4. RHYTHMIC AND SECONDARY STRESS

Experiment 3 has indirectly shown that in a host-and-clitic group that violates the SWFC the lexical stress of the host is subordinate to the enclitic stress which becomes the primary stress of the group (see also Chapter 3, section 3.4). The stress of the host is perceptually and acoustically the same as a subordinate primary stress. However, the lexical stress of the host has often been considered a secondary stress and in some analyses (e.g. M-DD), it has also been implicitly equated to rhythmic stress. The purpose of Experiment 4, is to examine whether secondary stress (i.e. the weakened stress of the host) and rhythmic stress are perceptually and acoustically the same as M-DD suggest. This is done by means of a perceptual test and of acoustic analysis of the material used in this test.

4.1 EXPERIMENT 4: METHOD

4.1.1 MATERIAL

For Experiment 4, four pairs of phonemically identical words with different spelling and stress patterns were chosen (see Table 1). One word in each pair had lexical stress on the antepenultimate – (a) in Table 1 – and the other on the last syllable – (b) in Table 1. These word pairs were incorporated into phonemically identical, but orthographically distinct sentences in which they were followed by a possessive enclitic (see Table 1). For clarity, (a) test words will be referred to as SS (for secondary stress) and (b) words as RS (for rhythmic stress), thus reflecting the terms used by various analyses but not necessarily my own opinion on the nature of stress in Greek. These two terms will be used from now on with the same caution.

The addition of the enclitic results in a change in the stress pattern of SS words as required by the SWFC. Thus, these words have a secondary stress on their antepenultimate syllable (i.e. the weakened lexical stress) and primary stress (i.e. the enclitic stress) on their last syllable. According to M-DD, RS words also have this stress pattern since (a) tetrasyllabic words with final stress carry rhythmic stress on their antepenultimate syllable and (b) rhythmic stress and secondary stress are not distinguished by M-DD. If their claims are correct, then the SS and RS words of each test pair are segmentally and metrically identical and therefore indistinguishable.

One objection to this argument could be that when RS words are incorporated into sentences the placement of rhythmic stress is determined not by the word alone but by the overall stress pattern of the sentence. However, in these test sentences the position of the rhythmic stresses should not be affected by the sentence's stress pattern: according to M-DD metrical trees follow a strictly trochaic pattern which leaves the rhythmic stress of all RS words in the same position as the secondary stress of SS words. Test words (1) and (3), which are tetrasyllabic, may also have a rhythmic stress on their proclitic article /i/. Since this rhythmic stress would appear in both SS and RS words, its possible presence does not affect the present argument; for this reason it will not be discussed further.

Table 1:

The test-words, underlined, in the context in which they were read.

1

(a) /i e.pitro'pi mas 'itan a'kurasti/
Our commissioners were indefatigable.

(b) /i epitro'pi mas 'itan a'kurasti/
Our committee was indefatigable.

2

(a) /pi'stevo 'oti i .simvu'li tu 'itan so'fi/
I believe that his counsellors were wise.

(b) /pi'stevo 'oti i simvu'li tu 'itan so'fi/
I believe that his advice was wise.

3

(a) /no'mizo 'oti i si.meto'xi tu 'ine e'ksisu apa'retiti/
I think that his co-participants are equally necessary.

(b) /no'mizo 'oti i simeto'xi tu 'ine e'ksisu apa'retiti/
I think that his participation is equally necessary.

4

(a) /mu 'eleɣe 'oti 'vriski ton .eni'ko tis po'li enoxliti'ko/
She was telling me that she finds her tenant very annoying.

(b) /mu 'eleɣe 'oti 'vriski ton eni'ko tis po'li enoxliti'ko/
S/he was telling me that s/he finds her [use of] "singular" very annoying.

Four pairs of distractors incorporated into identical sentences were also included (see Table 2). The distractor words were devised on the same pattern as the test-words, but they differed only in the position of the primary stress; e.g. /a'poxi/ *hunting net* : /apo'xi/ *abstention.*

Finally, both the test sentences and the distractors were followed by an explanatory phrase which the speakers had to read. For example, test sentence (4a), *She was telling me that she finds her tenant very annoying*, was followed by *He is rude and constantly noisy*, while test sentence

Table 2:

The distractor words, underlined, in the context in which they were read.

1

(a) /ma a'fto 'ine porto'kali/
But this is an orange.

(b) /ma a'fto 'ine portoka'li/
But this is orange.

2

(a) /i a'poxi tus 'itan po'li me'γali/
Their hunting-net was very big.

(b) /i apo'xi tus 'itan po'li me'γali/
Their abstention was great.

3

(a) /teli'ka to 'kerδise to me'talio/
Finally he won the medal.

(b)/teli'ka to 'kerδise to meta'lio/
Finally he won the mine.

4

(a) /stin omi'lia tu ana'ferθike stus 'nomus tus/
In his speech he referred to their laws.

(b) /stin omi'lia tu ana'ferθike stus no'mus tus/
In his speech he referred to their counties.

(4b), *He was telling me that he finds her [use of] "singular" very annoying*, was followed by *He would prefer her to address him in plural.* These explanatory phrases were added to provide a context which would enable the speakers to correctly interpret all sentences. In addition, the explanatory sentences prevented a "list-reading" rhythm and helped the speakers read the sentences as naturally as possible without putting too much emphasis on the test-words.

4.1.2 SUBJECTS

The same speakers that recorded the material of Experiment 3 (HP, AP, KAP, AA) served in Experiment 4. In addition, two more female speakers (EI and MK) of similar age and education as HP, AP and AA took part in the recording.

All the listeners that took part in Experiment 3 did Experiment 4 as well. The responses of one of the listeners who did not understand what she was asked to do and left most test pairs unmarked were discarded. Thus, the responses of 17 rather than 18 listeners are reported for Experiment 4.

4.2 PERCEPTUAL TEST: PROCEDURE AND RESULTS

4.2.1 PROCEDURE

For the recording of the material, the first two speakers (EI and MK) read the sentences from hand-written cards three times each. The other four speakers (AP, KAP, AA, HP) read the sentences from a typed randomised list which included six repetitions of each test sentence and distractor. In both the cards and the typed list, each test sentence and distractor was followed by the appropriate explanatory phrase. The material was written in Greek. The recording, which took place in a sound treated room in the Phonetics Laboratory of the Linguistics Department, Cambridge University, was monitored, as before, by myself. Prior to the recording, the speakers were instructed to read the sentences as naturally as possible and to avoid emphasis on the test- and distractor words. The speakers were asked to repeat a sentence if they failed to follow these instructions.

To make the listening tape, the recorded material was low-pass filtered at 7.8 kHz and digitised at 16 kHz. One token of each test sentence and distractor was selected from the recording of each speaker. The tokens selected were those that sounded most natural to me, in that they had no special emphasis that could distinguish SS and RS words, did not contain any pauses etc. The selected stimuli were recorded onto cassette tape at a sampling rate of 16 kHz using computer-generated randomisation by blocks. There were 3 sec of silence between sentences and 5 sec after every tenth sentence. The first 4 sentences were repeated at the end of the tape, and the first 4 responses of each listener were discarded. Each listener heard a total of 100 sentences: 6 speakers x (8 test sentences + 8 distractors) + 4 repeated stimuli.

For the running of Experiment 4 the same procedure as that described in Chapter 3, section 3.2 was followed. In fact the listeners did Experiments 3 and 4 in one sitting with a small break in between. No-one complained about the length of either test. The answer sheet for Experiment 4 gave 200 possible answers, i.e. 100 stimuli x 2 alternatives, typed in Greek. Before doing the test the spelling differences between SS and RS words (but not their respective stress patterns) were pointed out to the listeners. It was then explained to them that their task was to choose which of the two answers given for each stimulus they thought they had heard.

4.2.2 RESULTS

The listeners gave a total of 816 responses excluding the distractors (17 listeners x 48 responses/answer sheet). The responses show that 97% of the test-words were correctly identified (see Table 3); this figure is essentially the same as that for the distractor words (98.2%). Nine listeners made no errors in the test-words and the other seven made a total of 23 errors. Of the listeners that made mistakes, five made between 1 and 3, the other two making 6 and 7 mistakes respectively. Only four people made mistakes in the distractors: 1, 2, 3 and 9 mistakes respectively. The persons who made the highest number of mistakes in the test-words made the highest number of mistakes in the distractors as well. These results confirm that rhythmic and secondary stress can be easily distinguished by native speakers of Greek; in fact they are as easily distinguished as the placement of primary stress on different syllables of homophones, as the distractor results show. Therefore it is incorrect to equate rhythmic and secondary stress as M-DD do.

Table 3:

Contingency table of type of stimulus by listener response.

(a) Observed frequencies

	RESPONSE		
STIMULUS	SS	RS	Total
SS	402	6	408
RS	17	391	408
Total	419	397	816

(b) Expected frequencies and deviances (in brackets)

	SS	RS
SS	209.5 (176.87)	198.5 (186.68)
RS	209.5 (176.87)	198.5 (186.68)

Total deviance (χ^2) = 727.1 1df, $p<0.001$

4.3 ACOUSTIC ANALYSES: MEASUREMENTS AND RESULTS

4.3.1 MEASUREMENTS

All three tokens of each test sentence of the original recording of EI and MK and the first three tokens of HP's recording (which include the tokens used in the perceptual test) were low-pass filtered at 7.8 kHz and digitised at 16 kHz. Audlab was used to measure duration, amplitude and F0. Measurements were performed in the same way as for Experiment 3, described in Chapter 3, section 3.3.1. The only difference in the measurements was that for Experiment 4, fundamental frequency information was obtained using the Audlab F0 tracker facility, which is less reliable than the ILS one used in all other measurements of F0. To ensure the reliability of the F0 tracks, narrow-band spectrograms were also made and the contour of the harmonics tracked and measured. Discontinuities in the F0 tracks were smoothed out by hand to correspond to the contour of the harmonics in the narrow-band spectrograms. Since what is essential is the difference between the contours of SS and RS words, the entire contours are described and contrasted, instead of F0 measurements being made at particular places in each contour.

