EFFECTS OF PROSODIC BOUNDARY VERSUS ACCENT IN THE ARTICULATION OF ENGLISH /æ / IN #VC AND #CVC

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ABSTRACT

The current study investigates effects of prosodic boundary and accent on lip opening and tongue movement of English /æ/ in 'add', 'had' and 'pad'. Boundary-induced strengthening is found in both V-initial (#VC) and C-initial (#CVC) words, although different kinematic measures are influenced by the segmental contexts. 'Had' patterns better with phonetically similar 'add' (sharing no constriction at the supralaryngeal level) than with phonologically similar 'pad' (sharing a CV syllable structure). Accent-induced strengthening is found in more kinematic measures than the boundary effect. Results also support that accent and boundary effects are differentially encoded in speech planning, in such a way that the accent-induced strengthening is reflected in the tongue fronting and the boundary-induced strengthening in the tongue lowering.

Keywords: domain-initial strengthening, accent, vowel, supralaryngeal constriction

1. INTRODUCTION

The phonetic realization of segments is known to be affected by prosodic boundary and accent. Domain initial strengthening (henceforth DIS) is a well-known example of boundary-induced prosodic strengthening. Domain-initial consonants show articulatory (spatiotemporal) expansion and acoustic lengthening [3, 5, 7, 10]. Unlike its effects on consonants, however, the DIS effect on vowels is still inconclusive, with a limited, inconsistent, or even null DIS effect [1, 3, 7, 10]. All of these studies, however, investigated DIS on vowels in #CV, so the vowels were not strictly domain-initial, as opposed to the frequently-studied consonants in #CV. We therefore cannot tell whether the weak DIS effect on vowels is because the effect is mainly local to the first segment and decreases as segments get farther away from the boundary [4, 7, 9], or because of prosodic/phonological functions of vowels (e.g., stress-marking in English [1]). A recent study by [12] examined tongue traces with ultrasound to test DIS on English /ɛ/ and /ɔ/ in both #CV and #V positions, and found the DIS effect in #V, suggesting that strictly initial vowels do undergo more robust domain-initial strengthening. This study, however, did not consider the confounding effect of accent at the phrase boundary, and hence we do not know how much of the DIS effect found in their study is in fact attributable to the accent effect (e.g, [2, 5, 7]).

The current study therefore investigates whether, and how, DIS is realized on vowels in the strictly vowel-initial and consonant-initial conditions, and how the boundary effect is differentiated by and interacts with the accent effect arising with contrastive focus. We focus specifically on the lip and tongue kinematics of /æ/ in the words 'pad', 'add', and 'had'.

We first compare DIS effect on /æ/ in #CV ('pad') versus #V ('add') contexts. If boundary-induced strengthening of a vowel is determined by its distance from the boundary, the initial vowel in 'add' should show DIS, while the effect would be still limited if the vowel is set aside for expressing stress/accent-induced prominence [1]. Note, however, that English word-initial vowels are often glottalized, and much more so at the beginning of a full intonational phrase [8] (cf. [9] on French). If the glottalization serves a primary function as a boundary marker, there would be no strong driving force for DIS on vowels in #V, and hence no robust DIS effect on them.

We also compare DIS on /æ/ in 'add' and 'had'. We included 'had' in order to examine whether the locality of DIS depends on phonological or phonetic distance from the boundary. Although the phonological sequence of 'had' starts with the consonant /h/, it does not involve a consonantal constriction at the supralaryngeal level. 'Add' and 'had', therefore, are similar as far as the supralaryngeal phonetic constriction is concerned. If the scope of DIS were phonetically determined, /æ/ in both 'had' and 'add' would show similar DIS effects. On the other hand, if DIS operated at a more abstract phonological level, /æ/ in 'had' would pattern with /æ/ in 'pad'.

