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Gaberril Drachman	drachman@sbg.ac.at
Geoffrey Horrocks	gch1000@hermes.cam.ac.uk
Irene Philippaki-Warbuton	I.Philippaki-Warbuton@reading.ac.uk
Brian Joseph	joseph.1@osu.edu

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## The phonetics of stress in Greek\*

Amalia Arvaniti  
University of Cyprus

This paper reports on two experiments that investigate the acoustic correlates of primary stress in Greek. The results clearly show that the most robust correlate is amplitude integral, a measurement that combines those of duration and (average) amplitude, and thus is closer to the perceptual property of *prominence* that characterises stressed syllables. The paper also discusses the role of pitch in signalling stress, by presenting new and re-analysing existing data on this issue. The significance of the present results for our understanding of Greek rhythmic structure is briefly discussed.

**Keywords:** stress, prosody, Greek, timing, stress clash, intonation

### 1. Introduction

The present study reports on two experiments that examine the acoustic correlates of stress in Greek. The aim of the study was first to provide a quantitative account of Greek stress, and second to relate the results to previously reported data on stress in Greek and other languages, particularly as regards the relationship between stress, intonation and prosodic timing.

#### 1.1 Acoustic and perceptual correlates of stress

Early phoneticians defined stress as force of utterance (Sweet 1906; Jones 1976; Abercrombie 1967; for extensive reviews see Lehiste 1970, and Beckman 1986). This definition implied that stress should have concrete physiological and acoustic correlates, namely high subglottal pressure and high amplitude respectively. This view, however, was not confirmed, in its strong interpretation, either

by acoustic or by physiological measurements (e.g. Ladefoged, Draper & Whitteridge 1958; Ladefoged 1963; Gay 1978). Rather it was shown that correlates such as duration, fundamental frequency ( $F_0$ ), and vowel quality also played a part in signalling stress (Fry 1955, 1958, 1965). In particular, the results of Fry's experiments showed that the perceptual cues to stress are, in order of importance,  $F_0$  duration, amplitude and formant structure. The supremacy of  $F_0$  as a stress cue was corroborated by Bolinger (1958) and Morton & Jassem (1965).

More recent studies, however, have questioned this view. For instance, Beckman (1986) showed that the relatively minor role of amplitude reported by Fry was the result of the way amplitude was measured and manipulated in his experiments. She also showed that if peak amplitude (the measurement used by Fry) is replaced by *total amplitude*, a measure that takes the sound's duration into account, then amplitude becomes the most robust acoustic and perceptual cue of stress in English.<sup>1</sup> The reason is that total amplitude is closer to *loudness*, the perceptual correlate of amplitude, which is significantly influenced by duration in short sounds like those used in speech (Moore 1989).

Further, several studies have shown that the importance of the various cues depends on the position of a word in the utterance.  $F_0$  was the overriding cue in *nuclear* position (i.e. when the word carried what has often been termed 'sentence-stress'). In pre-nuclear position, however, duration and vowel quality were virtually as important as  $F_0$ , while in post-nuclear position duration became the most robust cue (Nakatani & Aston 1978; Huss 1978; Beckman 1986).

The results of these studies show that care should be taken in choosing the way of measuring physical parameters. More importantly, though, they suggest that  $F_0$  is not an indispensable correlate of stress, since the perception of stress can arise without it; rather the role of  $F_0$  as a cue to stress depends on the position of the stressed syllable within the utterance. Thus,  $F_0$  can be seen only as an indirect stress cue: changes in  $F_0$  accompany certain stressed syllables, particularly the syllable with 'sentence-stress' (as happened in Fry's experiments in which the stimuli consisted of one-word utterances).

These results have given rise to a different way of viewing the relationship between stress and  $F_0$  (e.g. Pierrehumbert 1980; Beckman 1986; Beckman & Edwards 1994). According to this view — which has often been referred to as 'autosegmental-metrical' (e.g. Ladd 1996) — the shape of the  $F_0$  contour is not determined by stress but by intonational structure. In turn, stress is seen as relative prominence among prosodic constituents; its function is primarily 'culminative', i.e. stress marks the heads of constituents in the prosodic hierarchy. Stress may also have distinctive function in a given language (cf. Greek examples

like *χάρος* ['xoros] 'space' and *χρόρος* ['xoros] 'ball'), but this is at best limited in scope (Beckman 1986; Beckman & Edwards 1994).

Phonetically, stress can be expressed by a variety of correlates, such as duration, amplitude and vowel formant structure, although a given language may utilise only some of these correlates or accord them different degrees of importance (Beckman 1986; Beckman & Edwards 1994). Experiments on languages other than English corroborate this understanding of the correlates of stress. For instance, Bertinetto (1980) and Farnetani & Kori (1990) conclude that in Italian duration and amplitude are more robust acoustic and perceptual cues of stress than vowel quality. Duration is a robust stress cue in Arabic as well, while vowel quality differences between stressed and unstressed vowels are small and inconsistent (de Jong & Zawaydeh 1999). Similarly, Sluijter & van Heuven (1996) report that in Dutch duration is the most robust cue in all contexts, with spectral tilt (intensity differences in different frequency bands) coming a close second; total amplitude and vowel quality, on the other hand, turned out to be rather weak stress cues in Dutch.

## 1.2 Stress in Greek

It is generally accepted that Greek has stress (e.g. Setatos 1974; Joseph & Philippaki-Warbuton 1987; Mackridge 1990; Revithiadou 1998; Drachman & Malkouti-Drachman 1999), and all analyses agree on the following points about its characteristics. First, stress in Greek cannot be predicted on the basis of phonological structure alone; rather stress placement depends on a complex interaction between morphology and phonology, with morphology playing the most important part. Second, primary stress must fall on one of the word's last three syllables. Finally, each word has only one stressed syllable, i.e. Greek has only one level of stress. This last point has been contested by Malkouti-Drachman & Drachman (1981) and Nespor & Vogel (1989), who claim that Greek has rhythmic stresses which are added postlexically to repair stress lapses (sequences of two or more unstressed syllables). There is however no convincing *acoustic* evidence for these rhythmic stresses even in polysyllabic words in Greek (Arvaniti 1994).

From the phonetic point of view, Greek has traditionally been described as a language with 'dynamic stress' (Mirambel 1959; Setats 1974; Joseph & Philippaki-Warbuton 1987) — also known as 'stress-accent' (Beckman 1986); i.e. Greek is seen as a language in which stress is acoustically manifested primarily by means of intensity and duration. Although some experiments on

this issue have already been conducted, our understanding of the acoustic correlates of stress in Greek is still incomplete. First, some of the experiments include stress only as one of the factors affecting some other variable, such as the temporal coordination of consonant clusters (Fourakis 1986), or the acoustics of Greek vowels (Kondosopoulos, Xiromeriti & Tsitsa 1987; Fourakis, Botinis & Katsaiti 1999); thus although these studies offer insight into the acoustics of stress, they cannot possibly present a complete picture. Second, some of the reported empirical data lack solid statistical backing or have been obtained using measurements such as peak amplitude which have been shown to be unreliable (Dauer 1980a; Botinis 1989). Finally, in some cases research has been based on the misunderstanding that pitch is one of the acoustic correlates of stress (Botinis 1989).

The present study aims at addressing these shortcomings. It is based on a corpus of acoustically analysed and statistically treated data and utilises novel measurements (for Greek). Further, it assumes that stress is distinct from intonation and therefore that pitch is not among the correlates of stress in Greek. However, despite focusing on the other correlates of stress, the paper also discusses the relationship between stress and intonation, as this emerges from the present data, which it relates to recent research findings on the intonational structure of Greek (Botinis 1989; Arvaniti & Ladd 1995; Arvaniti, Ladd & Mennen 1998, 2000; Arvaniti & Baltazani 2000, to appear).

## 2. Experiment 1

### 2.1 Experiment 1: Method

#### 2.1.1 Materials

The corpus of Experiment 1 consisted of ten disyllabic words embedded in the carrier phrase *Éfite ... tópa* [ʔipe ... 'toral] 'S/he said ... now' (see Table 1). Each word consisted of two identical CV syllables and was stressed either on the initial or on the final syllable. There were five CVCV combinations, each containing one of the five vowels of Greek [i, e, a, o, u]. The fact that the words consisted of a repetition of the same CV syllable allowed not only paradigmatic but also syntagmatic comparisons of the data (i.e. comparisons both across and within test-words). Having this possibility was preferred to using exclusively existing words (in this experiment half of the test-words were nonsense yet grammatical formations).