Comparisons of the antepenultimate and final syllables of the SS words with the equivalent syllables of the RS words were made. For instance, the duration, F0 and amplitude values of /sim/ in SS word /.simvu'li tu/ *councillors* were compared to those of /sim/ in RS word /simvu'li tu/ *advice*. The most important comparison is that between antepenultimate syllables, because any acoustic differences between them reflect differences in the manifestation of secondary and rhythmic stress. Comparisons between final syllables of SS and RS words were made to see whether their results would corroborate those of Experiment 3, by showing that there are no differences between the final syllables of SS words, which carry enclitic stress, and those of RS words, which carry lexical stress.

4.3.2 DURATION

Durations of antepenultimate and final syllables for all test-word pairs are presented in Table 4. The data were analysed statistically by means of 2-way repeated-measures analyses of variance (type of stress x speaker). Separate ANOVAs for each test-word pair were performed on the durations of antepenultimate and final syllables. The data were not pooled over test pairs because of the considerable differences in the segmental makeup of the syllables under investigation. ANOVAs were also performed on vowel durations, but as the vowel data agree completely with the syllable data they will not be discussed further.

The durational data strongly support the results of the perceptual test. As shown in Table 5, in all test-word pairs the duration of the antepenultimate syllables of SS words is longer than the duration of the corresponding syllables of RS words. In contrast, the durations of final syllables are the same whether their stress is primary (RS words) or enclitic (SS words) (see Table 5). There were no differences among the subjects.

4.3.3 AMPLITUDE

The AI and RMS data are presented in Table 6; mean AI values of final syllables for each speaker are shown in Figure 1. The AI and RMS data were statistically analysed in the same way as the durational data.

The AI data for antepenultimate syllables agree very well with the durational data. As shown in Table 7, the antepenults of the SS test-words have higher AI than the RS antepenults in all test pairs. There are no significant interactions.

Table 4:

Mean durations (ms) and standard deviations of antepenultimate (top) and final (bottom) consonants, vowels and syllables for all speakers. The relevant syllables are in capitals. The means and standard deviations of /s/ and /m/ of /simvuli/ are presented together in the consonant column; those of /s/ are on the left and those of /m/ on the right.

Test word		Consonant(s)	Vowel	Syllable
1. ePItropi (SS)	Mean	87	73	160
	S.D.	18	6	20
1. ePItropi (RS)	Mean	62	51	113
	S.D.	13	8	13
2. SIMvuli (SS)	Mean	137 70	50	257
	S.D.	18 16	6	36
2. SIMvuli (RS)	Mean	102 73	31	206
	S.D.	18 9	8	25
3. siMEtoxi (SS)	Mean	70	84	154
	S.D.	18	11	27
3. siMEtoxi (RS)	Mean	60	51	111
	S.D.	9	5	10
4. Eniko (SS)	Mean	-	-	93
	S.D.	-	-	16
4. Eniko (RS)	Mean	-	-	61
	S.D.	-	-	8

1. epitroPI (SS)	Mean	90	114	204
	S.D.	12	14	22
1. epitroPI (RS)	Mean	94	109	203
	S.D.	19	30	47
2. simvuLI (SS)	Mean	75	94	169
	S.D.	12	12	11
2. simvuLI (RS)	Mean	79	96	175
	S.D.	18	21	28
3. simetoXI (SS)	Mean	124	83	207
	S.D.	20	14	31
3. simetoXI (RS)	Mean	122	78	200
	S.D.	24	20	40
4. eniKO (SS)	Mean	68	166	234
	S.D.	16	29	38
4. eniKO (RS)	Mean	70	174	244
	S.D.	14	16	24

Table 5:

F-ratios and probability levels from 2-way ANOVAs for comparison of durations of SS and RS antepenultimate syllables (left) and of final syllables of SS and RS words (right).

	Antepenults		Final syllables		
Test pair	F(1,6)	p	F(1,6)	p	Test pair
1. ePItropi	111.72	0.0002	0.038	n.s.	epitroPI
2. SIMvuli	55.38	0.0006	0.036	n.s.	simvuLI
3. siMEtoxi	62.85	0.0005	0.430	n.s.	simetoXI
4. Eniko	34.06	0.0015	0.350	n.s.	eniKO

The AI results for final syllables are not as clear as those for antepenultimate ones. Specifically, while in /epitropi/ the final syllables of SS and RS words have the same AI, in /eniko/ RS final syllables have higher AI than SS ones (see Figure 1). In the test pairs /simvuli/ and /simetoxi/ there is an interaction between speakers and type of stress (see Table 7). The statistically significant F-ratio of /simvuli/ is due to the data of one speaker: as seen in Figure 1, HP has higher AI in the final syllable of the RS word, while EI and MK have the same AI in both SS and RS final syllables (HP: $F(1,6)=14.29$, $p<0.009$; EI: $F(1,6)=0.1$, n.s.; MK: $F(1,6)=5.29$, n.s.). In /simetoxi/, although the pooled data show a statistically significant difference between the AI of SS and RS words (see Table 7), none of the subjects shows a difference between the two AIs that reaches the 5% probability level (EI: $F(1,6)=0.709$, n.s.; HP: $F(1,6)=2.5$, $p<0.015$; MK: $F(1,6)=4.43$, $p<0.078$). In short, 8 of the 12 possible comparisons (4 test-words x 3 speakers) show that final syllables have the same AI whether their stress is enclitic or lexical. In the other 4 cases, however, syllables with lexical stress have higher AI than those with enclitic stress.

There are some differences in this experiment between the AI and RMS values of antepenultimate syllables in the test pairs /eniko/, /simvuli/ and /simetoxi/ (the AI and RMS of the test pair /epitropi/ follow the same pattern). Although these discrepancies are not important, as a statistically significant AI result can be due only to the contribution of duration (see Chapter 2, section 2.5.1), the differences arising in this experiment are documented here for completeness. Table 8 shows that, contrary to the AI data, there is no difference between the RMS of SS and RS antepenults in the test pair /eniko/. In the test pairs /simvuli/ and /simetoxi/ there is an interaction between speakers and type of stress. As shown in Figure 2, in /simvuli/, MK and HP have higher RMS on the SS antepenults, but in EI's data there is no difference between the two (MK: $F(1,6)=16.23$, $p<0.007$; HP: $F(1,6)=31.7$, $p<0.001$; EI: $F(1,6)=2.73$, n.s.). Figure 2 also shows that in /simetoxi/, MK has higher RMS on the SS antepenult, but EI and HP have no difference between the two (MK: $F(1,6)=16.47$, $p<0.007$; EI: $F(1,6)=1.6$, n.s.; HP $F(1,6)=0.14$, n.s.). Briefly, the AI and RMS data for antepenults agree only in 6 out of 12 cases.

Table 6:

Means and standard deviations of normalised AI and RMS of antepenultimate (top) and final syllables (bottom) for all speakers. The relevant syllables are in capitals.

Test word		AI	RMS
1. ePItropi (SS)	Mean	35	133
	S.D.	4	18
1. ePItropi (RS)	Mean	21	91
	S.D.	7	26
2. SIMvuli (SS)	Mean	60	153
	S.D.	9	28
2. SIMvuLI (RS)	Mean	54	136
	S.D.	7	19
3. siMEtoxi (SS)	Mean	67	157
	S.D.	9	19
3. siMEtoXI (RS)	Mean	59	152
	S.D.	5	12
4. Eniko (SS)	Mean	40	131
	S.D.	4	21
4. Eniko (RS)	Mean	33	121
	S.D.	4	9

---

1. epitroPI (SS)	Mean	40	117
	S.D.	5	15
1. epitroPI (RS)	Mean	39	113
	S.D.	6	17
2. simvuLI (SS)	Mean	50	106
	S.D.	4	10
2. simvuLI (RS)	Mean	59	115
	S.D.	8	16
3. simetoXI (SS)	Mean	33	105
	S.D.	3	11
3. simetoXI (RS)	Mean	39	120
	S.D.	7	16
4. eniKO (SS)	Mean	48	119
	S.D.	10	27
4. eniKO (RS)	Mean	57	132
	S.D.	10	26

Table 7:

F-ratios and probability levels from 2-way ANOVAs for comparison of AI of SS and RS antepenults (left) and of AI of final syllables of SS and RS words (right). A * indicates interaction between speakers and type of stress.

