Effects of prosodic phrasing on hiatus across words in Greek

MARY BALTAZANI

UCLA, USA

1. INTRODUCTION
Recent studies have shown that segment realizations are influenced by prosodic contexts, especially the location within a prosodic group and the strength of the prosodic group. The particular domains examined in this study are different sizes of prosodic phrases. The motivation behind such an undertaking is that in recent years several acoustic studies have shown that prosodic phrasing affects segments in various ways: segments are more 'strengthened' (e.g., longer duration and wider contact areas for stop closure) in phrase-initial positions than in phrase-medial ones (Pierrehumbert & Talkin 1992, Jun 1993, Dilley, Shattuck-Hufnagel & Ostendorf 1996) also found that the degree of glottalization at vowel-initial words is higher at higher prosodic units. In this paper we investigate the effects of prosodic phrasing on the segmental level in Athenian Greek. In particular we look into how prosodic phrasing affects the duration and formant frequencies of vowels that participate in hiatus.

Hiatus is created when two vowels occur immediately adjacent to each other. Cross-linguistically there is a tendency to avoid hiatus and different languages employ different strategies to avoid it (Casali 1997). In Greek, it has been reported that hiatus occurring across orthographic word boundaries is usually resolved in fast or casual speech, and the most frequent—but certainly not the only—hiatus resolution strategy for is deletion of the first vowel in the W sequence (Hadzidakis 1905, Kaisse 1977, Condoravdi 1990, Fallon 1994). Among these studies there is disagreement as to how extensive hiatus resolution is and also what environments license it or block it. Several factors have been argued to play a role in hiatus resolution: for example, in Kaisse 1977 certain vowels are claimed to be more prone to delete than others, depending on the syntactic relation between the words that contain them; in Condoravdi 1990 the prosodic domain where the hiatus vowels are found is the decisive factor for which vowel will delete; Fallon 1994 found that certain vowels display a greater resistance to deletion than others. However, all these studies are based on introspective, intuitive judgments of native speakers. To my knowledge there has not been any quantitative, instrumental examination of the hiatus phenomenon, so it is not clear how complete a process the deletion of vowels is or whether vowels tend to resist deletion in certain domains.
In this paper we present results of an experimental study of how prosodic phrasing in Greek affects vowels VIV2 that occur next to each other, VI at the end of one word and V2 at the beginning of the following word. The questions we address are: How often is one of the vowels deleted? If on the one hand we find that deletion does happen, is the probability for deletion affected in any way by the strength of prosodic boundary between the two vowels? If there is no vowel deletion, is vowel duration affected at all, and if so, do prosodic boundaries play a role on the duration of the two vowels? Also is vowel quality affected at all, that is, is there any kind of assimilation taking place between the two vowels? If so, does the prosodic boundary between the two vowels play determine how extensive assimilation is?

2. PROSODIC STRUCTURE OF GREEK

The prosodic organization of Greek assumed here is a hierarchical system where small prosodic constituents are nested within larger ones (Arvaniti & Baltazani (2000)) in accordance to the original ToBI conventions (Silverman, Beckman, Pitrelli, Ostendorf, Wightman, Price, Pierrehumbert & Hirschberg, 1992). A greater, stronger prosodic boundary is present across an Intonational Phrase and the strength of the boundary diminishes for the lower levels, as shown schematically in Fig. 1.

![Figure 1: Prosodic structure of Greek (Arvaniti & Baltazani 2000)](image)

The hypothesis examined here is that both duration and quality (expressed in terms of the values of the first two formants, F1 and F2) of the hiatus vowels will be affected as a function of the strength of the boundary between the two vowels: stronger boundaries will induce greater resistance of vowels to shorten or merge. Hiatus-induced deletion is not viewed here as an absolute process but as a gradient one: the hypothesis is that vowels next to strong boundaries will tend to have the longest duration and vowels next to weaker boundaries will tend to shorten in a mode inversely proportional to boundary
strength. Correspondingly, the hypothesis regarding vowel quality is that when the two vowels occur across a weaker boundary, the formant values of the two adjacent vowels will tend to become similar but such a tendency will be blocked across stronger boundaries.

3. EXPERIMENT METHODS
The ten vowel pairs tested are [aa], [ae], [ao], [ie], [ia], [eo], [oa], [oe], [ou], and [ua]. For each of these pairs, three different contexts were designed so that the words containing them occurred across three types of boundary. Word (wd), intermediate phrase (ip), and intonational phrase (IP). Five Athenian Greek speakers participated in the experiment. Each speaker repeated each of the context sentences three times. The data were recorded in a quiet room and then durations and formants were analyzed using Pitchforks, a program developed in UCLA phonetics Lab. Results from four speakers are reported in the current paper.

Table 1 shows the three contexts for [ou]. Similar contexts were created for the remaining nine pairs. In Table 1, sentence (1) illustrates a vowel pair across a prosodic word boundary (Wd). The two vowels in exactly the same two words are separated by an intermediate phrase boundary (ip) in sentence (2) and separated by an Intonational Phrase boundary in sentence (3).

1. Θα σου έτοιμασω ενα νόστημα [νόστημα] wd uzaki me μεζέ.
   will for-you prepare one tasty ouzo with tidbits
   'I’ll prepare tasty ouzo with tidbits'

2. Αν έξει μεζέ νόστημα [νόστημα] ip uzaki pinoun olois.
   If has tidbits tasty ouzo drink all
   'If the tidbits are tasty, everyone drinks ouzo'

   Will eat tidbits if is tasty ouzo not drink
   'I’ll have tidbits if they’re tasty. I won’t drink ouzo'

Table 1. Examples of 3 prosodic contexts for [ou]. The location of prosodic boundary is indicated by a bracket and the type of boundary written after it. The hiatus vowels are shown bold-faced and underlined.