Table 1. The test-words of Experiment 1

Test-word	Gloss	Test-word	Gloss
<i>Πίπη</i> [pɪpɪ]	man's name acc	<i>πίπη</i> [pɪpɪ]	'urine'
<i>πέπε</i> [pɛpɛ]		<i>πεπέ</i> [pɛpɛ]	
<i>Πάπα</i> [pa pa]	'Pope' acc	<i>παπά</i> [pa pa]	'priest' acc
<i>πόπο</i> [po po]		<i>ποπό</i> [po po]	'backside' acc
<i>πούπου</i> [pu pu]		<i>πουπού</i> [pu pu]	

#### 2.1.2 Speakers

Four female (GA, HP, DA, AA) and one male (AK) speaker, all in their twenties, took part in the experiment. At the time of the recording they were all graduate students at Cambridge University and had lived in the UK between four years and one year. They were all native speakers of Standard Athenian Greek, with the possible exception of HP who had lived in northern Greece as a child and retained traces of a northern accent (e.g. a more close variety of /o/). None of the speakers reported any speech or hearing problems. Apart from AA (the author<sup>2</sup>), they were all naïve as to the purposes of the experiment.

#### 2.1.3 Procedure

The recording took place in a sound-treated room in the Phonetics Laboratory of the Linguistics Department, Cambridge University. The speakers read the test phrases seven times, in random order, from cards handwritten in Greek. Prior to the recording, the speakers were instructed to read the sentences as naturally as possible and were given some time to practise. During the recording they were asked to repeat any sentence that was uttered with 'fast reading' intonation, or with contrastive stress on the test-word (e.g. *S/he said PRIEST now* [*not Pope*]), or with a pause after the test-word (which put it in phrase-final position); the reason for the requested repetition was that such renditions could affect the realisation of stress or interact with it.

#### 2.1.4 Measurements

The recordings were low-pass filtered at 4.4 kHz and digitised at 10 kHz. Durations were measured from waveforms following standard criteria of segmentation (Naeser 1970<sup>3</sup>). The stops were measured from the point at which periodic perturbations for the preceding vowel stopped to the point of the burst, if there was one, or to the beginning of periodicity for the following

vowel, if there was no burst (on the absence of visible plosion see also Dauer 1980a). In a number of cases voicing continued during stop closure; in these cases, stop closure was defined as the very low amplitude part of the waveform between the clearly defined envelopes of the flanking vowels. VOT was measured as part of the following vowel. This could not have considerably affected the duration of the vowels for two reasons: first, Greek voiceless stops are unaspirated and the VOT of /p/ in particular does not exceed 10 ms (Fourakis 1985; Arvaniti 1987); second, Fourakis (1986) has shown that VOT duration in Greek is not affected by stress, a result supported by those from other languages, such as French and Thai (e.g. Kessinger & Blumstein 1997).

## 2.2 Experiment 1: Results

The duration of the consonants, the vowels and the syllables was analysed separately for each pair of test-words by means of two-way repeated-measures analyses of variance (ANOVAs) (SPEAKER  $\times$  STRESS  $\times$  POSITION), with STRESS and POSITION as the repeated-measures factors. STRESS and POSITION had two levels each: *stressed* and *unstressed* for STRESS, and *initial* and *final* for POSITION (i.e. part of the test-word's initial syllable or part of the test-word's final syllable). SPEAKER was expected to yield significant results because of individual differences in speaking rate and loudness; for this reason, SPEAKER results will not be discussed, unless SPEAKER interacted with one of the other factors and the investigation of the interaction showed that the data of different speakers exhibited different patterns with respect to the variable under investigation. Interactions between factors were examined by means of *post-hoc* Scheffé tests; three-way interactions were examined using the Tukey HSD test.<sup>4</sup> All statistical results, including those of *post-hoc* tests, are significant at  $p < 0.01$ , unless otherwise stated.

### 2.2.1 Consonant durations

As can be seen in Figure 1, STRESS strongly affected the duration of /p/, with /p/ closure being significantly longer in stressed syllables for all test-pairs [for /pipi/,  $F(1,30) = 197.82$ ; for /pepe/,  $F(1,30) = 170.73$ ; for /papa/,  $F(1,30) = 178.98$ ; for /popo/,  $F(1,30) = 142.81$ ; for /pupu/,  $F(1,30) = 84.81$ ].

POSITION, on the other hand, did not yield such consistent results. In the pairs /pipi/ and /pepe/, POSITION did not affect the duration of /p/ closure. In the /papa/ pair, there was interaction between POSITION and STRESS [ $F(4,30) = 22.77$ ]: according to the results of Scheffé tests, this was due to the fact that /p/

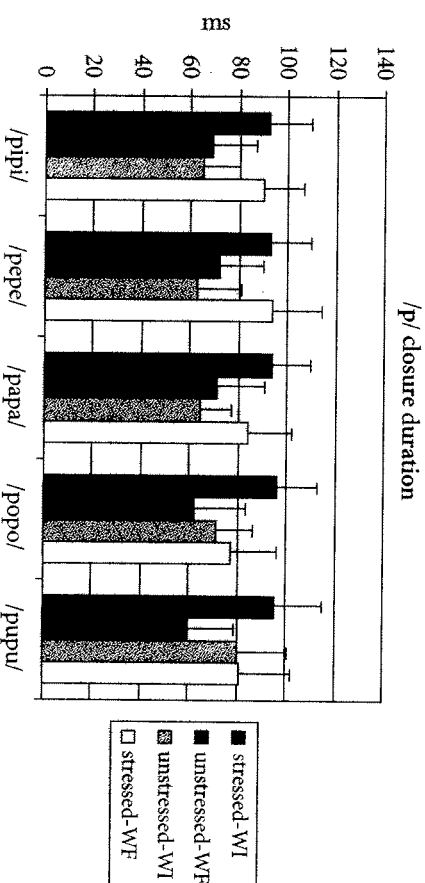


Figure 1. Experiment 1: means (in ms) and standard deviations of /p/ closure duration per test-pair; 'WI' stands for *word-initial*, and 'WF' for *word-final*.

closure in stressed syllables was longer word-initially, while in unstressed syllables it was not affected by POSITION. In /popo/ and /pupu/, POSITION interacted with SPEAKER [for /popo/,  $F(4,30) = 5.48$ ; for /pupu/,  $F(4,30) = 4.5$ ,  $p < 0.04$  in both cases]. Scheffé tests showed that in both cases, GA and AK had longer /p/ closure in initial position [ $p < 0.05$ ], while for the other three speakers there was no effect of POSITION on the duration of /p/ closure.

### 2.2.2 Vowel durations

As shown in Figure 2, stressed vowels were significantly longer than unstressed vowels in all test-pairs [for /pipi/,  $F(1,30) = 709.5$ ; for /pepe/,  $F(1,30) = 811.74$ ; for /papa/,  $F(1,30) = 827.96$ ; for /popo/,  $F(1,30) = 624.16$ ; for /pupu/,  $F(1,30) = 460.87$ ].

In addition, STRESS interacted with POSITION in all cases [for /pipi/,  $F(4,30) = 32.08$ ; for /pepe/,  $F(4,30) = 60.52$ ; for /papa/,  $F(4,30) = 30.43$ ; for /popo/,  $F(4,30) = 30.17$ ; for /pupu/,  $F(4,30) = 31.86$ ]. Scheffé tests showed that this interaction was due to the fact that stressed vowels were longer in final place, while unstressed vowel duration was not affected by POSITION. For the /popo/ test-pair in particular, this result does not hold for all speakers, as there was also a STRESS  $\times$  POSITION  $\times$  SPEAKER interaction [ $F(4,30) = 6.1$ ,  $p < 0.04$ ]. Tukey HSD tests showed that in the /popo/ pair only speaker AA had longer vowel duration in stressed final syllables, while the results for the other four speakers were not statistically significant. As in the other test-pairs, in /popo/, unstressed vowels were not affected by POSITION.