	Antepenults		Final syllables		
Test pair	F(1,6)	p	F(1,6)	p	Test pair
1. ePItropi	34.13	0.001	0.52	n.s.	epitroPI
2. SIMvuli	8.00	0.029	13.70*	0.010	simvuLI
3. siMEtoxi	12.19	0.010	6.89*	0.038	simetoXI
4. Eniko	14.70	0.008	20.46	0.004	eniKO

The AI and RMS of final syllables follow the same pattern for all test pairs. The final syllables of SS and RS /epitropi/ have the same RMS, while the final syllables of RS /eniko/ have higher RMS than the final syllables of SS /eniko/. Again, there is an interaction of speakers and type of stress in the /simvuli/ and /simetoxi/ data. As shown in Figure 2, in /simvuli/, EI and MK have the same RMS in final SS and RS syllables, while HP has higher RMS on RS final syllables (EI: F1,8)=0.75, n.s.; MK: F(1,6)=4.6, n.s.; HP: F(1,6)=12.9, p<0.01). Figure 2 also shows that in /simetoxi/, EI and HP have no difference between the two conditions, while MK has higher RMS in RS final syllables[1] (EI: F(1,6)=1.37, n.s.; HP: F(1,6)=2.39, n.s.; MK: F(1,6)=9.06, p<0.02). The RMS data show that the observed differences in the AI of SS and RS final syllables are due to differences in RMS rather than duration which is the same for SS and RS final syllables.

Table 8:

F-ratios and probability levels from 2-way ANOVAs for comparison of RMS of SS and RS antepenults (left) and of RMS of final syllables of SS and RS words (right). A * indicates interaction between speakers and type of stress.

	Antepenults		Final syllables		
Test pair	F(1,6)	p	F(1,6)	p	Test pair
1. ePItropi	20.88	0.004	0.80	n.s.	epitroPI
2. SIMvuli	21.37*	0.004	7.90*	0.029	simvuLI
3. siMEtoxi	3.35*	n.s.	10.90*	0.016	simetoXI
4. Eniko	2.84	n.s.	6.16	0.046	eniKO

[1] This RMS difference in MK's data is manifested only as a trend in her AI data.

In brief, although syllables with secondary stress and syllables with rhythmic stress have the same RMS in half of all possible comparisons, the AI data confirm that secondary stress is acoustically more prominent than rhythmic stress; thanks to the longer duration of their vowels, syllables with secondary stress have always higher AI than syllables with rhythmic stress. On the other hand, there is some disagreement between Experiments 3 and 4, concerning the AI data for final syllables. In Experiment 4, there are cases in which the AI of syllables with enclitic stress is lower than that of syllables with lexical stress, while in Experiment 3 no such differences were found. Nevertheless, the majority of Experiment 4 data supports those of Experiment 3. A possible explanation of the differences between the AI and RMS of antepenults and for the differences between Experiments 3 and 4 is offered in section 4.4.

4.3.4 FUNDAMENTAL FREQUENCY RESULTS

F0 contours, one for every test-word pair, are shown in Figures 3, 4, 5 and 6. In the data of all speakers, the F0 contours differ considerably between SS and RS test words as far as the F0 of the antepenults is concerned. The F0 of the SS antepenult is high and rising, whereas the F0 of the RS antepenult is low and either flat or falling. As has been shown in Chapters 2 and 3, the former F0 contours are associated with stressed syllables, while the latter are associated with unstressed syllables. It was, however, observed in Chapter 2 that when a word has initial stress the F0 of the stressed syllable may be low and relatively flat, i.e. its contour may be similar to that of the RS antepenults in Experiment 4. The crucial difference is that if a syllable is stressed and its F0 is flat, the F0 of the following syllable is high (see e.g. the upper graphs of Figures 6 and 9 of Chapter 2). In contrast, in RS words not only is the F0 of RS antepenults low and flat or falling, but the same trend is continued on the F0 of the following syllable; that is, in RS words there is only one F0 perturbation, and this is associated with the final primary stress.

No important differences between the contours of the final syllables of SS and RS words were found. They all started with slightly low F0 that rose to a high value. Like Experiments 2 and 3, Experiment 4 shows that the F0 peak is not associated with the stressed syllable but rather with the beginning of the following, unstressed syllable.

Figure 1

Means of normalised AI of final syllables for all test-word pairs. For each speaker the SS word is on the left and the RS word on the right.

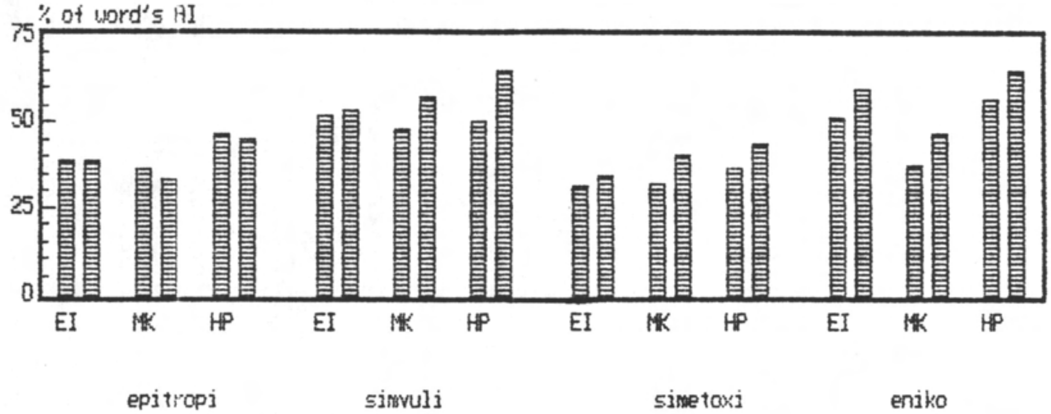


Figure 2

Means of normalised RMS of antepenultimate (left) and final syllables (right) of test-word pairs /simvuli/ and /simetoxi/. For each speaker the SS word is on the left and the RS word on the right.

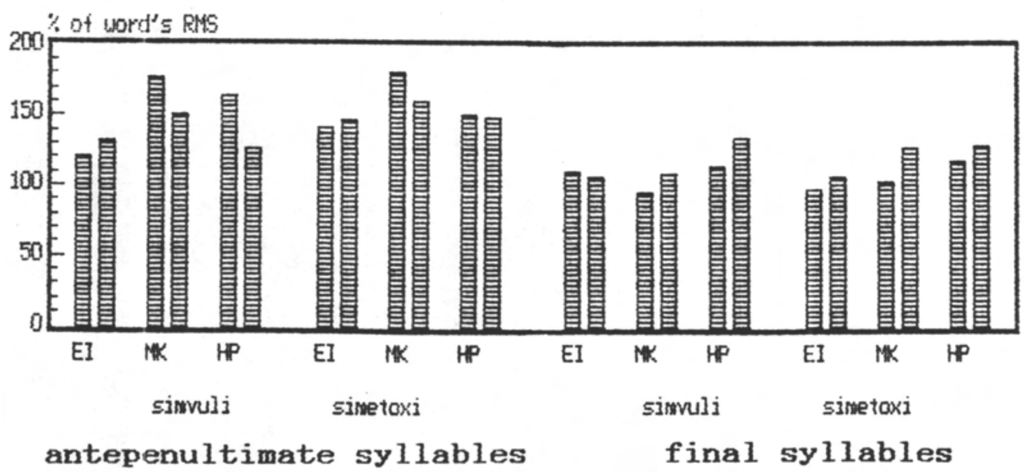


Figure 3

Speaker EI: narrow band spectrograms and smoothed F0 contours of the phrases /i e.pitro'pi mas/ (top graph) and /i epitro'pi mas/ (lower graph).