In addition to DIS on vowels, we compare the effects of boundary and accent and their interactions on various articulatory measures. In doing so, we will also investigate whether boundary and accent markings are differentially encoded. Studies seem to suggest that they are [5, 7]. For example, [5] found that the English vowels /ɑ, i/ in /#bɑ/ and /#bi/ are differentially realized under the effects of boundary (with tongue lowering) and of accent (with tongue fronting). We will thus explore if a similar encoding strategy is exploited in production of /æ/ in #VC and #CVC context.

2. EXPERIMENT

Six native speakers of American English, who were in their 20's, participated in the experiment.

Three target words (*add*, *had*, *pad*) were located in IP-initial and IP-medial positions in carrier sentences. Each prosodic condition consisted of two sentences in order to control for accent with a contrastive focus. The second sentence contained the target word. Table 1 shows how boundary and accent factors were manipulated across test sentences with 'add'. Note that when 'add' was the accented target word in the second sentence, the contrasting word was 'had' in the first sentence (as in Table 1A, 1C). For target words 'had' and 'pad', the contrasting words in the first sentence were 'pad' and 'add', respectively.

Table 1: A list of carrier sentences with four prosodic conditions. Accented words are capitalized and marked in bold. The target word (in this case, 'add') is underlined. '#' indicates an IP boundary in A and B and an IP-medial word boundary in C and D.

A. IP-initial, accented
After **I** say 'Diana,' '**HAD** again' will be the next phrase to say. But after **THEY** say 'Diana,' # '**ADD** again' will be the next phrase to say.
B. IP-initial, unaccented
After **I** say 'Diana,' 'add again' will be the **NEXT** phrase to say. But after **THEY** say 'Diana,' # 'add again' will be the **FINAL** phrase to say.
C. IP-medial, accented
To say 'Diana **HAD** again' with me is going to be difficult. But to say 'Diana **# ADD** again' with me is going to be easy.
D. IP-medial, unaccented
To say 'Diana add again' with **JOHN** is going to be difficult. But to say 'Diana **#** add again' with **ME** is going to be easy.

The 2D Electromagnetic Midsagittal Articulography (Carsten AG200) was used to track sensors adhered to the tongue dorsum (henceforth TD), the jaw, and the upper and lower lips. (The data on jaw are not reported here.) In addition, two sensors on a bite plate were used to obtain the occlusal plane (*x*-axis), to which the data were rotated. *Y*-axis was perpendicular to the occlusal plane. The entire articulatory movement data were sampled at 200Hz and low-pass filtered at a cut-off frequency of 20Hz.

Subjects read the carrier sentences three times in a pseudo-randomized order. The collected data were screened by two AE ToBI transcribers. When there was a disagreement between them, the token was excluded from the data analysis. Tokens with abnormal velocity trajectory patterns were also excluded. Nineteen tokens were excluded from 216 (2 boundaries x 2 accent conditions x 3 words x 3 repetitions x 6 speakers) through these procedures, and hence 197 tokens were analyzed.

The following is the list of articulatory measures.

(1) *Lip Displacement*: spatial difference between the lip opening onset and the target
(2) *Lip Max-to-Max Displacement*: spatial difference between lip closing and opening maxima
(3) *Lip Opening Maximum*: the maximum point of the lip aperture
(4) *Lip Opening Peak Velocity*: the peak velocity value during the lip opening movement.
(5) *Lip Opening Movement Duration*: the time interval from the onset to the target
(6) *TD-x Extremum*: the horizontal extreme point of the TD during the vowel production
(7) *TD-y Extremum*: the vertical extreme point of the TD during the vowel production

(Jaw opening data are being analyzed and the result will be reported at the conference.)

3. RESULTS AND DISCUSSION

Given that a lip closing gesture for /p/ is involved only for 'pad', not all the measures listed above are directly comparable between 'pad' and 'add', while 'add' and 'had' are comparable. Thus, 'pad' was first examined by a two-way RM ANOVA with two factors: Boundary (IP initial vs. IP medial) and Accent (Accented vs. Unaccented). And then one three-way RM ANOVA was performed for 'add-had' with the additional Initial Segment factor (/æ/ vs. /h/). The main effects of Boundary and Accent are summarized in Table 2 with detailed numerical reports of statistical analyses. Note that the Initial Segment effect (in the analyses of 'add' vs. 'had') was found significant only for peak velocity, with 'add' faster than 'had' ($F[1,5]=28.72$, $p=.003$). Since 'add' and 'had' did not significantly differ from each other, and showed no interactions with

prosodic factors in most cases, we report the combined results of 'add/had' and compare them with the results from 'pad'.