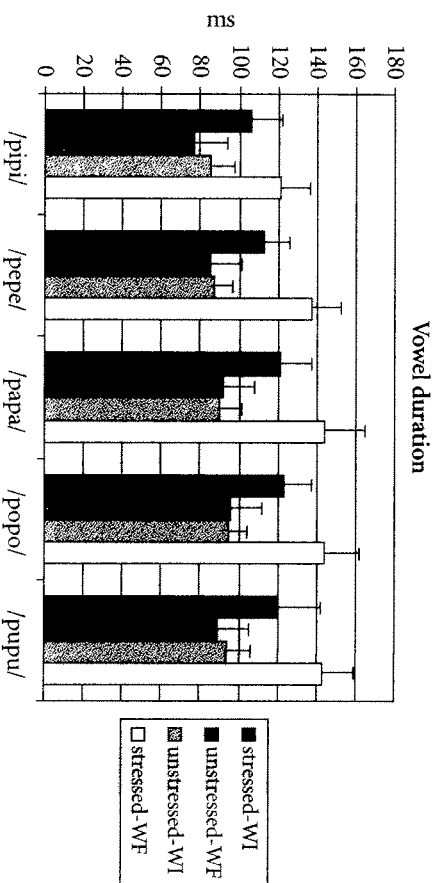


Figure 2. Experiment 1: means (in ms) and standard deviations of vowel durations per test-pair; 'WI' stands for *word-initial*, and 'WF' for *word-final*.

### 2.2.3 Syllable durations

As shown in Figure 3, in all test-pairs stressed syllables had longer duration than unstressed syllables [for /pipi/,  $F(1,30) = 709.5$ ; for /pepe/,  $F(1,30) = 811.74$ ; for /papa/,  $F(1,30) = 793.45$ ; for /popo/,  $F(1,30) = 929.74$ ; for /pupu/,  $F(1,30) = 456.43$ ].

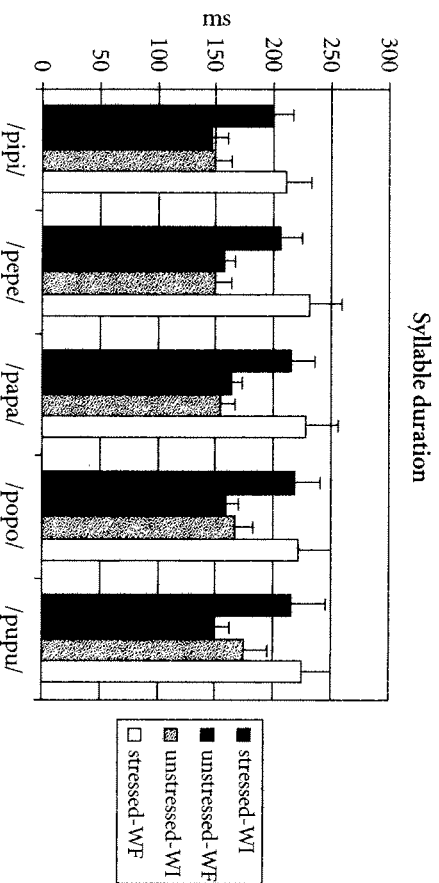


Figure 3. Experiment 1: means (in ms) and standard deviations of syllable durations per test-pair; 'WI' stands for *word-initial* and 'WF' for *word-final*.

Position on the other hand yielded mixed results. In test-pair /popo/, position did not significantly affect syllable duration, while in the /papa/ pair

it resulted in longer word-final syllables [ $F(1,30) = 26.04$ ]. In test-pairs /pipi/ and /pupu/, position interacted with stress [for /pipi/,  $F(4,30) = 13.87$ ; for /pupu/,  $F(4,30) = 53.04$ ]. According to Scheffé tests, in /pipi/ stressed syllables were longer word-finally, but unstressed syllables were unaffected by position; in contrast, in /pupu/ there was no position effect on the stressed syllables, but unstressed syllables were shorter word-finally. In the /pepe/ data, there was a three-way interaction [ $F(4,30) = 2.62$ ,  $p < 0.05$ ]: according to Tukey HSD tests, stressed syllables were longer word-finally in the data of DA and AA (with HP showing a similar statistical trend); unstressed syllables, on the other hand, were unaffected by position in the data of all speakers except HP ( $p < 0.03$ ).

### 2.2.4 Comparisons within words

The results presented above show clearly that duration is a robust correlate of stress in Greek. However, all comparisons so far involved stressed and unstressed segments and syllables in both members of each test-pair. What is of most interest however is to see whether these durational differences are equally robust *within* each test-word; that is, whether the stressed syllable of each test-word is indeed longer than the word's unstressed syllable (ditto for the vowels and consonants). The reason is that stress is not an absolute attribute of a given constituent, but a relational property (Lieberman & Prince 1977); e.g. in a word like *γοργόνα* /yor'ɣona/ 'mermaid', /ɣo/ is perceived as stressed because it is more prominent than the other two syllables of the word, /yor/ and /na/. Consequently, what matters most for the perception of stress is *syntagmatic* differences, i.e. differences within words, and not so much *paradigmatic* differences, i.e. differences across words.

For the syntagmatic comparisons, Scheffé tests were conducted between the stressed and unstressed segments and syllables of each test-word. The results of these tests showed that in almost all cases stressed consonants, vowels and syllables were longer than their unstressed counterparts within each test-word (see also Figures 1–3). The only exceptions were /p/ closure in [popo] and [pupu]; in these two test-words there was no difference between the closure of the stressed and the unstressed /p/ (see Figure 1).

It was further decided to investigate whether the above mentioned syntagmatic differences between stressed and unstressed syllables and segments were valid for the data of each speaker separately. For these speaker-specific comparisons Tukey HSD tests were performed. The results of these tests showed that occasionally speakers had similar duration between the stressed and unstressed segments of a test-word. This was particularly true for /p/ closure, for which 22

out of the 50 possible comparisons (10 test-words × 5 speakers) turned out to be statistically non significant. In contrast, stressed syllables were longer than unstressed syllables in the data of all speakers; the same result holds for vowels, with only one exception, AK's [popo] data.

### 2.3 Experiment 1: Discussion

The results of Experiment 1 clearly show that duration is a robust cue for stress, although the noted exceptions indicate that it might not be indispensable. Stress did not result in longer duration only for vowels and syllables, as previous studies suggest (Dauer 1980a; Botinis 1989), but also in longer duration for consonants, a result that agrees with those reported in Fourakis (1986). The effect of stress, however, was not as robust on consonant duration as it was on vowels and syllables.

On the other hand, the results on the effects of prosodic position are not as clear cut and certainly not as consistent as those of stress. Consonants and unstressed vowels and syllables were largely unaffected by their position in the word. *Stressed* vowels, on the other hand, were longer word-finally, as were, to an extent, stressed syllables. One possible explanation for this result could be word-final lengthening, a phenomenon that has been observed in several languages (for American English, Klatt 1976; Nakatani, O'Connor & Aston 1981; Edwards & Beckman 1988; Beckman & Edwards 1990; for British English, Fant, Kruckenberg & Nord 1991; for Scottish English, Turk & White 1997; for French, Fant et al. 1991; Fletcher 1991; for Swedish, Fant et al. 1991; for Arabic, de Jong & Zawaydeh 1999). This explanation is not very satisfactory, however, because it does not account for the fact that lengthening was largely limited to stressed vowels. Furthermore, there is indirect evidence from previous studies that word-final lengthening does not take place in Greek (Dauer 1980a: 274; Botinis 1989: 36ff).

An alternative explanation is that the observed lengthening of stressed vowels is due to the stress clash that was inadvertently created between the test-word and the following carrier phrase, when the test-word was stressed on its final syllable. This explanation tallies with phonological accounts of the resolution of stress clashes as 'beat addition', which would be phonetically manifested as extra duration of the first vowel in the two clashing syllables (e.g. Selkirk 1984; Nespor & Vogel 1989). The absence of durational differences in unstressed vowels in the present data is consistent with this hypothesis. Thus, the data show a durational effect which might not be directly related to stress, but to the stress clash. For this reason, the data were not analysed further.

Instead new test materials without stress clashes were recorded. It was hypothesised that if the longer duration of word-final stressed vowels was due to the stress clash, the lengthening would disappear in materials that were clash free; if, on the other hand, the difference was the result of word-final lengthening, the effect would remain.

## 3. Experiment 2

### 3.1 Experiment 2: Method

#### 3.1.1 Materials

Since Experiment 1 had shown that vowels behaved uniformly with respect to stress, in Experiment 2 only [papal] and [papal], which are meaningful and frequent, were used as test-words. The stress clash was avoided by using two carrier phrases, each of which contained two stresses, one two syllables before the test-word's stress and one two syllables after it. In order to avoid disparate coarticulatory effects on the test-words, the carrier phrases were, as far as possible, segmentally similar in their boundaries with the test-word (see Table 2).