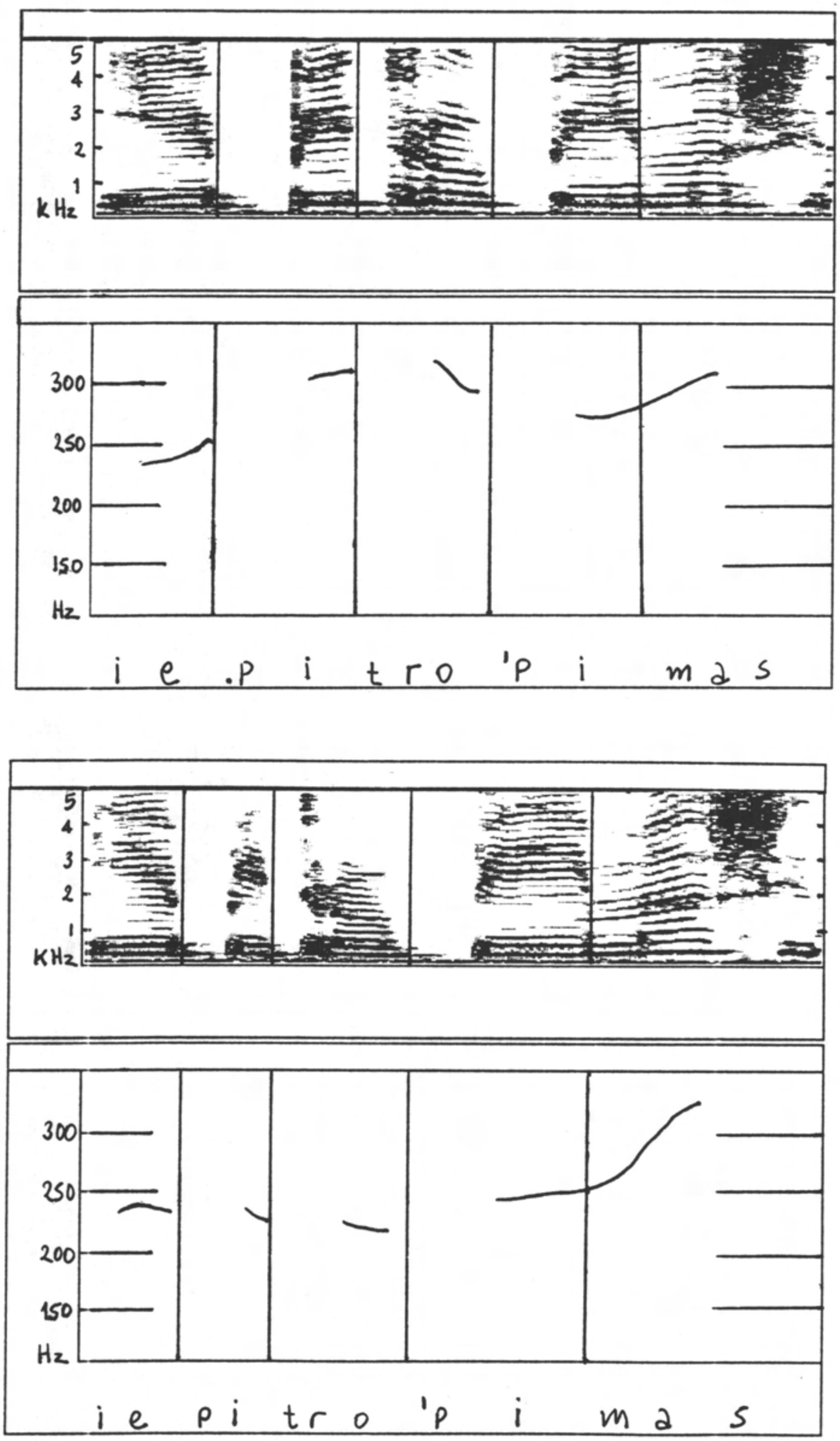


Figure 4

Speaker EI: narrow band spectrograms and smoothed F0 contours of the phrases /i .simvu'li tu/ (top graph) and /i simvu'li tu/ (lower graph).

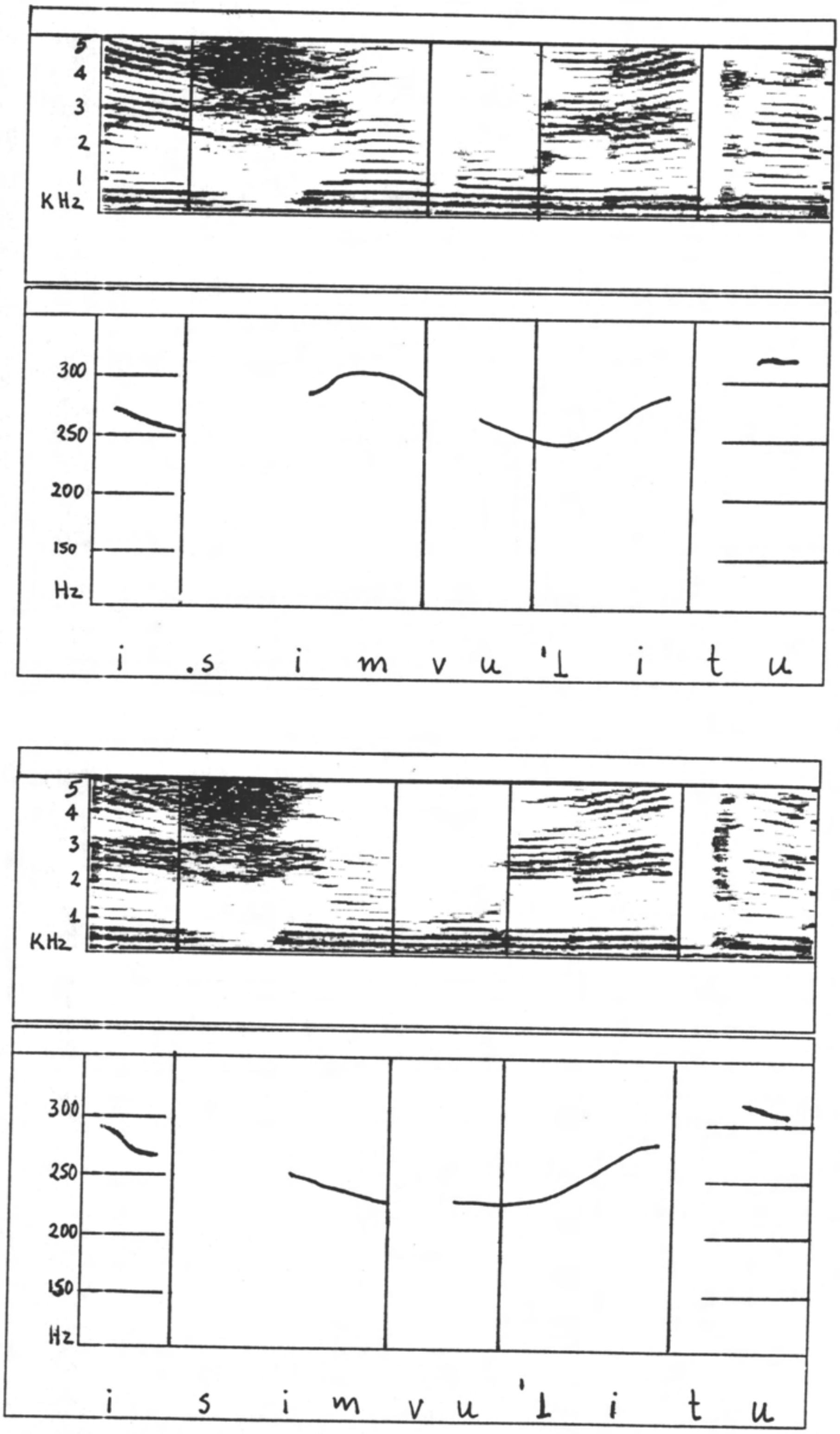


Figure 5

Speaker MK: narrow band spectrograms and smoothed F0 contours of the phrases /i si.meto'xi tu/ (top graph) and /i simeto'xi tu/ (lower graph).

