PROSODIC BOUNDARY EFFECTS ON DURATIONS AND VOWEL HIATUS IN MODERN GREEK

Evia Kainada

Department of Linguistics and English Language, University of Edinburgh, UK
evia@ling.ed.ac.uk

ABSTRACT

Research on the prosodic structure of languages has been based on processes such as durational patterns and sandhi phenomena. One of the underlying assumptions is that such processes signal, and are regulated by, the same structure. This paper is part of ongoing research on the effect of prosodic boundary strength on segmental and supra-segmental phenomena. It investigates the effect of boundary strength on two processes, namely pre-boundary lengthening and resolution of external (between-words) vowel hiatus on Modern Greek. Results show that a) pre-boundary lengthening is influenced by boundary strength in a hierarchical gradient manner, and b) degree of coalescence (F2 values at the mid point of vowels in hiatus) is not influenced by boundary strength. Preliminary results also suggest that the first vowel (V1) of vowels in hiatus is not elided in Gr.

Keywords: prosodic structure, pre-boundary lengthening, vowel hiatus

1. INTRODUCTION

The effect of prosodic boundary strength on several phonetic processes, such as pre-boundary lengthening and sandhi phenomena, has been extensively examined in the literature. Previous research has shown that pre-boundary lengthening is organized hierarchically, in that durations are longer in the proximity of stronger prosodic boundaries [8]. Similar results have been attested for coarticulatory phenomena such as vowel hiatus [3]. The assumption within this line of research holds that such different types of segmental and suprasegmental processes are regulated by the same structure, and will undergo similar changes under the influence of changing prosodic boundary strength.

This paper is part of ongoing research designed to evaluate this assumption by testing several processes in parallel under different prosodic conditions. Data comparing the effect of prosodic boundary strength on pre-boundary lengthening and hiatus resolution in Greek are presented. Pre-boundary lengthening was expected to occur in the proximity of stronger prosodic boundaries. Prosodic boundary strength was also expected to affect formant values of vowels in hiatus in that a) F2 at the mid point of vowels in hiatus should be influenced by prosodic boundary strength (less coalescene in higher domains suggests more differences between the target vowels), and b) F2 at the beginning and end of the vowels in hiatus should resemble more that of baseline vowels in higher, than in lower domains (baseline vowel hiatus made of two same vowels).

2. METHOD

2.1. Participants

Six native speakers (3 male, 3 female) of Athenian Greek, with no known speech, language or reading difficulties were recorded. They were all in their twenties.

2.2. Materials

To examine pre-boundary lengthening and vowel hiatus, two sets of materials were constructed, one for each phenomenon. Prosodic boundary effect was manipulated using 5 different syntactic conditions, which potentially elicit gradually stronger prosodic levels (numbered below from C1 to C5 in order of increasing size). The syntactic/prosodic boundary was always placed between an adjective and a noun (shown in small caps and bold). The 5 syntactic constructions were:

C1: $[_S[_{PP}$Prep$[_{AdjP}$ Det **ADJ NOUN**]]$[_{VP...}$
C2: $[_S[_{PP}$Prep$[_{AdjP}$Noun **ADJ**]$[_{NP}[_{AdjP}$ **NOUN** Adj]$[_{VP...}$
C3: $[_S[_{Ssub}$ Particle$[_{VP}$ V$[_{NP}$Noun **ADJ**]$[_S[_{NP}$ **NOUN**…
C4: Same as C3 with longer Subordinate and Main sentences.
C5: Same as C4 with the Subordinate and Main Sentences as two sentences, separated by a full stop.

The number of syllables of the sentences within each syntactic condition was kept constant. The number of syllables of the adjectives and nouns, and the stress-positions were also kept constant. Eight *Adjective+Noun* constructions were created for each phenomenon as follows:

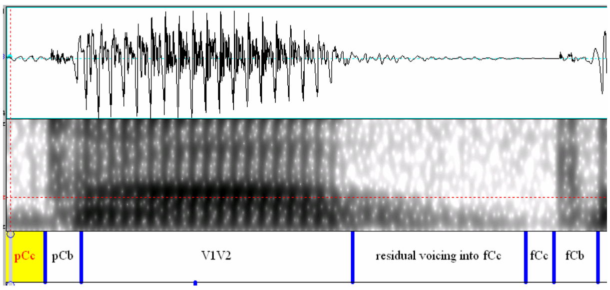
Duration: Pre- and post-boundary syllables consisted of *voiceless stop+vowel*, e.g. /ki'noto**pi ko**'pela/. All three voiceless stops were used in combination with the vowels /a, o, i/.

Vowel Hiatus: The vowel hiatus pair examined was [ao]. The pre-boundary syllable was C+[a] and the post-boundary [o]+C. The segmental make-up of the preceding and following syllables was kept the same for all items, so that differences from formant transitions do not interfere with the results. Baseline conditions were also recorded with the vowels in hiatus being [aa] and [oo], under the same contextual conditions.