Table 2. The materials of Experiment 2. The test-words are in bold

Test sentence	Gloss
1. <i>Ελεγε Πάπα καλύτερα</i> [eleve 'papa ka'li'tera]	'S/he used to say <b>Pope</b> better'
2. <i>Είπε ππάρα καθαρά</i> [ipe p'pa kaθ'ra]	'S/he said <b>priest</b> clearly'

#### 3.1.2 Speakers and procedure

Five speakers were recorded, of whom three were female (DT, VK, AA) and two male (TI, SC). All the speakers were of the same age group, origin and dialect as those who took part in Experiment 1, and apart from AA, they were native as to the purposes of the experiment.

The procedure followed for Experiment 2 was the same as for Experiment 1. The recording took place in the recording studio of the Department of Linguistics, University of Edinburgh. Each speaker read each sentence six times from a typed randomised list written in Greek.

The data were digitised at 16 kHz with appropriate low-pass pre-filtering. Measurements of duration and amplitude, as well as  $F_0$  contours of the recorded utterances were obtained. Duration was measured from waveforms following the same criteria of segmentation as for Experiment 1. Fundamental frequency contours were plotted and measured using the  $F_0$  tracker facility of a signal-processing package, which performed measurements of  $F_0$  every 10 ms over a 32 ms Hamming window.

For amplitude, three measurements were obtained: peak amplitude (P.A.), root mean square amplitude (R.M.S.), which represents the 'average' amplitude of a segment, and amplitude integral (A.I.), which combines 'average' amplitude and duration information. For P.A., measurements were made by eye from waveforms at the point of highest amplitude in each syllable nucleus. R.M.S. and A.I. were calculated automatically between specified points in the waveform.<sup>5</sup> The original amplitude measurements, which were in arbitrary units given by the signal processing package, were normalised, to cancel out differences due to both accidental changes (such as a speaker's leaning towards the microphone or uttering some sentences louder than others), and to the fact that some speakers naturally talk louder than others. To achieve normalisation, the P.A. of each syllable was divided by the highest P.A. in the test-word, while the R.M.S. and A.I. of each syllable was divided by the word's R.M.S. and A.I. respectively. All statistical analyses were performed on the normalised data.

### 3.2 Experiment 2: Results

#### 3.2.1 Duration

The analysis of the data followed the same lines as for Experiment 1; that is, two-way repeated-measures (SPEAKER  $\times$  STRESS  $\times$  POSITION) ANOVAs were performed on the consonant, vowel and syllable measurements.

*/p/ closure:* As shown in Figure 4, STRESS resulted in longer /p/ closure in the stressed syllables [ $F(1,25) = 195.27$ ]. However, the investigation of a STRESS  $\times$  SPEAKER interaction [ $F(4,25) = 3.96$ ] by means of Scheffé tests indicated that this result did not hold for the data of AA. SPEAKER also interacted with POSITION [ $F(4,25) = 17.53$ ], an interaction due to SC having shorter /p/ closure in final syllables, according to Scheffé tests; there was no POSITION effect for the other speakers.

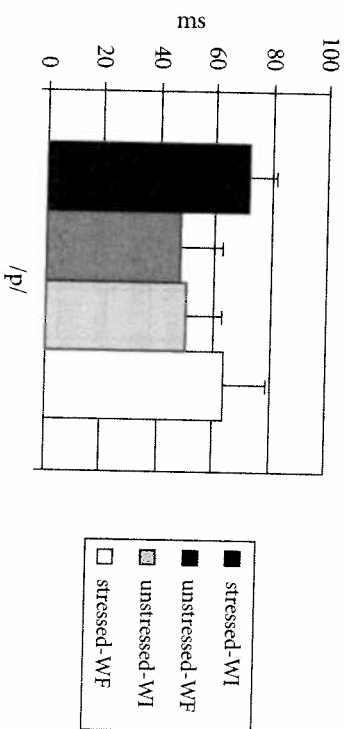


Figure 4. Experiment 2: means (in ms) and standard deviations of /p/ closure duration in the two test-words; 'WT' stands for *word-initial* and 'WF' for *word-final*.

*Vowels:* As can be seen in Figure 5, stressed vowels were longer than unstressed ones [ $F(1,25) = 245.58$ ]. There was also interaction between STRESS and POSITION [ $F(4,25) = 13.38$ ]: Scheffé tests showed that this interaction was due to the unstressed vowels being shorter in the final syllable, while stressed vowels were not affected by their position in the word.

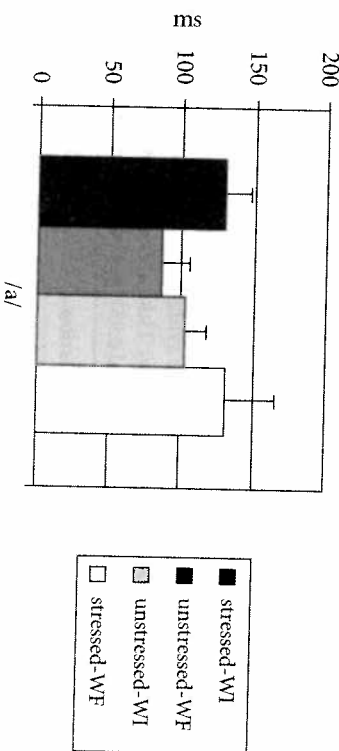


Figure 5. Experiment 2: means (in ms) and standard deviations of vowel duration in the two test-words; 'WT' stands for *word-initial* and 'WF' for *word-final*.

*Syllables:* As shown in Figure 6, stressed syllables were longer than unstressed syllables [ $F(1,25) = 379.51$ ]. POSITION, on the other hand, yielded a mixture of results due to a SPEAKER  $\times$  POSITION interaction [ $F(4,25) = 23.3$ ]. The investigation of this interaction by means of Scheffé tests indicated that POSITION did not affect syllable duration for TL and AA, and that while DT and SC had shorter final syllables, VK had longer syllables in final position.

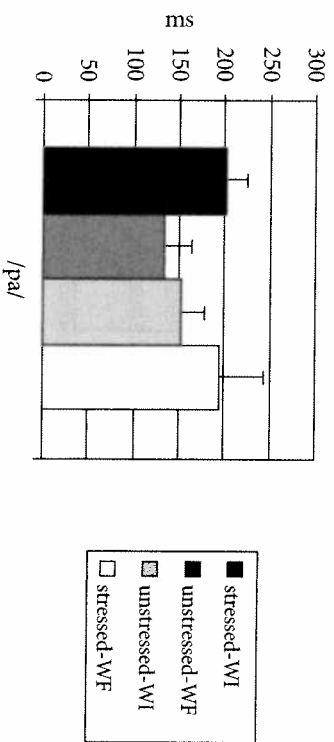


Figure 6. Experiment 2: means (in ms) and standard deviations of syllable duration in the two test-words; 'WT' stands for *word-initial* and 'WF' for *word-final*.

*Syntagmatic comparisons:* In Experiment 2, syntagmatic comparisons, performed using Scheffé tests, showed that in all cases stressed segments and syllables were longer than their unstressed counterparts within the same test-word (see also Figures 4–6). When these differences were further investigated by means of Tukey HSD tests, to see whether they held for the data of each speaker, it was revealed that the differences between stressed and unstressed segments and syllables were not always present; results are presented in Table 3.

Table 3. Results of Tukey HSD tests on the syntagmatic comparisons for each test-word and speaker (SP) separately. Ticks show cases where the test gave a significant result [confidence interval 0.05]; 'n.s.' stands for *non significant*.

SP	/p/ closure		Vowel duration		Syllable duration	
	[papa]	[papapa]	[papa]	[papapa]	[papa]	[papapa]
TL	✓	n.s.	✓	n.s.	✓	✓
DT	✓	✓	✓	n.s.	✓	n.s.
VK	n.s.	✓	✓	✓	✓	✓
SC	✓	n.s.	n.s.	n.s.	✓	n.s.
AA	n.s.	n.s.	✓	n.s.	✓	n.s.

### 3.2.2 Amplitude

*Peak Amplitude:* P.A. showed significant main effects for all factors [for SPEAKER,  $F(4,25) = 28.45$ ; for STRESS,  $F(1,25) = 101.88$ ; for POSITION,  $F(4,25) = 43.59$ ], but also a three-way interaction [ $F(4,25) = 9.12$ ]. Tukey HSD tests indicated that in the data of all speakers except AA, stressed vowels had higher P.A. than unstressed ones. Further, the tests showed that there was no effect of POSITION on the P.A. of stressed vowels for any speaker (see Figure 7). For the unstressed vowels, on the other hand, it was found that DT, AA and SC had similar P.A. in both word-initial and word-final position, while TL and VK had lower amplitude word-finally.