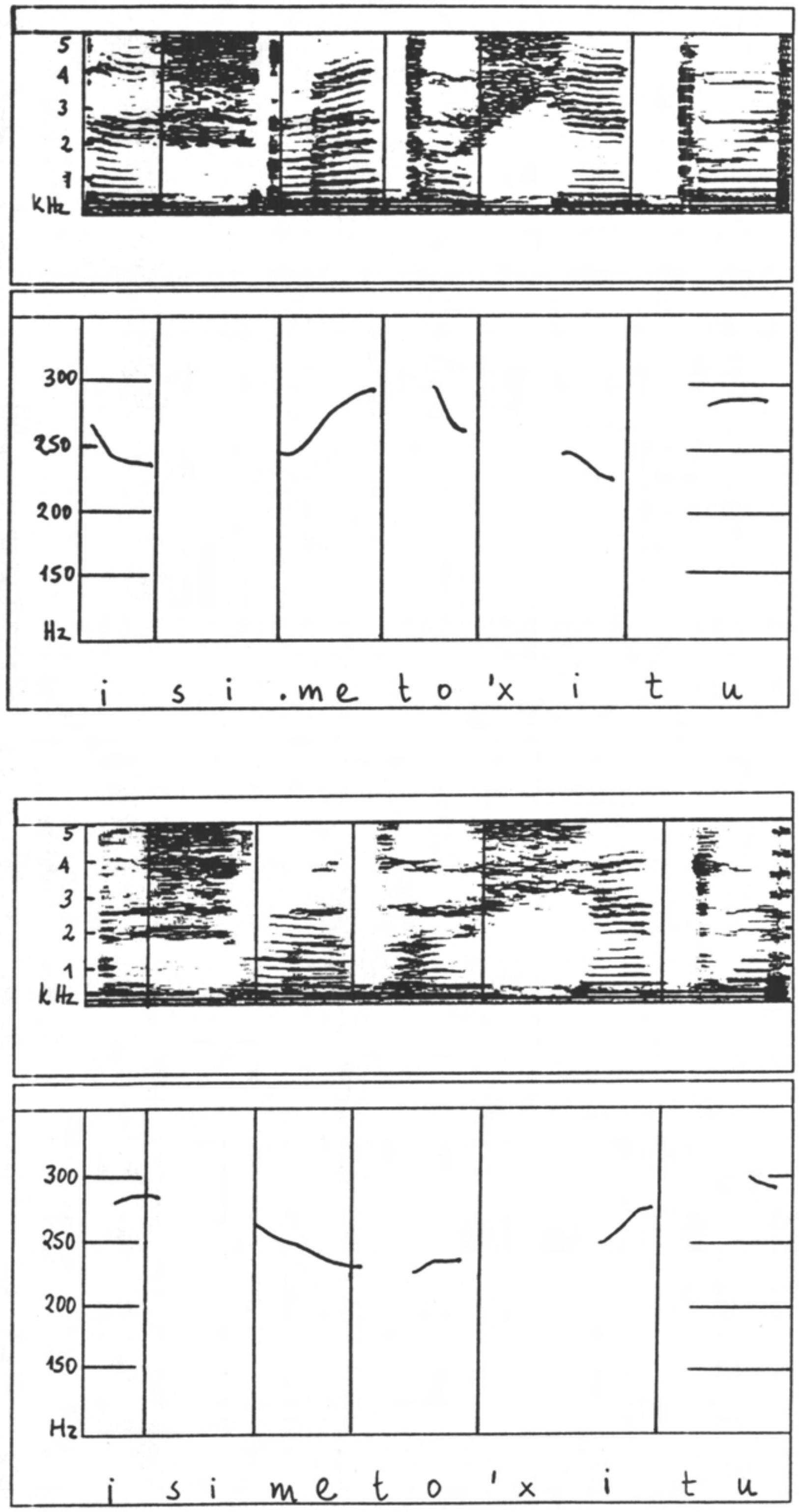
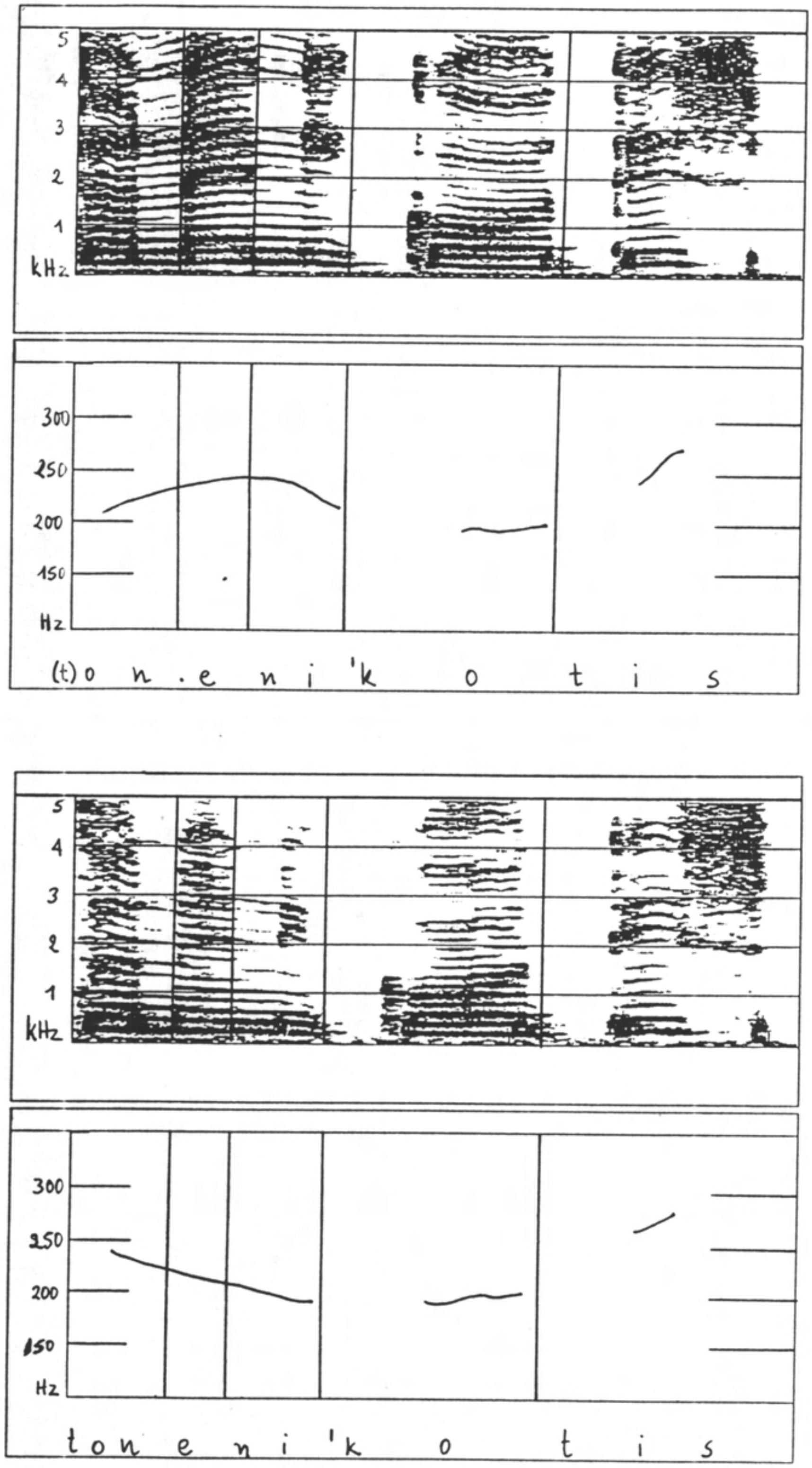


Figure 6

Speaker HP: narrow band spectrograms and smoothed F0 contours of the phrases /ton .eni'ko tis/ (top graph) and /ton eni'ko tis/ (lower graph).



4.4 DISCUSSION

Experiment 4 demonstrates that secondary stress (i.e. the weakened lexical stress of the host) and rhythmic stress are both perceptually and acoustically very different. First, rhythmic and secondary stress can be easily differentiated by native speakers of Greek when they are in the same context. Second, the syllables which carry secondary stress are acoustically more prominent than syllables thought to carry rhythmic stress. Syllables with secondary stress have longer duration and higher AI than syllables that carry rhythmic stress, and they are associated with considerable F0 fluctuations. Therefore, it is unsatisfactory to use the same phonological representation for syllables with rhythmic stress and for those with secondary stress, as M-DD do.

Moreover, while secondary stress is acoustically similar to primary stress, there is very little acoustic evidence for rhythmic stress. The short duration, low AI, and the low and falling F0 of syllables which are thought to have rhythmic stress makes them very similar to unstressed syllables. There is one indication that syllables with rhythmic stress may be acoustically more prominent than unstressed syllables; namely the fact that in some instances syllables with rhythmic stress have the same RMS as syllables with secondary stress. However, as has been noted in Chapter 2, sections 2.4.2 and 2.5.1, it is possible for unstressed syllables to have the same RMS as stressed syllables so long as the AI of the latter remains higher[2] . In other words, the fact that in some cases the RMS of RS and SS syllables is the same does not necessarily mean that the RMS of RS syllables is high; rather it could mean that the RMS of SS syllables is relatively low. If this suggestion is correct, it follows that it cannot be inferred from the data of Experiment 4 that syllables with rhythmic stress have higher RMS than unstressed syllables. Obviously, a direct comparison between syllables with rhythmic stress and unstressed syllables is necessary for a more definite answer. (This is undertaken in Chapter 5.)

Experiments 3 and 4 together demonstrate that syllables with secondary stress are acoustically like syllables with subordinate primary stress, rather than syllables with rhythmic stress. In addition to questioning the existence of rhythmic stress, the acoustic similarity of secondary and primary stress raises another question, namely whether the term *secondary stress* is appropriate for a stress which is acoustically the same as a subordinate lexical stress, rather than a rhythmic stress as the term *secondary* implies. The difference between a subordinate lexical stress and the subordinate stresses of words may not seem clear. However, it must be remembered that these two types of stress have not always been considered the same. Liberman & Prince (1977:255), for instance, refer to Trager & Smith (1951) who "argued for a distinction between nonprimary stresses within a word, and subordinated main stresses of independent words, a distinction that could be expressed by a one-level downgrading of all nonprimary stresses within the confines of a given word; thus

2 In Chapter 2, the unstressed syllables, which are compared to stressed syllables, immediately precede or follow stressed ones, so there is no possibility that they carry rhythmic stress.

```
     3    1
(1)  Tennessee
```

but

```
     2    1
(2)  Aral Sea."
```

It seems to me that the stress pattern in (2) expresses something similar to what happens in Greek host-and-clitic groups. In other words, in Greek, the host's stress should not be considered similar to a nonprimary stress within a word as in (1) above, but rather to the subordinate stress of a separate word, as in (2). This is what the prosodic trees in section 3.4 of Chapter 3 represent, namely that in a host-and-clitic group we deal with two ωs, just as we deal with two ωs when the same sequence of syllables forms two independent words. This may at first appear to contradict something else that has been said about host-and-clitic groups in Chapter 3, section 3.4; namely that these groups behave like one ω with respect to focus placement. This apparent contradiction demonstrates why it is necessary to link the host-and-clitic group's ωs to a compound ω; because in certain respects, like stress prominence patterns, host-and-clitic groups behave like two independent ωs, while in other respects, like focus placement, they behave like one ω. The fact that the present representation can account for both types of behaviour is its strength.

The present results for final syllables, which are taken to carry the main stress either lexical or enclitic, are not in complete agreement with those of Experiment 3, which showed that when there are two stresses in a φ then the final one is the most prominent, whether it is lexical or enclitic[3] . The main difference between the material in Experiments 3 and 4 is that in Experiment 3 there are two stresses in the φ formed by each member of a test pair, while in Experiment 4 RS words form φs with only one stress and SS words form φs with two stresses[4] . Perhaps this difference can explain the somewhat different acoustic results between Experiments 3 and 4. Specifically, when there are two stresses in a φ then they somehow "share" the prominence, in that the first one of the two does not weaken to a great extent and the second one is not much more prominent than the first one. In contrast, when there is only one stress in a φ (as in RS words) then this stress assumes all the prominence. Therefore, acoustic differences between the

[3] Strictly speaking, in Experiment 3, the φs are: /'ari 'sta su/ and /ja to .ari'sta su/ in (1a) and (1b) respectively, and /psa'ra δi'ko tus/ and /a'po to psa.raδi'ko tus/ in (2a) and (2b) respectively. (This is based on the rules of φ formation of NV (1986).) The added words in (1b) and (2b), /ja/ and /a'po/, are prepositions, which in Greek have clitic status, i.e. no stress (I have marked stress on /a'po/ simply because it is bisyllabic). Thus, these words do not affect the present argument.

[4] In test pairs (2) and (3) the φs are: /'oti i simvuli tu/ and /'oti i simetoxi tu/ respectively. However, /'oti/ *that* is very likely to lose its stress; i.e. its presence in these φs is unlikely to affect the current argument.

one- and two-word versions of Experiment 3 concerning the manifestation of the main stress should be unlikely, while acoustic differences between the main stresses of SS and RS words could be possible. When considered together, the data for secondary and enclitic stress suggest that in Greek there are very few stress levels, which are unlikely to require a representation with deep embedding as is appropriate for English.

