but it spreads to the next member of the consonant cluster.

We have also found a robust DIS effect on the following vowel, at least with the vowel intensity measure, showing that the vowel is louder IP-initially than IP-medially, which is exactly what was observed in Cho & Keating [5]. This again confirms that the DIS effect does extend to the vowel even beyond the second member of the /sC/ cluster. Unlike with the intensity measure, however, the boundary factor did not generate a significant main effect on the vowel duration, but a significant interaction between Boundary and Accent indicated that the vowel undergoes DIS when it receives no prominence—i.e., when it is 'unaccented.' It appears that the DIS effect may be saturated with the robust accent-induced lengthening effect (i.e., a ceiling effect) and it surfaces when the accent effect is no longer present.

The accent-sensitive partial DIS effect on the vowel is generally in line with the idea that the DIS effect is gradient as a function of distance from the boundary [2, 5]. The fact that the DIS effect can spread into the vowel, but only with no prominence, can be explained by the assumption that the effect becomes weaker and therefore is likely to be overridden by the accent-induced lengthening effect. This appears to be in contradiction with Barnes' [1] phonological argument for the locality constraint of DIS—i.e., the DIS effect does not spread into the vowel in CV syllables in English because vowel duration is used primarily for marking stress. However, the absence of the DIS effect when there was prominence could be at least in part accounted for by the notion that stress (in a broader sense) suppresses DIS in English.

Another important finding was a 'shortened' VOT for the voiceless stop in /sCV/ syllables in prosodic strengthening environments. There was a robust accent effect on it, while the DIS effect was found only when the syllable was 'unaccented,' which is again presumably due to saturation effect (this time a floor effect) from the robust accent-induced 'shortening' effect. One of the hypotheses we discussed at the beginning was that if prosodic strengthening were principally to maximize phonemic contrast, VOT would be lengthened to enhance the relevant phonological feature [+spread glottis]. However, the shortening of VOT found under prosodic strengthening suggests that this is not always the case. Instead, it supports the alternative hypothesis: if prosodic strengthening could operate on a phonological rule (i.e., a stop becomes unaspirated after /s/), the resulting allophonic phonetic feature [-spread glottis] would be reinforced. More broadly, this illuminates the nature of prosodic strengthening, which is closely intertwined with the phonological system of a given language, not simply through enhancing the phonemic contrast between sounds in the language, but at the level of phonetic implementation of a phonological rule.

Finally, our results showed that while there were some prosodic strengthening patterns common to both boundary- and prominence-marking (for example, as reflected in /s/ frication duration, stop closure duration, and vowel intensity), their distinction was manifested most clearly in RMS energy for /s/ (showing an exactly opposite pattern: it was larger when accented, but smaller domain-initially). The fact that only the Accent factor generated a main effect on some parameters such as COG, VOT, and vowel duration also indicates that accent-induced strengthening differs in nature from boundary-induced strengthening. These results, taken together, support the view that the two aspects of prosodic structure are separately encoded in speech planning [5]. Moreover, various Boundary by Accent interaction effects found in the present study imply that they are not encoded in a strictly independent way, but in an intricately interactive way.

5. REFERENCES

[1] Barnes, J.A. 2002. *Positional Neutralization: A Phonologization Approach to Typological Patterns.* Ph.D. dissertation. University of California, Berkeley.

[2] Byrd, D. 2000. Articulatory vowel lengthening and coordination at phrasal junctures. *Phonetica* 57(1), 3-16.

[3] Byrd, D., Choi, S. 2006. At the juncture of prosody, phonology, and phonetics—The interaction of phrasal and syllable structure in shaping the timing of consonant gestures. *LabPhon.10* Paris.

[4] Cho, T. 2008. Prosodic strengthening in transboundary V-to-V lingual movement in American English. *Phonetica* 65, 45-61.

[5] Cho, T., Keating, P.A. 2009. Effects of initial position versus prominence in English. *J. Phon*. 37, 466-485.

[6] Cho, T., McQueen, J. 2005. Prosodic influences on consonant production in Dutch: Effects of prosodic boundaries, phrasal accent and lexical stress. *J. Phon.* 33, 121-157.

[7] Cho, T., McQueen, J., Cox, E. 2007. Prosodically driven phonetic detail in speech processing: The case of domain-initial strengthening in English. *J. Phon.* 35(2), 210-243.

[8] Fougeron, C., Keating, P.A. 1997. Articulatory strengthening at edges of prosodic domains. *J. Acoust. Soc. Am.* 101(6), 3728-3740.

[9] de Jong, K.J. 2004. Stress, lexical focus, and segmental focus in English: Patterns of variation in vowel duration. *J. Phon.* 32, 493-516.

[10] de Jong, K.J., Zawaydeh B. A. 2002. Comparing stress, lexical focus, and segmental focus: Patterns of variation in Arabic vowel duration. *J. Phon.* 30, 53-75.

[11] Keating, P.A., Cho, T., Fougeron, C., Hsu, C. 2003. Domain-initial strengthening in four languages. *LabPhon. 6: Phonetic interpretations*. Cambridge, UK: Cambridge University Press, 145-163.