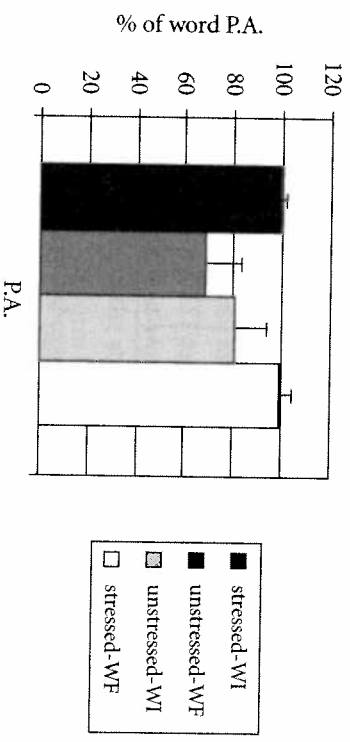


Figure 7. Experiment 2: means (in ms) and standard deviations of (normalised) P.A. in the two test-words; 'WT' stands for *word-initial* and 'WF' for *word-final*.

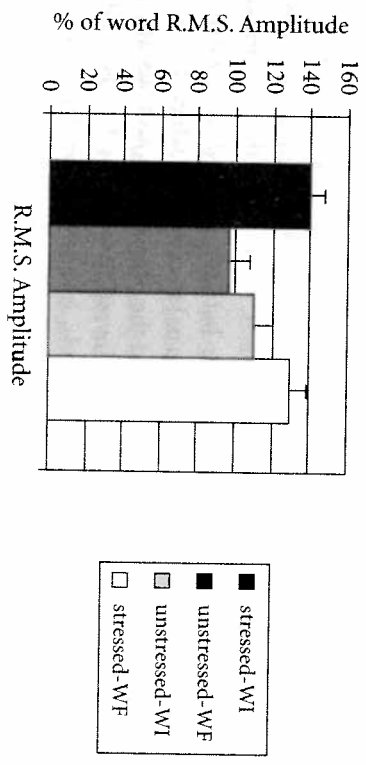


Figure 8. Experiment 2: means (in ms) and standard deviations of (normalised) R.M.S. Amplitude in the two test-words; 'WT' stands for *word-initial* and 'WF' for *word-final*.

*Root Mean Square Amplitude:* The R. M. S. results, seen in Figure 8, showed interaction of both *STRESS* and *POSITION* with *SPEAKER*. The investigation of the *STRESS* × *SPEAKER* interaction [ $F(4,25)=4.58$ ] by means of Scheffé tests indicated that TL, DT, VK and SC had higher R. M. S. in stressed than in unstressed syllables, but AA did not. Scheffé tests regarding the *POSITION* × *SPEAKER* interaction [ $F(4,25)=6.74$ ], showed that *POSITION* did not affect R. M. S., except in the data of VK, who had higher R. M. S. in initial position.

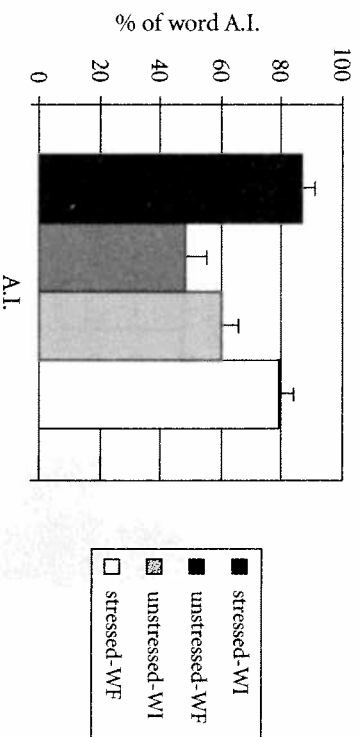


Figure 9. Experiment 2: means (in ms) and standard deviations of (normalised) A.I. in the two test-words: 'WI' stands for *word-initial* and 'WF' for *word-final*.

*Amplitude Integral:* As shown in Figure 9, stressed vowels had higher A.I. than unstressed ones [ $F(1,25)=425.46$ ], while both stressed and unstressed initial vowels had higher A.I. than final ones [ $F(1,25)=80.09$ ]. (There were no interactions and no *SPEAKER* effect).

*Syntagmatic comparisons:* In the syntagmatic comparisons, all three amplitude measurements yielded similar results; according to Scheffé tests, stressed vowels had in all cases higher P.A., R. M. S. and A.I. than their unstressed counterparts within the test-word (see also Figures 7-9). When speaker-specific comparisons were made using Tukey HSD tests, it was found that in some cases there were no P.A. or R. M. S. differences between stressed and unstressed vowels. This was particularly true for the [papal] test-word, in which TL, SC and AA showed similar P.A. for the stressed and the unstressed vowel; AA also had similar R. M. S. in this case. In contrast, the investigation of the A.I. data did not yield non significant results: in other words, in both test-words the stressed vowel had higher A.I. in the data of all speakers.

### 3.2.3 Fundamental frequency

Generally speaking the intonational schema used in the data was consistently the same both within and across speakers; it involved a pitch rise in the beginning of the utterance, followed by a dip and another rise, which was followed by a fall continuing all the way to the end of the utterance.

Regarding the test-words in particular, we can observe the following. As illustrated in Figures 10a and 11a, in [papal],  $F_0$  on the stressed syllable is either flat or rising from a low point. On the unstressed syllable,  $F_0$  is high and flat or falling from a high point; in either case, it starts higher than the  $F_0$  on the stressed syllable.<sup>6</sup> In [papal], illustrated in Figures 10b and 11b, the  $F_0$  on the unstressed initial syllable starts lower than the end of the carrier phrase's  $F_0$  and is always low or falling, while the final stressed syllable is rising with a 'jump' between it and the preceding unstressed syllable.

As the  $F_0$  patterns stand, they seem to suggest that in Greek both stressed and unstressed syllables in statements can be associated with high  $F_0$ . This is particularly true for the test-word [papal]; it is worth noting that in this case the highest  $F_0$  point within the test-word coincides with the beginning of the unstressed vowel and not with the stressed syllable itself. It is only in [papal] that the Greek data seem to conform to the view that only stressed syllables are associated with high  $F_0$ . Thus, at first glance it seems that the Greek data are inconsistent as to the evidence they offer for the use of  $F_0$  as a stress cue.

### 3.3 Experiment 2: Discussion

First, the results of Experiment 2 showed that the duration of stressed vowels was not affected by their prosodic position, while unstressed vowels exhibited a tendency for reduction in word-final place. The absence of vowel lengthening in Experiment 2 supports the explanation offered for the lengthening observed in Experiment 1, namely that it was due to the stress clash, and not to prosodic position.

With respect to stress, the results of Experiment 2 support those of Experiment 1 in clearly showing that stress has a lengthening effect on segments (particularly vowels), and consequently on syllables. In addition, Experiment 2 showed that not only duration but amplitude as well is a robust correlate of stress in Greek (thereby corroborating impressionistic descriptions of Greek as having 'dynamic stress'; e.g. Setatos 1974). However, stressed syllables did not necessarily have both longer duration and higher R. M. S. Amplitude, although they did show higher value for at least one of these correlates. This suggests that