4.5 CONCLUSION

In brief, Experiment 4 shows without doubt that it is wrong to equate the weakened lexical stress of a host in a host-and-clitic group, i.e. secondary stress, to rhythmic stress. While the host's stress retains its acoustic prominence, which makes it acoustically identical to a subordinate primary stress (as Experiment 3 has shown), syllables with rhythmic stress are acoustically very close to unstressed syllables. In addition, the data for final syllables support, albeit rather weakly, those of Experiment 3, in that they show that the enclitic stress is acoustically very similar to a primary stress. The acoustic differences between secondary and rhythmic stress prompt further investigation on the acoustic manifestation of rhythmic stress, a task which is undertaken in Chapter 5.

5. THE ACOUSTICS OF RHYTHMIC STRESS

In Chapter 4, the comparison between secondary and rhythmic stress on perceptual and acoustic grounds showed that secondary stress is both perceptually and acoustically distinct from rhythmic stress to which it has often been equated. It was observed that syllables said to have rhythmic stress are acoustically very similar to unstressed syllables. However, it is possible that rhythmic stress is acoustically present and that Experiment 4 failed to show any evidence for it because syllables with rhythmic stress were compared only to syllables with primary stress. A comparison between syllables with rhythmic stress and unstressed syllables is necessary to confirm whether or not the two are acoustically the same. This task is undertaken here. The material used for this purpose will be referred to as Experiment 5.

5.1 EXPERIMENT 5: METHOD

5.1.1 MATERIAL

The corpus of Experiment 5 consisted of two sets of tetrasyllabic words, (1) and (2) in Table 1, embedded in carrier phrases. Each set comprises three phonemically identical[1] test-words with different stress patterns: test-words (1a) and (2a) are stressed on the antepenultimate syllable, test-words (1b) and (2b) on the penultimate syllable, and test-words (1c) and (2c) on the final syllable (see Table 1). As the glosses indicate, the test-words in each set were semantically related to a greater or lesser extent[2] . The two sets of words allow the observation of potential differences with respect to rhythmic stress between vowels that can be reduced, the /u/ of the /akustikan/ set, and vowels that cannot, the /a/ and /o/ of the /xamoɣela/ set and the /a/ of the /akustikan/ set. (The conditions under which vowel reduction takes place, and the differences between the two sets in relation to it are discussed in section 5.3.)

Different carrier phrases were chosen for each test-word stress pattern, and care was taken for the carrier phrases to be phonemically similar in their boundaries with the test-words. (The carrier phrases differed slightly between sets (1) and (2) to facilitate the segmentation of the initial /a/ of the test words in set (2).) The aim was to create sentences which would have the same overall stress pattern. Thus, each sentence contains three stresses, one before and one after the stress of the test-word; in all cases there are three unstressed syllables between the stress of the test-word and each of the stresses of the carrier phrase (see Table 1).

This pattern results in different possibilities for rhythmic stress on the test-word, depending on the position of its primary stress. In (1a) and (2a), where the test-word is stressed on the

1 With the exception of test-word (2c) which does not contain a final /n/. This minor difference could not have had any effect on the acoustic manifestation of rhythmic stress.

2 The (a) and (b) stress patterns of set 2, /a'kustikan/ and /.aku'stikan/ *they were heard*, are equally common in standard Greek.

Table 1:

The two sets of test-words in their carrier phrases.

1

(a) /'eleɣe <u>xa'moɣela</u> ka'la/
She/he used to say smiles (n.) well.

(b) /'ipe <u>.xamo'ɣela</u> kaθa'ra/
She/he said smile (imper.) clearly.

(c) /θa 'po <u>xa.moɣe'la</u> kanoni'ka/
I will say she/he smiles properly.

2

(a) /'eleɣes <u>a'kustikan</u> ka'la/
You used to say they were heard well.

(b) /'ipes <u>.aku'stikan</u> kaθa'ra/
You said they were heard clearly.

(c) /θa 'pis <u>a.kusti'ka</u> kanoni'ka/
You will say headphones properly.

antepenult, there can be no rhythmic stress on the test-word, since a rhythmic stress on its initial syllable would result in a stress clash[3] . In (1b) and (2b), where the test-word is stressed on the penult, the first syllable of the test-word can carry rhythmic stress, as it is the middle one of the three unstressed syllables between the first two primary stresses of the sentence. Finally, in (1c) and (2c), where the test-word is stressed on the ultima, a rhythmic stress can fall on the antepenult of the test-word which is the middle one of three unstressed syllables. Thus, within a set of test-words it is possible to compare the initial syllables of the three words, to see whether the initial syllable of (b), which can carry rhythmic stress, is acoustically more prominent than the initial syllables of (a) and (c) which are unstressed. It is also possible to compare the antepenultimate syllables, to see whether the antepenult of (c), which can have rhythmic stress, is acoustically closer to the antepenult of (a), which carries primary stress, or to the antepenult of (b) which is unstressed.

Table 2 schematically presents the possibilities for the first two syllables of each word to carry rhythmic stress according to the test word's stress pattern. For clarity, in subsequent discussions initial and antepenultimate syllables which can carry rhythmic stress are preceded by /./, e.g.

[3] According to NV and M-DD it is possible for these words to have rhythmic stress on their final syllable, but this is not relevant here.

/.mo/, syllables carrying primary stress are preceded by /'/, e.g. /'mo/, and unstressed syllables are written without a diacritic. (Note that, due to typographical limitations, in Chapter 5 the dot symbol, /./, indicates rhythmic stress, while in Chapters 3 and 4 it indicates secondary stress.) As the initial syllable of both (a) and (c) test-words is unstressed, whenever a distinction between the two is necessary the position of primary stress on the word they belong to is mentioned.

Table 2:

Stress of initial and antepenultimate syllables.

	initial syllables	
1a. /'eleγe xa'moγela/	2a. /'eleγes a'kustikan/	unstressed
1b. /'ipe .xamo'γela/	2b. /'ipes .aku'stikan/	rhythmic stress
1c. /θa 'po xa.moγe'la/	2c. /θa 'pis a.kusti'ka/	unstressed
	antepenultimate syllables	
1a. /'eleγe xa'moγela/	2a. /'eleγes a'kustikan/	primary stress
1b. /'ipe .xamo'γela/	2b. /'ipes .aku'stikan/	unstressed
1c. /θa 'po xa.moγe'la/	2c. /θa 'pis a.kusti'ka/	rhythmic stress

In addition to the test sentences, the recording material included 6 distractor sentences which were added to the reading list to avoid a very rhythmical and monotonous reading of the test sentences. The distractors, which are presented in Table 3, included phonemically identical words with stress on different syllables.

5.1.2 SPEAKERS

DT, VK, SC and AA, four of the speakers who took part in Experiment 2, served in Experiment 5 as well (see Chapter 2, section 2.3.2 for details).

5.1.3 PROCEDURE

The same procedure as for all previous recordings was followed. The recording took place in the recording studio of the Department of Linguistics of the University of Edinburgh. The speakers read each test sentence 6 times from a randomised list typed in Greek.

5.1.4 MEASUREMENTS

The material was low-pass filtered at 8 kHz and digitised at 16 kHz. Duration, amplitude and F0 measurements of the first two syllables of each test-word, i.e. of those that were likely to have rhythmic stress, were obtained. Measurements were made as described in Chapter 3, section 3.3.1.

Table 3:

The distractor sentences.

1

(a) /i 'lena 'etroɣe 'ena porto'kali/
Lena was eating an orange.
(b) /fo'ruse 'ena a'pesio portoka'li ma'jo/
She/he was wearing an awful orange bathing suit.

2

(a) / i ja'ja mu δen pi'stevi sta 'maja/
My grandmother does not believe in magic.
(b) /'evala ti ma'ja na fu'skosi/
I put the yeast to froth.

3

(a) /o pa'teras mu psa'revi me a'poxi/
My father uses a net for fishing.
(b) /i maθi'tes 'ekanan apo'xi/
The pupils abstained from classes.

5.2 EXPERIMENT 5: RESULTS

5.2.1 DURATION

The pooled durational data are presented in Tables 4 and 5; mean syllable durations for each speaker separately are shown in Figures 1 and 2. Syllable and vowel durations were statistically analysed by means of 2-way repeated-measures analyses of variance (type of stress x speaker). Separate ANOVAs were performed on the data from each set, because the segmental makeup of the syllables under investigation was quite dissimilar.

The initial syllables /.xa/ and /.a/ of test-words with penultimate stress were compared with the initial syllables /xa/ and /a/ of test-words with antepenultimate and final stress. /.xa/ has the same duration as the /xa/ of /xa.moɣe'la/ ($F(1,20)=0.2$, n.s.). The comparison of /.xa/ with the /xa/ of /xa'moɣela/ shows an interaction between speakers and type of stress. Table 6 shows that the interaction is due to AA, in whose speech the /xa/ of /xa'moɣela/ is significantly longer than the /.xa/ of /.xamo'ɣela/ (see Figure 1). This difference does not support the rhythmic stress hypothesis, since the unstressed /xa/ is longer than the /.xa/ with rhythmic stress.

The comparison of /.a/ to the /a/s of /a'kustikan/ and /a.kusti'ka/ also shows an interaction between speakers and type of stress. Table 7 shows that the interaction is due to VK in whose speech /.a/ is longer than either unstressed /a/ (see Figure 2). This difference in VK's speech supports the rhythmic stress hypothesis.