2.3. Procedure

Recordings took place in the recording booth of the University of Edinburgh. Sentences were written on paper and randomized. Each item was repeated twice for each phenomenon (8 items * 2 repetitions * 5 syntactic conditions * 6 speakers * 2 phenomena = 960 items in total). Participants were prompted with questions to elicit the same intonational patterns in all renditions between and within speakers. All speakers adopted a relatively fast speech rate.

Figure 1: Example of vowel hiatus, and vowel-to-stop segmentation in CVVC context (C=voiceless stop).



2.4. Segmentation and Measurements

Materials were segmented using PRAAT. Residual voicing in the closure of a following stop was not measured as part of the vowel. The burst of the preceding consonant was marked, and was added to the duration of the following vowel. An example of vowel hiatus segmentation is given in Fig. 1.

Table 1: Mean durations of pre-boundary vowels (with and without a pause following the vowel) for each syntactic construction.

	C1	C2	C3	C4	C5
no pause	79	96	101	124	154
with pause	-	136	134	129	92

From the data set on pre-boundary lengthening, the duration of the pre-boundary vowel was measured. For the vowel hiatus materials, the duration of the vowel *pair* was measured (i.e. the pre- and post-boundary vowels, henceforth V1V2, as shown in Fig. 1). Also, three formant measures were taken: at one quarter, a half, and three quarters of the duration of the two vowels. If there was a pause, the duration of the two vowels was added and no formant values were taken. A script by [6] was used to measure and check formants.

3. RESULTS

3.1. Pre-boundary lengthening

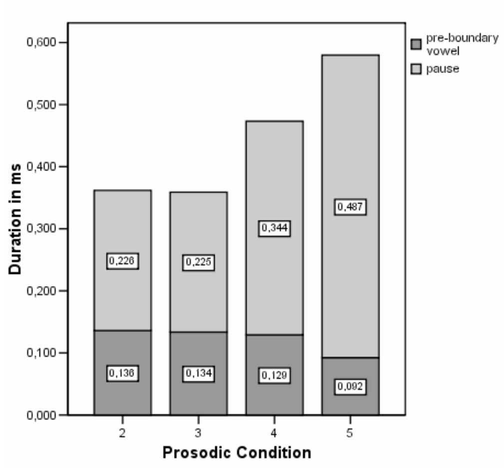
Due to the existence of pauses after the pre-boundary vowel (two out of three male speakers consistently placed pauses in C2-C5) results are analysed in two sets, one for the data without a pause, and one for the data with a pause. Table 1 shows the mean duration of the pre-boundary vowel for both sets. Statistical analyses were only performed in the former set, due to insufficient instances in the latter.

A one-way repeated measures ANOVA on the "without pauses" data showed that the duration of the pre-boundary vowel was significantly affected by the prosodic boundary strength [$F(2.79, 134.17)=53.5$, $p<.001$]. Paired-samples t-tests showed the following hierarchical pattern: C1<C2,C3<C4<C5. This pattern reveals a gradient phonetic output, with durations getting gradually longer with increasing boundary strength.

Interestingly, C4 was significantly different to C3 and C5. Having only changed the length of the constituents from C3 to C4, this finding cannot be accommodated by a view of direct mapping from syntax to the prosodic structure. Rather, it agrees with findings showing that the length of the constituent before and after the boundary are important factors for the boundary placement and strength [7].

The "pauses" dataset on the other hand does not show such a hierarchical pattern. When the duration of the pause is added to the pre-boundary duration though, the duration of the pause seems to

Figure 2: Mean duration of pre-boundary vowel + mean duration of pause in four conditions (no C1 instances with pauses).



compensate for the shorter pre-boundary duration, and the gradient output emerges again (Fig. 2).

3.2. Vowels in Hiatus

3.2.1. Duration of vowels in hiatus

In this section, two vowel pairs are examined: [ao] and [oa] (only durational data are reported in this paper for the latter pair; formant measurements are currently analysed). These two pairs are also compared to two baseline pairs: [aa] and [oo]. Table 2 shows mean durations for the four pairs in four prosodic conditions (C5 is not reported, due to several instances being uttered with pauses).

Table 2: Durations of the vowel pairs [ao], [oa], [aa] and [oo] in four syntactic conditions (data without pauses).

	ao	oa	oo	aa
C1	104	98	88	70
C2	127*	123*	97	95
C3	132	126	86	131*
C4	160*	151*	108*	142

*significantly different to one level lower at p<.05

One-way ANOVAs showed that the effect of prosodic boundary strength was significant for both [ao] $F(4, 84)=9.7$, $p<.001$, and [oa] $F(4, 117)=10.6$, $p<.001$. Paired-samples t-tests revealed the following patterns:

- [ao] and [oa] → C1 < C2, C3 < C4
- [oo] → C1, C2, C3 < C4
- [aa] → C1, C2 < C3, C4

All vowel pairs show a hierarchical influence of prosodic strength. A similar effect is also reported in [1], even though their absolute values are longer. Note that, C1 and C3 group differently across vowel pairs. This might be seen as evidence for a gradient output according to which specific lengthening is not attached to particular levels within a strictly defined prosodic structure.