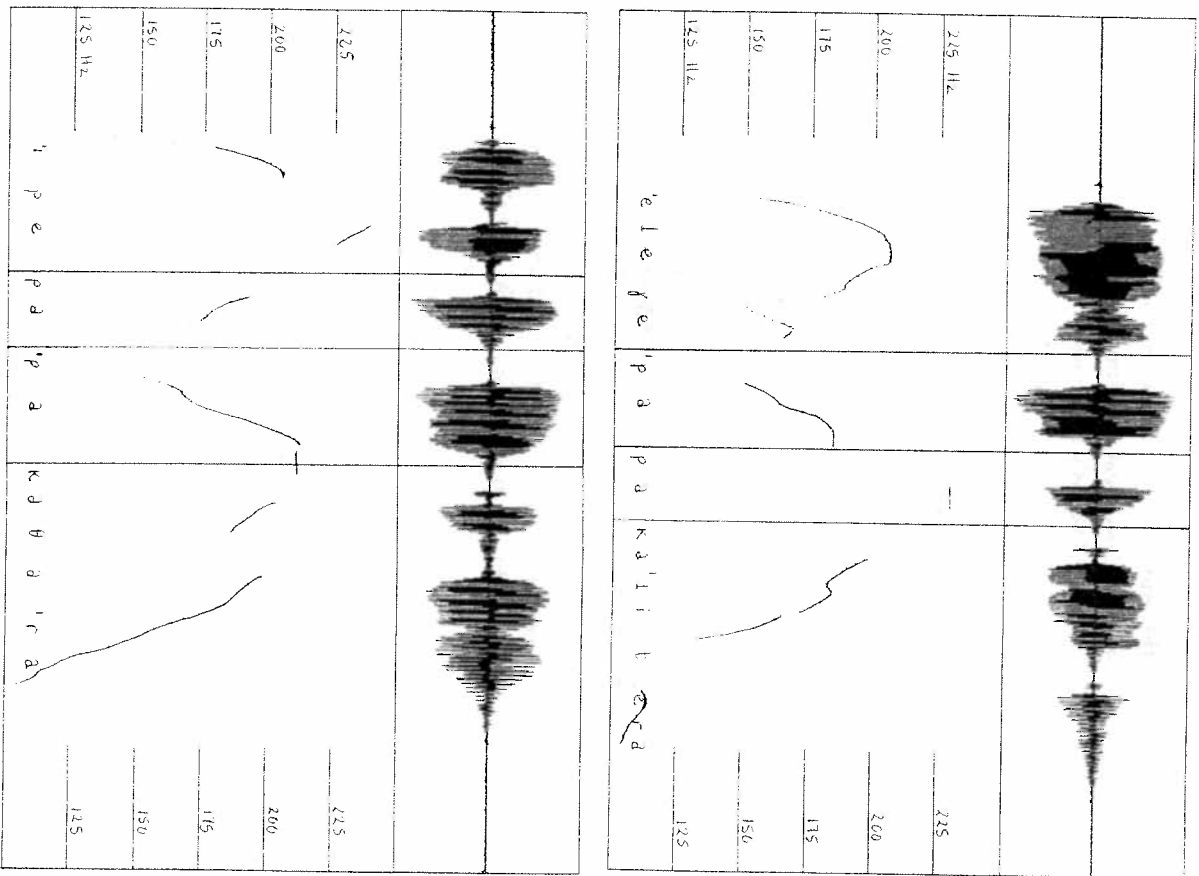


Figure 10. Waveforms and  $F_0$  contours of the sentences 'Eleye Papa kalitera' [eleye papa kalitera] 'S/he used to say 'Pope better' (a), and 'Eire para kaθapa' [i'pe papa kaθara] 'S/he said priest clearly' (b), from the data of speaker VK.

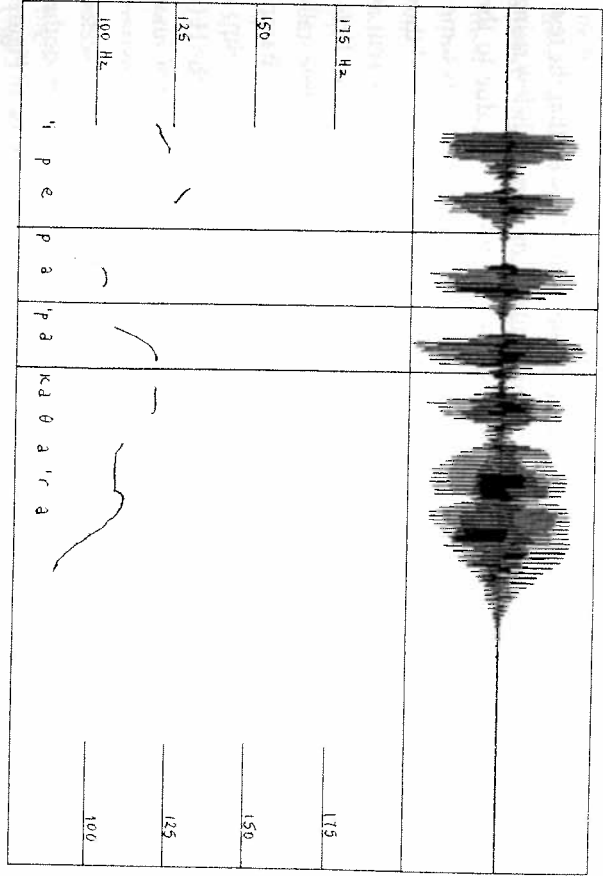
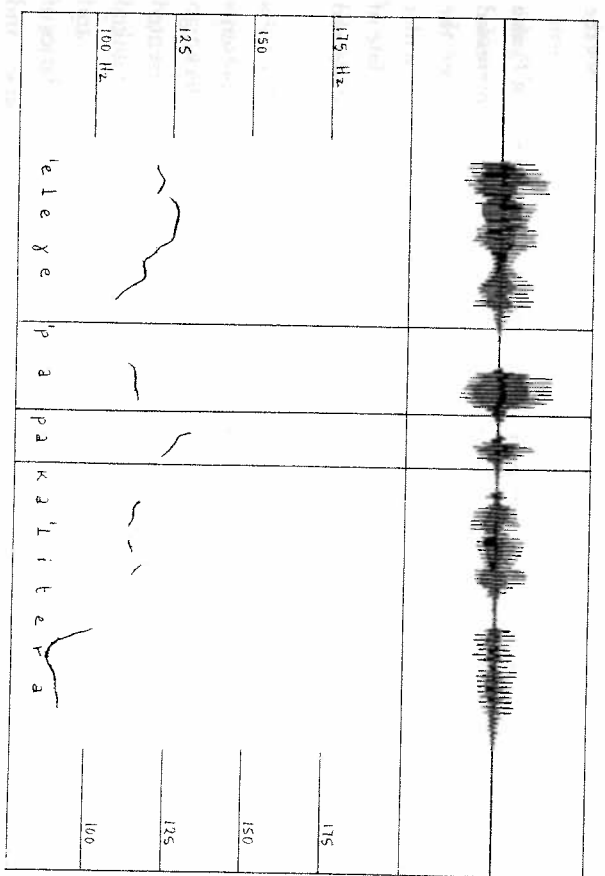


Figure 11. Waveforms and  $F_0$  contours of the sentences 'Eleye Papa kalitera' [eleye papa kalitera] 'S/he used to say 'Pope better' (a), and 'Eire para kaθapa' [i'pe papa kaθara] 'S/he said priest clearly' (b), from the data of speaker SC.

a more appropriate indicator of stress is amplitude integral, which combines the effects of amplitude and duration in one measurement.

Finally, as noted, the results seem to be ambivalent about the role of  $F_0$  as a cue to stress, since they show high or rising  $F_0$  for both stressed and unstressed syllables, particularly in the test-word with penultimate stress. However, the results seem unclear only if one subscribes to the view that  $F_0$  (and in particular high  $F_0$ ) is a correlate of stress. If instead  $F_0$  is seen as the acoustic correlate of intonational structure, and as such distinct from stress, then the observed patterns become transparent.

Concretely, in the autosegmental-metrical view, intonation forms a phonological tier separate from metrical structure, which in turn represents stress and prosodic phrasing (Pierrehumbert 1980; Pierrehumbert & Beckman 1988; Ladd 1996). On the intonation tier, *High* and *Low* tones are represented as autosegments that fall into three categories: 'pitch accents', which are linked to prominent (i.e. stressed) syllables and are notated with \* (e.g. H\*); and 'phrase accents' and 'boundary tones' which are linked to phrasal boundaries of different strength;<sup>7</sup> phrase accents and boundary tones are notated using – and % respectively (e.g. H–, 1%).