Table 4:

Means (in ms) and standard deviations of the consonant, vowel and syllable durations for /xa/ (top) and /mo/ (bottom) of the /xamoγela/ set for all speakers.

		consonant	vowel	syllable
xa’moγela	Mean	94	56	150
	S.D.	11	7	12
.xamo’γela	Mean	89	49	137
	S.D.	13	8	17
xa.moγe’la	Mean	90	45	135
	S.D.	12	8	15
xa’moγela	Mean	85	97	182
	S.D.	12	10	18
.xamo’γela	Mean	66	71	137
	S.D.	11	12	17
xa.moγe’la	Mean	59	60	120
	S.D.	9	8	14

The antepenultimate syllable of /xa.moγe’la/, /.mo/, is shorter than /’mo/ which has primary stress ($F(1,20)=112.4$, $p<0.000$). Table 8 shows that /.mo/ is also shorter than the unstressed /mo/ in the data of DT, SC and AA, while it is of the same duration as /mo/ in VK’s data (see Figure 1). Neither the data of the former subjects, nor those of the latter support the rhythmic stress hypothesis. Similarly, /.ku/ is shorter than /’ku/ ($F(1,20)=164.2$, $p<0.000$), and of the same duration as /ku/ ($F(1,20)=0.15$, n.s.). In brief, syllable durations of both initial and antepenultimate syllables provide no evidence for rhythmic stress, with the exception of VK’s data in which the /.a/ of /.aku’stikan/ is longer than the /a/s of /a’kustikan/ and /a.kusti’ka/.

The vowel data agree well with the syllable data; some rare discrepancies between the two are observed in the /xa/ and /mo/ data only. Although none of these discrepancies constitutes evidence for rhythmic stress, they are mentioned here because they are relevant for the interpretation of the AI data (AI is measured on the syllable nucleus, not the whole syllable). Specifically, in AA’s speech the vowel of /.xa/ has the same duration as that of /xa/ of /xa’moγela/ ($F(1,20)=2.45$, n.s.), while in DT’s data the vowel of the same /xa/ is longer than that of /.xa/ ($F(1,20)=9.58$, $p<0.005$); also in AA’s data, the vowels of /mo/ and /.mo/ have the same duration ($F(1,20)=1.06$, n.s.).

Table 5:

Means (in ms) and standard deviations of the consonant, vowel and syllable durations for /a/ (top) and /ku/ (bottom) of the /akustikan/ set for all speakers.

		consonant	vowel	syllable
a'kustikan	Mean	-	-	62
	S.D.	-	-	8
.aku'stikan	Mean	-	-	63
	S.D.	-	-	9
a.kusti'ka	Mean	-	-	60
	S.D.	-	-	9

		consonant	vowel	syllable
a'kustikan	Mean	77	97	172
	S.D.	12	7	14
.aku'stikan	Mean	59	65	124
	S.D.	8	15	16
a.kusti'ka	Mean	59	66	125
	S.D.	11	11	15

Table 6:

F-ratios and probability levels from planned comparisons between the durations of the initial syllables of /xa'moγela/ and /.xamo'γela/; /xa/ : /.xa/.

/xa/:/.xa/	DT	VK	SC	AA
F(1,20)	1.50	3.49	1.87	5.07
p	n.s.	n.s.	n.s.	0.03

Another type of analysis, similar to the normalisation of AI and RMS data, was used on the durational data of Experiment 5. The durations of the first two syllables of each test-word were divided by the duration of the word, in order to see what percentage of the whole word's duration each of these syllables occupied. It is possible that syllables with rhythmic stress, although not longer than unstressed syllables in absolute terms, occupy a larger proportion of a word's

Table 7:

F-ratios and probability levels from planned comparisons between the durations of the initial syllables of /a'kustikan/ and /.aku'stikan/, /a/ : /.a/, (top), and of the initial syllables of /.aku'stikan/ and /a.kusti'ka/, /.a/ : /a/, (bottom).

/a/:/.a/	DT	VK	SC	AA
F(1,20)	3.48	13.95	4.04	0.74
p	n.s.	0.001	n.s.	n.s.

/.a/:/a/				
F(1,20)	3.23	8.77	3.83	1.23
p	n.s.	0.007	n.s.	n.s.

Table 8:

F-ratios and probability levels from planned comparisons between the durations of the antepenults of /.xamo'γela/ and /xa.moγe'la/; /mo/ : /.mo/.

/.mo/:/mo/	DT	VK	SC	AA
F(1,20)	15.05	1.44	12.61	9.19
p	0.001	n.s.	0.002	0.006

duration, a feature that could make them more prominent.

Figure 3 shows that this hypothesis is not supported by the data: syllables with rhythmic stress are not proportionally longer than unstressed syllables. The rhythmically stressed /.xa/ of /.xamo'γela/ occupies a smaller proportion of the word's duration than /xa/ of /xa'moγela/ (F(1,20)=61.82, p<0.000), and the same proportion as /xa/ of /xa.moγe'la/ (F(1,20)=1.91, n.s.). The initial syllable of /.aku'stikan/ occupies the same proportion of the word's duration as both unstressed /a/s (F(2,40)=0.15, n.s.). /.mo/ is proportionally shorter than /'mo/ (F(1,20)=191.25, p<0.000); /.mo/ is also shorter than /mo/ in SC's and AA's speech, and has the same duration as /mo/ in DT's and VK's speech (SC: F(1,20)=5.9, p<0.02; AA: F(1,20)=5.37, p<0.029; DT: F(1,20)=1.8, n.s.; VK: F(1,20)=0.72, n.s.). Similarly, /.ku/ occupies a shorter proportion of the word's duration than /'ku/ ($F(1,20)=176.4$, $p<0.000$), and the same as /ku/, ($F(1,20)=2.09$, n.s).

In addition, the ratio of the initial to the antepenultimate syllable was obtained for the following reason: in test-words with penultimate stress it is the initial syllable that can carry rhythmic stress, while in test-words with final stress it is the antepenult that can carry rhythmic stress. It is possible that the syllable with rhythmic stress becomes more prominent by being proportionally longer than its neighbouring unstressed syllable. Thus, if the initial syllable's duration is divided by that of the antepenult's, then the ratio should be higher if rhythmic stress is on the initial syllable, and lower if it is on the antepenult. On the contrary, the ratios /.xa/-to-/mo/ and /xa/-to-/.mo/ are the same for AA, VK and DT (AA: $F(1,20)=1.67$, n.s.; VK: $F(1,20)=0.33$, n.s.; DT: $F(1,20)=2.99$, n.s.). SC's data do not show evidence for rhythmic stress either, as /xa/-to-/.mo/ is higher than /.xa/-to-/mo/ ($F(1,20)=9.74$, $p<0.005$). As Figure 4 shows, the ratio of /.a/-to-/ku/ is not different from that of /a/-to-/.ku/ ($F(1,20)=1.74$, n.s.). In conclusion, neither absolute nor relative durations of initial and antepenultimate syllables show any evidence of lengthening when they can carry rhythmic stress.

Figure 1

On the left, mean syllable durations of /xa/ of /xa'moγela/, /.xa/ of /.xamo'γela/ and /xa/ of /xa.moγe'la/, in this order; on the right, mean syllable durations of /'mo/ of /xa'moγela/, /mo/ of /.xamo'γela/ and /.mo/ of /xa.moγe'la/, in this order. Values are for each speaker separately.

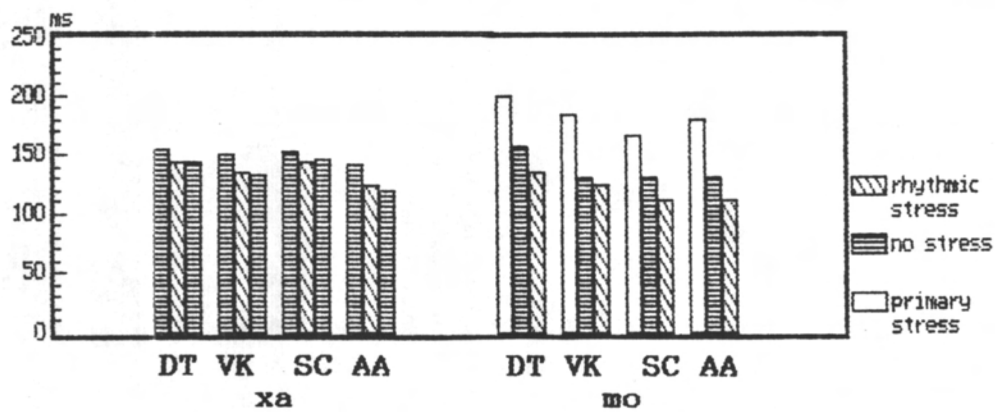


Figure 2

On the left, mean syllable durations of /a/ of /a'kustikan/, /.a/ of /.aku'stikan/ and /a/ of /a.kusti'ka/, in this order; on the right, mean syllable durations of /'ku/ of /a'kustikan/, /ku/ of /.aku'stikan/ and /.ku/ of /a.kusti'ka/, in this order. Values are for each speaker separately.