Table 2: Main effects of Boundary and Accent on 'Pad' and 'Add-Had'. A significant main effect is marked by * (p<.05), and a trend (.05<p<.07) is marked as (tr.). Non-significant effects are not listed. Degrees of freedom for F-ratio is [1, 5] in all cases.

Articulatory measures	*Pad*		*Add/Had*	
	Bound	Accent	Bound	Accent
Lip Opening Displ.	IPi>IPm F=28.81*	A > U F=74.18*		A > U F=35.58*
Lip Opening Max-to-Max Displ.	IPi>IPm F=35.92*	A > U F=81.5*	IPi>IPm F=5.97 (tr.)	A > U F=60.03*
Lip Opening Maximum		A > U F=61.09*		A > U F=105.1*
Peak Velocity	IPi>IPm F=20.28*	A > U F=23.89*		A > U F=6.5(tr.)
Lip Opening Movement Duration			IPi>IPm F=16.19*	A > U F=22.86*
TD-x Extremum ('>' = fronted)		A > U F=7.96*		A > U F=11.37*
TD-y Extremum ('>' = lowered)	IPi>IPm F=14.90*			A > U F=4.88 (tr.)

3.1. 'Pad' vs. 'Add/Had'

For 'pad', DIS is manifested with faster lip opening peak velocity, greater lip opening spatial magnitude (displacement measures), and lowered TD (TD-y extremum). For 'add/had', DIS is reflected in lip opening movement duration. Also, a trend toward greater lip opening magnitude is observed (max-to-max displacement) for 'add/had'. Results therefore suggest that DIS is not only found with domain-initial consonants ('pad') but also with strictly domain-initial vowels in #VC ('add/had'). Additional post-hoc inspection on the rate of glottalization show that 95% of 'add' tokens are produced with glottalization IP-initially, confirming that DIS is expressed at least in part by glottalization for a domain-initial vowel [9].

DIS of /bɑ/ reported in [6] was characterized by *faster* and *longer* (not larger) lip opening movement, while DIS of 'pad' in the present study shows *faster* and *larger* (not longer) pattern. Both studies therefore have an increase in peak velocity in common as a DIS effect. It appears that when bilabial consonants are involved, lip opening movements are at least faster domain-initially. When bilabial /p, b/ are not involved, however, lip opening movement is *not faster* domain-initially, but consistently *longer* (and possibly larger) as found with the case of 'add/had'. These results taken together suggest that DIS of lip opening movement for a vowel cannot be characterized by a certain kinematic pattern, but it varies with segmental contexts (and possible inter-speaker variation, see also [3]).

The effects of Accent are significant for 'pad' in almost all measures except for lip opening movement duration and TD-y extremum. 'Add/had' also show the Accent effects in all measures, although peak velocity and TD-y extremum show only trend effects. Thus, accent-induced strengthening appears to be realized in a very similar way for both 'pad' and 'add/had, but it is clearly manifested in more kinematic measures for vocalic articulation than DIS is.

3.2. 'Add' vs. 'Had'

The comparison between 'add' and 'had', which have the same supralaryngeal constriction, but differ in their phonological structures (VC vs. CVC), reveals that they are quite similar in the kinematic realization of DIS. (Note that /h/ in 'had' was clearly produced in all of the analyzed tokens, as confirmed by the acoustic data.) As aforementioned, they only differ in peak velocity (with 'add' faster than 'had'). Also, as shown in Table 2, 'add/had' show different boundary effects from 'pad'. This seems to suggest that DIS operates at the phonetic rather than the abstract phonological level—i.e., 'had' generally patterns more with the phonetically similar 'add' than with phonologically similar 'pad' in DIS.