As shown in Table 1, the target vowels, VI V2, were always preceded by a consonant and followed by a consonant. When two vowels were separated by pause, the duration of the first vowel (VI) was measured from the end of the preceding consonant to the beginning of silence following the vowel, and the duration of the second vowel (V2) was measured from the beginning of
voicing up to the beginning of the following consonant. For those pairs with no pause between the two vowels—that is all the vowels in the Word prosodic condition and some in the other two prosodic conditions—it was often impossible to determine the boundary between the vowels. In those cases, duration of both vowels was measured, and the sum of V1+V2 duration was compared across the three prosodic conditions. Some vowels at IP final position were either completely deleted, or consisted of one or two pulses\(^1\): in that case I report V2 duration alone as the duration of VI and V2.

For each vowel, first and second formants were measured in the middle of the vowel. When VI in IP final position was completely deleted, V2 was not measured either. When it was impossible to locate the boundary between the two vowels as in the Word condition, only one measurement was taken at the steadiest part of or in the middle of the whole V1V2 duration.

4. RESULTS

4.1 Duration

Results show that, for six out often vowel pairs, VI was always realized before an IP boundary, but, for the other four pairs ([ia], [ua], [eo], [ou]), VI was either not realized at all or was reduced to one or two glottal pulses before an IP boundary. Figure 2 shows the duration of VI and V2 for the six vowel pairs. For vowel pairs ([ae][ao][ia][oa]), the duration was longer when the vowels are across either IP or ip boundaries than when they are across a Word boundary. For vowel pairs [ie] and [oe], the duration was longest across an IP boundary, shorter across an ip boundary and the shortest across a word boundary.

Figure 3 shows the duration of the remaining four vowel pairs ([ia], [ua], [eo], [ou]). Since VI is not realized before an IP boundary, the total duration at the IP boundary condition is shorter than that at ip boundary condition. Notice however, that even for these pairs, vowels in the Word condition are shorter than in any other condition.

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\(^1\) I believe that this deletion was completely independent of hiatus, since the same phenomenon can be observed at different kinds of IP final environments, eg before consonants as well as utterance finally.
4.2 Vowel Quality
As a reference of first and second formant values of Greek vowels, data from Fourakis et al (1999) are shown in Figure 4. The F1 F2 values are from vowels averaged across fast and slow rates, focused and unfocussed, and stressed and unstressed conditions. The vowels in Fourakis et al were produced within sentences, just like in this present study, so the formant values between the two studies are comparable.
Results show that the F1F2 values of vowel pairs are closer to each other as the strength of the boundary between the vowels decreases from IP to IP to Word. That is, formant values of vowels across the Word condition show that one of the vowels tended to converge towards the other. Figure 5 shows that the values for the [i] are not very different from the typical ones shown in Figure 4, but this is not so for the position of [a] which in this environment has become much higher and fronter. In other words the second vowel in the pair has become acoustically similar to the first vowel.

![Figure 5 Formants for the [ia] pair in the Word condition](image)

However, the second vowel did not always assimilate to the first vowel. Figure 6 shows the case where the first vowel assimilates to the second vowel. In this figure, the formant values of the second vowel [o] are similar to those in Figure 4, but the values of the first vowel [e] is much backer than the typical one. thus closer to [a].

For the [eo] pair (Fig 6), again only the first vowel has changed: the values for the vowel [o] are similar to the typical ones in Figure 4, but the vowel [e] has become much backer than the typical one.

![Figure 6 Formants for the [eo] pair in the Word condition](image)
In the intermediate phrase condition, the vowels converge less than in the Word condition. The same phenomenon occurred in the Intonational phrase condition, as well. That is, vowels across an IP boundary converge less than in the ip condition and those in turn converge less than vowels in the Word condition. In general, as the boundary strength increased, the formant values tended to diverge so that the two vowels were more separated in the F1F2 space. Figure 7 shows the [ae] vowel pair in the ip condition. It is apparent that while [e] still occupies the same space as it did in the Word condition, vowel [a] has now moved away from it, becoming backer.

Figure 8 shows the [eo] pair this time in the IP condition, with the vowels at their greatest distance from each other, compared to the ip and word conditions. A similar situation obtained for the rest of the vowel pairs, that is, the greatest distance between the two vowels in each pair is observed in the IP condition and then in decreasing order in the ip and word conditions.
4. GENERAL DISCUSSION AND CONCLUSION
In summary, we found that VIV2 duration and the quality of each vowel depend on the prosodic boundary strength. In no case did we find the total deletion of VI as has been reported in the phonological research. Instead, the sum of the duration of the two vowels shrinks to almost the size of a single segment when they occur phrase medially and gradually increases proportionally to the strength of the boundary between them. Furthermore, there is assimilation between VI and V2. and usually one of the two vowels assimilates to the other instead of both vowels approaching some sort of middle ground. The two findings taken together, that is, the fact that phrase medially vowels shorten and become acoustically more similar to one another, explain the intuition of native speakers that the vowel has "deleted": If the two vowels together last as long as one segment and if they are not very distinguishable from each other acoustically, then it is natural to perceive the result as "deletion" of the vowel that assimilates to its neighbor. Further research will show whether further prosodic factors such as focusing also influence segment realization in hiatus environments.

REFERENCES