As far as the present data are concerned, it can clearly be seen that the test-words are associated with changes in  $F_0$  in particular with a generally low rising pattern (even though the observed contours are far from ideal, due to the interruptions of the  $F_0$  contour during stop closure). The  $F_0$  rise spans somewhat more than just the stressed syllable itself, yet it originates from it, and thus it is most probably a pitch accent. This kind of low rising pitch accent is typically associated with prenuclear stressed syllables in Greek (Arvaniti 1994; Arvaniti & Ladd 1995; Arvaniti et al. 1998, 2000), and has been autosegmentally analysed as a bitonal L\*+H pitch accent (Arvaniti 1994; Arvaniti & Baltazani 2000, to appear). Its main characteristic is the occurrence of the L (a  $F_0$  dip) a little bit before the onset of the stressed syllable, and the occurrence of the H (a  $F_0$  peak) approximately 10 ms after the onset of the *first post-accentual vowel* (Arvaniti & Ladd 1995; Arvaniti et al. 1998, 2000). This is precisely the pattern that we observe in Figures 10 and 11, once the particularities due to the voiceless stops are taken into account. A similar pitch accent, with a much smoother contour, can also be observed on the word [eʎeʎe] of the carrier phrase in Figures 10a and 11a. Dauer (1980a) and Botinis (1989) also describe similar patterns (though their descriptions are not couched in autosegmental terms). Thus, if the  $F_0$  data from Experiment 2 are seen within a framework that separates stress from intonation, they become easily interpretable. More importantly, this view

can account for the patterns observed in the data, particularly, the high  $F_0$  of unstressed syllables, in a principled manner. Finally, if the results are seen in this light, they lend support to the claim that  $F_0$  is an indirect cue to stress, by showing that stressed syllables can be associated with pitch accents, which are acoustically manifested as changes in  $F_0$ .

#### 4. General Discussion

##### 4.1 Duration and amplitude

The durational data of the two experiments together clearly show that stressed segments and syllables are longer than their unstressed equivalents, in comparisons both within and across words. There were, however, exceptions to this pattern. These exceptions held mainly for syntagmatic comparisons, and they affected mostly test-words with final stress and the duration of consonants (though vowels and syllables were by no means immune, as Table 3 shows).

These results are seemingly in disagreement with those of previous experiments on Greek stress, which show that segments and syllables are always longer when stressed (Dauer 1980a; Fourakis 1986; Botinis 1989; Fourakis et al. 1999). However, a closer look at the data of these studies reveals that the disagreement is most probably superficial. Fourakis (1986) and Fourakis et al. (1999) performed only *paradigmatic* comparisons, and did not investigate differences among speakers. Dauer (1980a), who did not run statistical tests on her data, points out that in disyllabic words with final stress durational differences between the two syllables were often absent. Finally, careful inspection of the data presented in Botinis (1989) reveals several cases in which an individual speaker had similar duration between stressed and unstressed syllables or vowels.<sup>8</sup> In short, those results that can be compared to the present data show that although duration is a stress correlate, it is not always present in the signal, thereby supporting the results presented here.

Turning to amplitude, the present P.A. results agree well with those of Dauer (1980a) and Botinis (1989), who also found that stressed syllables had higher peak amplitude than unstressed ones. The data of both studies, however, contain exceptions just like the present P.A. data do. The R.M.S. data of the present study seem to be in agreement with those of Fourakis et al. (1999). Unfortunately it is difficult to make direct comparisons between the two studies because, as already mentioned, Fourakis et al. did not investigate syntagmatic comparisons or differences among speakers.

Taken together, the data of the present and previous studies on the correlates of stress in Greek, suggest that neither amplitude (measured as P.A. or R.M.S.) nor duration alone can reliably distinguish stressed from unstressed syllables in Greek. Only A.I., which reflects the combined effect of amplitude and duration, was without exception higher in stressed syllables. This strongly suggests that R.M.S. and duration complement each other in signalling stress in Greek: for the A.I. of a stressed syllable to be higher than that of an unstressed one, it is sufficient for only one of the stressed syllable's A.I. components, duration and R.M.S. Amplitude, to be higher. This in turn implies that A.I. is a more reliable indicator of stress in Greek. This conclusion is indirectly supported by a perceptual experiment reported in Botinis (1989), in which listeners' responses dramatically shifted from *vomó* [nomo] 'law' to *vomó* [no'mo] 'prefecture' (and vice versa), when both amplitude and duration were changed together (effectively an A.I. change) from those of one word to those of the other.

In brief, the Greek data on amplitude and duration support the view that what we term 'stress' is a combination of acoustic correlates, and that the correlates used in a given language and their relative importance are language specific. In terms of the correlates it uses to signal stress, Greek appears to be similar to English — for which it has also been shown that amplitude integral is a robust stress correlate (Lieberman 1960; Beckman 1986) — and quite unlike, say, Dutch, in which amplitude integral has been reported to be a rather unreliable stress cue (Sluifiter & van Heuven 1996).

#### 4.2 Fundamental Frequency

The  $F_0$  patterns presented here are very similar to those presented in Dauer (1980a) and Botinis (1989). The main common point of all three studies is that the contours of both initially and finally stressed disyllabic words are essentially the same, low and rising, with the rise always coinciding with the stressed syllable, although its peak is not normally reached within the stressed vowel itself. The difference between initially and finally stressed disyllabic words lies mainly in the *timing* of the rise (the significance of which is strongly supported by Botinis's (1989) perceptual results).

However, the fact that the results of all the studies on Greek stress show that stressed syllables involve a pitch rise (or high pitch) should not be treated as evidence that pitch rises cue stress. Simply, the data of all these studies involve stressed syllables in pre-nuclear position in statements, i.e. syllables that carry  $L^*$ +H pitch accents. A pitch accent, however, does not necessarily involve a rise,

while a rising pitch movement does not necessarily signal stress. For instance, in yes-no questions in Greek, the nucleus ('sentence stress') is associated with a *dip* in  $F_0$ , i.e. a  $L^*$  accent; in contrast, at the end of yes-no questions, there is a rise-fall, which is not normally associated with a stressed syllable and does not signal prominence (Baltazani & Jun 1999; Arvaniti, Ladd & Mennen in rev.).

In brief, the Greek  $F_0$  data are not very different from those presented for English, Arabic or other intonation languages (Pierrehumbert 1980; Beckman & Pierrehumbert 1986; de Jong & Zawaydeh 1999). First, they show that stressed syllables may be associated with pitch accents. If they are, then  $F_0$  is the overriding perceptual cue to stress (Fry 1958 for English; Botinis 1989 for Greek). This is so, because the listener expects one (and, in Greek, only one) syllable in a word to be stressed; further s/he assumes that the syllable showing pitch movement must be the stressed one, since it carries a pitch accent and only stressed syllables may do so. Stress, however, can be reliably perceived in the absence of  $F_0$  movement, as experiments in Greek (Botinis 1989, mentioned earlier) and English (Huss 1978; Nakatani & Aston 1978) show.

#### 4.3 Other possible correlates of stress

The fact that the present data show that A.I. is a robust stress cue for Greek does not of course preclude the use of other correlates, such as vowel quality. This correlate has not been addressed in the present study because preliminary investigation of vowel spectra did not reveal notable differences between stressed and unstressed vowels, an observation that agreed with Dauer (1980a, 1980b) and Botinis (1989).<sup>9</sup>

More recent reports, however, suggest that some quality differences do exist between stressed and unstressed vowels in Greek (Fourakis et al. 1999). In particular, Fourakis et al. found that unstressed vowels define a reduced vowel space and show a lowering of  $F_1$  (with the exception of [e]). This lowering — which has also been found in Dutch (Sluifiter & van Heuven 1996) and Arabic (de Jong & Zawaydeh 1999) — indicates that "speakers tend to open their mouth less producing unstressed vowels than producing stressed vowels" (Sluifiter & van Heuven 1996: 2477), and supports the view that unstressed vowels are 'hypo-articulated' (Lindblom 1990; de Jong 1995), while stressed vowels are 'hyperarticulated' instead (Edwards & Beckman 1988; Beckman & Edwards 1994). For Greek however, further investigation of the perceptual relevance of the reported quality differences between stressed and unstressed vowels appears to be necessary. The reason is that stressed and unstressed

vowels do not contrast phonemically in Greek (as they do in English, for instance), and thus it is not clear whether acoustic differences in quality between them can be categorially perceived by native speakers.

#### 4.4 Effects of prosodic position

In addition to stress, the durational measurements of Experiments 1 and 2 provide information on two prosodic features of Greek, clash elimination and word-final lengthening. First, the present data indicate that in Greek word-final vowels may lengthen when involved in a stress clash, since lengthening was observed in Experiment 1 but not in Experiment 2. These results agree with the predictions of phonological theories of rhythm that clashes can be resolved by 'beat addition' (e.g. Malkouti-Drachman & Drachman 1981; Nespor & Vogel 1989). They are further supported by the experimental data of Arvaniti (1994), who specifically investigated stress clashes and found that lengthening of the first vowel in a clash occurred in three of ten sentences in her materials.