There is, however, some evidence that the phonological syllable structure may be also reflected kinematically—i.e., in the tongue lowering dimension (TD-y extremum). We found an almost significant Initial Segment x Boundary interaction in TD-y extremum ($F[1,5]=6.41$, $p=.052$). The tongue lowering DIS trend effect is observed for 'had' ($p<0.06$), but not at all for 'add.' Given that 'pad' also show a significant tongue lowering DIS effect, the 'had/pad' patterning suggests that the phonological structure may be reflected in DIS insofar as the tongue lowering dimension is concerned.

Here an important question arises as to why 'add' does not show the tongue lowering DIS while 'had' (that has the same supralaryngeal constriction) and 'pad' (that has an antagonistic upward pulling force for /p/) do. We propose that the generally less robust DIS for 'add' at the supralaryngeal level can be accounted for by the fact that DIS for 'add' is expressed more robustly by its glottalization. Given its clear function for

marking a prosodic boundary at the laryngeal level, there appears a lesser driving force to mark it at the supralaryngeal level.

Finally, there is a significant Boundary x Accent interaction with lip opening maximum ($F[1,5]=7.672$, $p=.039$), which is due to the fact that the mean lip opening values are larger in IP-initial than in IP-medial positions only when unaccented. The results therefore suggest that the boundary effect is overridden by the accent effect when the initial word is accented. It seems thus possible that DIS found in [12] for vowels in #VC could in fact be the combined effects of boundary and accent. The effects from accent should therefore be carefully factored out when investigating the DIS effect on vowels.

3.3. Encoding of accent vs. Boundary effects

Table 2 shows that when kinematic measures are affected by Boundary, they are also affected by Accent. But TD-y extremum is an exception to this tendency, showing only the Boundary effect (i.e., the tongue lowering DIS effect) which is most clearly reflected in 'pad' ($p<0.05$), while 'had' and 'add' show the same pattern as a trend effect and an insignificant direction, respectively. In contrast, TD-x extremum (the tongue fronting) shows the Accent effect only. This is indeed very similar to what has been found in [5], which showed that English vowels /ɑ, i/ are produced with more lowered tongue at a larger prosodic boundary (in line with sonority expansion, [2]) and with more fronted tongue when accented (in line with featural enhancement, [11]). Our data therefore support that the accent effect and the boundary effect are encoded separately, which is most clearly reflected in the vocalic tongue dimension, in such a way that the accent effect is realized in the horizontal tongue movement dimension (interpreted as an enhancement of frontedness) and the DIS in the vertical dimension (interpreted as an enhancement of sonority).

4. SUMMARY

In sum, the current study shows that DIS (domain-initial strengthening) is found with domain-initial V ('add'), suggesting that the previously observed weak DIS effect on the vowel in #CV was not primarily because the vowel is mainly utilized for prominence marking but because it is farther away from the boundary. However, segmental contexts ('pad' versus 'add/had') seem to determine which kinematic measures are to be influenced by boundary-induced strengthening. The lack of supralaryngeal constriction in a consonant (i.e., 'had') results in more vowel-like DIS pattern as in 'add' in many aspects, supporting the view that DIS operates at the phonetic level. However, 'had' also patterns with 'pad' in terms of the tongue lowering DIS effect, alluding to the possibility that the phonological syllable structure still plays a role. Alternatively, however, the failure for 'add' to pattern with 'had' and 'pad' may not be because of its phonologically different syllable structure, but because of its frequent glottalization for marking a prosodic boundary, thus alleviating its functional load at the supralaryngeal level. Accent-induced strengthening differs from DIS in many aspects. In particular, the accent effect is manifested more consistently in C-initial and V-initial words (larger, faster and longer movement) than the DIS effect, and the former is reflected in the tongue fronting while the latter is in the tongue lowering, supporting that different aspects of prosodic structure are encoded separately in speech production.

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