Overall, results from this section generally agree with those reported in Section 3.1; the duration of segments at the proximity of prosodic boundaries was influenced hierarchically, and had a gradient output.

3.2.2. F2 of vowels in hiatus

Two issues are addressed in this section: a) whether prosodic boundary strength affects F2 at the midpoint of V1V2, and b) whether F2 at the beginning and end of V1V2 in higher domains is more similar to baseline measurements for [aa] and [oo], suggesting less coalescence in the proximity of stronger boundaries.

Due to the fact that two out of three male speakers were consistently placing pauses on instances from C2 to C5 (see also Section 3.1), results are only reported for the female speakers, so as to avoid any confounds by the renditions followed by a pause. Again no results are given for C5, as in the previous sections.

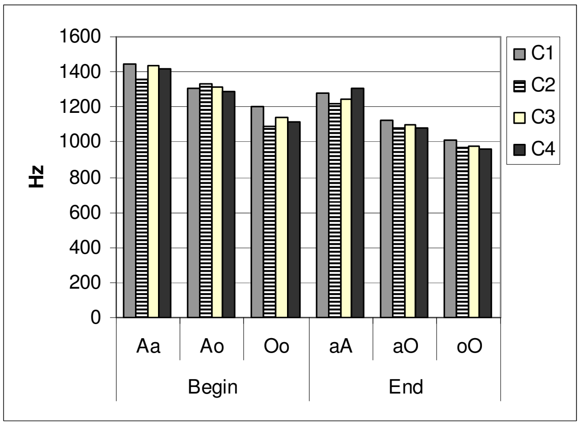
Table 3 shows the mean values of F2 at the midpoint of [ao]. F2mid values were submitted to a one-way ANOVA to test the effect of the prosodic boundary. The midpoint of V1V2 was selected as the point where we would expect to find the most coarticulatory effect. The effect of prosodic boundary was not significant ($F<1$).

Table 3: Mean values in Hz for F2 at the midpoint of [ao].

	C1	C2	C3	C4
ao	1185	1172	1210	1212

Regarding the second issue under investigation, the degree of coalescence in [ao] between conditions was tested by comparing F2 values at the beginning and end of [ao] to those of the baseline vowel pairs, [aa] and [oo]. We expected the beginning of [ao] in higher domains to resemble that of [aa], and the end of [ao] to resemble that of [oo]. Since more coarticulation was expected in lower domains, differences between F2 values of the two vowel pairs and the baseline pairs should not be as prominent in lower domains. Fig. 3 shows the beginning and end F2 values for each vowel pair. Capital letters indicate measurement position within V1V2.

Figure 3: Mean formant values in Hz for F2 at the beginning and end of vowel pairs [ao], [aa], and [oo] in four prosodic conditions.



Two sets of comparisons were performed. First, F2 at the beginning of [ao] was compared to the beginning of [aa] and [oo] in all prosodic conditions. Paired-sample t-tests showed that [ao] was significantly different to [oo] but not [aa] in all prosodic conditions. Secondly, F2 at the end of [ao] was compared to the end of [aa] and to the end of [oo]. Paired-samples t-tests showed that [ao] was not significantly different to either [aa] or [oo]. The fact that formant values for [a] were apparent at the beginning of [ao], suggests that V1 is not elided in Greek. This effect was persistent across prosodic conditions (V1 was prominent and similar to [aa] in all four conditions) suggesting no prosodic boundary effect.

At the end of [ao] some type of coalescence takes place, since the values of F2 were between those for the end of [aa] and [oo]. V2 was also similar to both [aa] and [oo] throughout the four conditions, again suggesting no effect of prosodic boundary strength. More analyses are in order to test the effect of prosodic boundary strength on different types of measurements, such as slope of trajectories or Euclidean distances. It is interesting, however, to note that the raw values of [ao] always fall between those of [aa] and [oo], suggesting some type of coalescence for all prosodic domains.

4. DISCUSSION

This paper examined the effect of prosodic boundary strength on pre-boundary lengthening and the resolution of vowel in hiatus. The duration of vowels in pre-boundary and hiatus positions was found to be influenced by increasingly stronger prosodic boundary strength in a hierarchical manner, with a gradient phonetic output.

The effect of prosodic boundary strength was also measured on the F2 of the vowel pair [ao]. Its influence on the F2 midpoint was not significant, a finding which goes against our expectations and previous research. To confirm this finding, further analyses using several techniques (e.g. F1 and F2 slope/trajectories, correlations between formant trajectories and duration, Euclidean distances) are still being carried out. Should the absence of prosodic boundary effect persist, it would showcase an asymmetry between the durational and formants data.

Finally, both durational and F2 data show that V1 of V1V2 is not elided in Greek, which is in accordance with previous findings on Greek [1, 5]. However, they contradict findings such as in [2], where V1 is found to be more commonly elided.

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