However, first-vowel lengthening is clearly not the only option available to the speakers for clash resolution, since they only used it occasionally in both the present Experiment 1 and in the data of Arvaniti (1994). Similarly ambiguous results have been reported for stress clash resolution in English: on the one hand, Silverman & Pierrehumbert (1990) found that syllable duration was longer in a stress clash context, on the other, Cooper & Eady (1986), and Beckman, de Jong & Edwards (1988) found no such effect. Clearly the resolution of stress clashes in different languages and under different prosodic conditions (such as different phrasing and intonation patterns) is a matter that requires further investigation.

Second, the present data indicate that Greek does not use lengthening to mark the end of prosodic words: in Experiment 2, which did not include stress clashes, only one out of five speakers, VK, showed word-final lengthening. The absence of final lengthening in Experiment 2 agrees with results reported in Dauer (1980a) and Botinis (1989), while similar results have also been reported for Italian (Farnetani & Kori 1990). In contrast, as mentioned in 2.3, evidence for word-final lengthening is very robust in several languages, such as English (e.g. Nakatani et al. 1981), French (Fletcher 1991), Arabic (de Jong & Zawaydeh 1999) and Swedish (Fant et al. 1991). Considered together, the data from these studies indicate that word-final lengthening is not universal, but rather a language-specific phenomenon. Thus empirical research is necessary to determine the influence of prosodic phrasing on segmental timing in a given language.

Regarding unstressed vowels, the results revealed differences between the two experiments, in that in Experiment 1 unstressed vowels were not affected by position, but in Experiment 2 they were shorter word-finally. At present, it is difficult to offer a satisfactory explanation for this difference. One hypothesis could be that it is the result of rhythmic effects on the timing of individual segments; e.g. Dauer (1980b) reports that unstressed syllables preceding stressed ones within a word are relatively long, while those following them are relatively short. Unfortunately this explanation was not supported by the present data: a one-way ANOVA on the duration of unstressed /a/ in the two experiments showed that [pa|pa] in Experiment 2 had the longest unstressed /a/, while (if Dauer were correct) this /a/ should be of similar duration to the unstressed /a/ of [pa|pa] in Experiment 1. This result cannot be attributed to differences in speaking rate between experiments, since similar results were obtained with ratios (unstressed vowel/word duration). Clearly, this is a point that requires further research.

Finally it should be noted that the limited prosodic effects on duration in both experiments were of rather small magnitude: in Experiment 1 word-final stressed vowels lengthened by 15–20% relative to stressed vowels in initial position; the shortening of unstressed final vowels in Experiment 2 was also within the same range. In contrast, the stressed vowels of both experiments together were on average 43% longer than the unstressed ones (syllables averaged a 39% increase in duration). Thus, although the stress-induced lengthening is clearly perceptible, the prosodic lengthening effects must be barely audible (Lehiste 1970; Klatt 1976). Taken all together, the present results indicate that prosodic position, at least within prosodic word boundaries, may not be as important a timing factor for Greek, as it has been shown to be for other languages. However, this conclusion should be treated with caution, as the results on which it is based were not consistent either across speakers or across experiments.

#### 5. Conclusion

In conclusion, the data from Experiments 1 and 2 show that the acoustic correlates of Greek stress are duration and amplitude. Stressed syllables have longer duration and higher amplitude than unstressed syllables and may be associated with  $F_0$  changes, seen here as pitch accents. The fact that some speakers do not show both higher average amplitude and longer duration on

stressed syllables suggests that amplitude integral is a better indicator of stress than either duration or R. M. S. alone. These results show that the acoustic correlates of stress in Greek are similar to those reported for other languages, such as Italian, English, Dutch and Arabic, though the importance attributed to each correlate differs from language to language. Thus, the data support the view of Beckman & Edwards (1994: 9) that stress is not an autosegment but a "structural feature that is derived from relationships among many different content features". Finally, the present data provide information about certain rhythmic aspects of Greek: they suggest that Greek does not exhibit word-final lengthening, and that stress clashes can be eliminated by lengthening the vowel of the first syllable in the clash. Although these results were not as robust as those on stress, they do indicate that prosodic effects on segmental timing are language specific, and as such subject to further empirical investigation.

## Notes

\* This paper is a substantially revised version of a previously unpublished part of my doctoral dissertation. I am grateful to Sarah Hawkins, my supervisor, for her teaching and feedback during my Ph. D. years, and to Mary Beckman and Brian Joseph for encouraging me to revise and submit the material presented here. I would also like to thank the three anonymous reviewers for their very helpful comments.

1. The importance of amplitude integral was also recognised by Lieberman (1960).
2. It should be noted that AA's data were no different from those elicited from the naive speakers who participated in the experiment.
3. Naeser (1970) refers to duplex oscillograms, not digital processing, but as both techniques are based on waveforms, her segmentation criteria are generally valid for both.
4. The Scheffé and the Tukey HSD are statistical tests that allow a researcher to explore significant results of an ANOVA design that s/he had not anticipated, by comparing specific pairs of means. The Tukey test is designed to allow comparisons between all possible pairs of means. The Scheffé test is not recommended for this situation, because it has been designed so as not to increase the overall familywise type I error (wrongly rejecting the null hypothesis), and thus it is less powerful than the Tukey test (Keppel 1991).
5. To calculate R. M. S., the amplitude of each sampled point within the range representing the syllable nucleus (according to the duration measurements) was squared, and the sum of squared amplitudes was divided by the number of points. A. I. measurements were obtained by simply calculating the square root of the sum of squared amplitudes of all points within the syllable nucleus without dividing the sum by the number of points. Like the duration measurements, A. I. and R. M. S. include the VOT of /p/. This should minimally affect the

results (as mentioned, the VOT of /p/ is very short in Greek), and has the advantage of rendering comparable the amplitude and duration results.

6. As far as the first syllable of the test words was concerned, the data did not always show the high F0 perturbation on the vowel onset that was expected because of the voiceless stop (House & Fairbanks 1953). This type of perturbation however could nearly always be observed at the onset of the second vowel (cf. Figure 11a). The description in Section 3.2.3 discards such microprosodic perturbations.
7. The role of phrase accents and boundary tones presented here is that adopted in Pierrehumbert & Beckman (1988). For a thorough discussion of this issue see Grice, Ladd & Arvaniti (2000).
8. For instance, for one speaker, the mean duration of the stressed vowel of *vógho* [homó] 'law' was 78 ms (s.d. 8.3) and that of the unstressed vowel was 70 ms (s.d. 7); the respective syllable durations were 136 ms and 132 ms (no standard deviations given). Such differences are unlikely to be statistically significant and/or perceptually relevant. The statistical significance of the pooled results reported in Botinis (1989) is probably due to the fact that for each measurement the mean of each speaker's data was calculated, and these means (rather than the raw data) were used as input to *t*-tests. This procedure considerably reduced standard deviations and consequently led to a large number of significant *t*-test results.
9. One anonymous reviewer points out that in Greek /i/ and /u/ centralise in unstressed positions, while /a/, /e/ and /o/ do not. However, neither Fourakis et al. (1999), who have thoroughly investigated vowel quality under different prosodic conditions, nor any other quantitative study (to my knowledge) offers evidence in support of this claim.

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## Περίληψη

Στο παρόν άρθρο παρουσιάζονται δύο περάσματα που εξετάζουν τα ακουστικά χαρακτηριστικά του προωρεθόντος τόνου στα ελληνικά. Τα αποτελέσματα καταδεικνύουν ότι το πλέον χαρακτηριστικό γνώρισμα του τόνου στα ελληνικά είναι η *ολοκληρωτική ένταση*, μια μέτρηση που συνδέεται αυτές της διάρκειας και της μέσης έντασης, και συνεπώς πλησιάζει περισσότερο από τις άλλες μετρήσεις στην αντιληπτική ιδιότητα του «εξέχοντος» που χαρακτηρίζει τις τονιζόμενες συλλαβές. Στο άρθρο γίνεται επίσης αναφορά στο ρόλο του ύψους της φωνής για τον τονισμό, με την παρουσίαση νέων δεδομένων και την ανάλυση προγενέστερων. Τέλος γίνεται σύντομη αναφορά στη σημασία των παρόντων αποτελεσμάτων για την κατανόηση της ελληνικής ρυθμικής δομής.

## Aim & Scope

The Greek language is among the most deeply and intensely studied languages known, yet most scholarly attention has been focused on Ancient Greek, including Homeric, Classical, and New Testament Greek. Within the past few decades, however, interest in the later stages of Greek — Byzantine, Medieval, and especially Modern Greek — has increased.

In view of this heightened awareness of the contribution that the linguistic examination of the latter stages of Greek can make, the *Journal of Greek Linguistics* focuses on the more recent stages of the language.

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