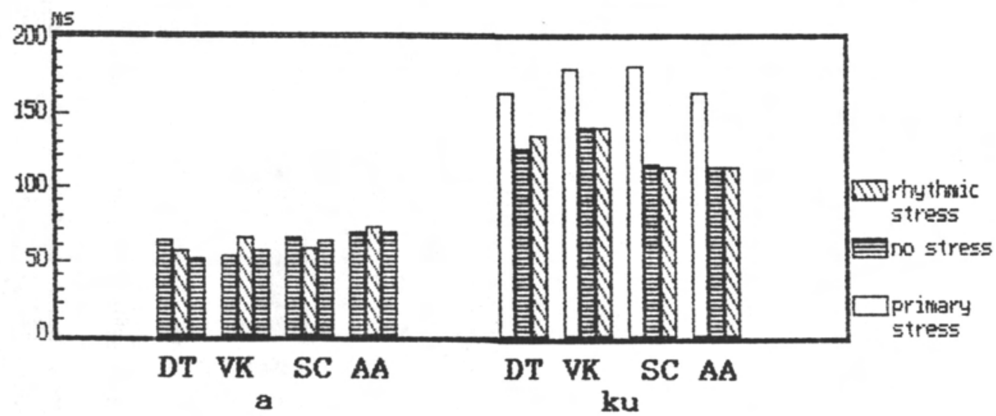


Figure 3

Mean syllable durations of /xa/ and /mo/ of the /xamoγela/ set, and of /a/ and /ku/ of the /akustikan/ set, expressed as percentages of the word's duration, for all speakers.

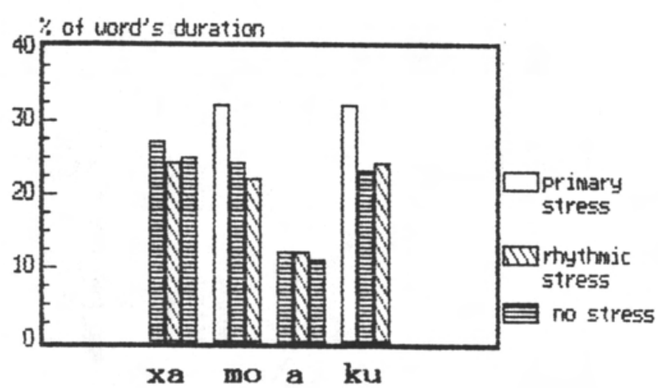
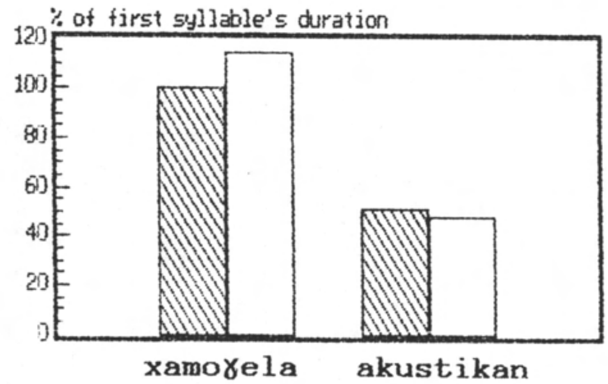


Figure 4

Mean ratios of first-to-second syllable duration, expressed as percentages, for all speakers. Hatched bars represent rhythmically stressed-to-unstressed syllable durations, /.xa/-to-/mo/ (left) and /.a/-to-ku/ (right); clear bars represent unstressed-to-rhythmically stressed syllable durations, /xa/-to-/.mo/ (right) and /.a/-to-/ku/ (left).



5.2.2 AMPLITUDE

Means and standard deviations of AI and RMS for all speakers are presented in Table 9; amplitude integral means for each speaker are presented in Figures 5 and 6. The AI data, which were also examined by means of 2-way repeated-measures ANOVAs (type of stress x speaker), give somewhat more evidence than the durational data in favour of rhythmic stress.

The /.xa/ of /.xamo'ɣela/ has the same AI as the two /xa/s (F(2,40)=0.23, n.s.). In the data from the initial /akustikan/ syllables, however, there is speaker and type of stress interaction, which, as Table 10 shows, is due to DT and SC (see also Figure 6). In DT's speech /.a/ has greater AI than both /a/s. In contrast, in SC's speech the /a/ of /a.kusti'ka/ has greater AI than the /.a/ of /.aku'stikan/. Thus, although DT's data show evidence for rhythmic stress, SC's data do not.

Table 9:

Means and standard deviations of the normalised AI and RMS of the initial syllables (top) and of the antepenults (bottom) of both sets of test-words for all speakers.

		/xa/ AI	RMS	/a/ AI	RMS	
xa'moγela	Mean	34	105	42	123	a'kustikan
	S.D.	7	15	7	19	
.xamo'γela	Mean	33	113	46	132	.aku'stikan
	S.D.	5	17	9	22	
xa.moγe'la	Mean	33	115	49	146	a.kusti'ka
	S.D.	6	16	8	18	
		/mo/		/ku/		
xa'moγela	Mean	53	128	54	127	a'kustikan
	S.D.	4	10	10	21	
.xamo'γela	Mean	37	104	22	63	.aku'stikan
	S.D.	4	10	8	21	
xa.moγe'la	Mean	41	124	26	74	a.kusti'ka
	S.D.	5	11	9	25	

The rhythmically stressed /.mo/ has smaller AI than /'mo/ which has primary stress ($F(1,20)=189.23$, $p<0.000$). As shown in Table 11, /.mo/ has the same AI as /mo/ in VK's and SC's speech, but in AA's and DT's speech it has greater AI than /mo/ (see Figure 5). Similarly, /.ku/ has smaller AI than /'ku/ ($F(1,20)=227.6$, $p<0.000$); as Table 12 shows, /.ku/ has the same AI as /ku/ in VK's, SC's and AA's speech, but in DT's speech it has higher AI than /ku/ (see Figure 6). Thus, among the antepenultimate syllables, there are 3 out of a total of 8 instances (2 test-words x 4 speakers) which support the rhythmic stress hypothesis (two in DT's data and one in AA's).

In summary, in the /xamoγela/ set, there is no evidence for rhythmic stress on /.xa/ of /.xamo'γela/, but both DT and AA show evidence for rhythmic stress on /.mo/ of /xa.moγe'la/. In the /akustikan/ set, VK, SC and AA show no evidence for rhythmic stress on either the /.a/ of /.aku'stikan/ or the /.ku/ of /a.kusti'ka/, but DT shows evidence for rhythmic stress on both of these syllables. Thus, 1 of these 4 speakers seems to produce weak rhythmic stresses fairly consistently. As there are no differences in the durations of vowels with rhythmic stress and

Table 10:

F-ratios and probability levels from planned comparisons between the AI of the initial syllables of /a'kustikan/ and /.aku'stikan/, /a/ : /.a/, (top), and of the initial syllables of /.aku'stikan/ and /a.kusti'ka/, /.a/ : /a/, (bottom).

/a/:/.a/	DT	VK	SC	AA
F(1,20)	7.55	2.29	1.25	0.8
p	0.01	n.s.	n.s.	n.s.

/.a/:/a/				
F(1,20)	11.37	0.21	23.54	1.44
p	0.003	n.s.	0.000	n.s.

Table 11:

F-ratios and probability levels from planned comparisons between the AI of the antepenults of /.xamo'γela/ and /xa.moγe'la/, /mo/ : /.mo/.

/mo/:/.mo/	DT	VK	SC	AA
F(1,20)	20.89	0.99	0.04	5.22
p	0.000	n.s.	n.s.	0.03

Table 12:

F-ratios and probability levels from planned comparisons between the AI of the antepenults of /.aku'stikan/ and /a.kusti'ka/, /ku/ : /.ku/.

/ku/:/.ku/	DT	VK	SC	AA
F(1,20)	5.08	1.01	0.43	3.38
p	0.03	n.s.	n.s.	n.s.

unstressed vowels, these AI differences must be due to differences in RMS. This is confirmed by the RMS data which mirror the AI ones.

Figure 5

On the left, mean normalised AI of /xa/ of /xa'moγela/, /.xa/ of /.xamo'γela/ and /xa/ of /xa.moγe'la/, in this order; on the right, mean normalised AI of /'mo/ of /xa'moγela/, /mo/ of /.xamo'γela/ and /.mo/ of /xa.moγe'la/, in this order. Values are for each speaker separately.

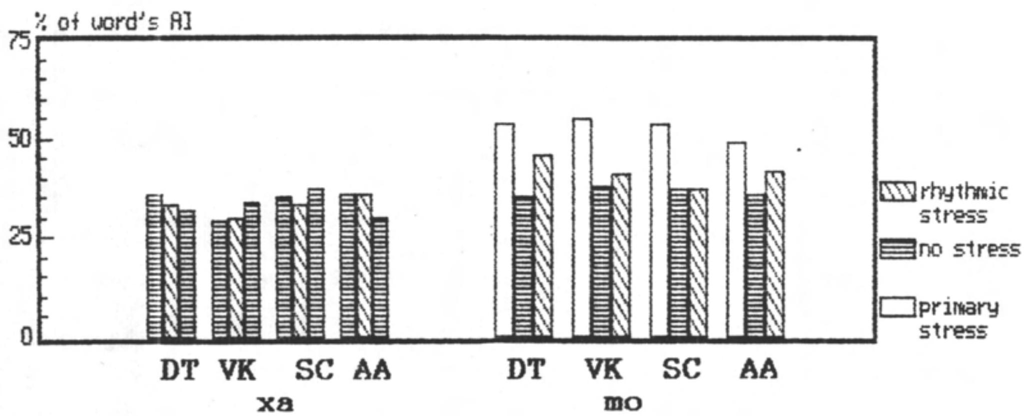
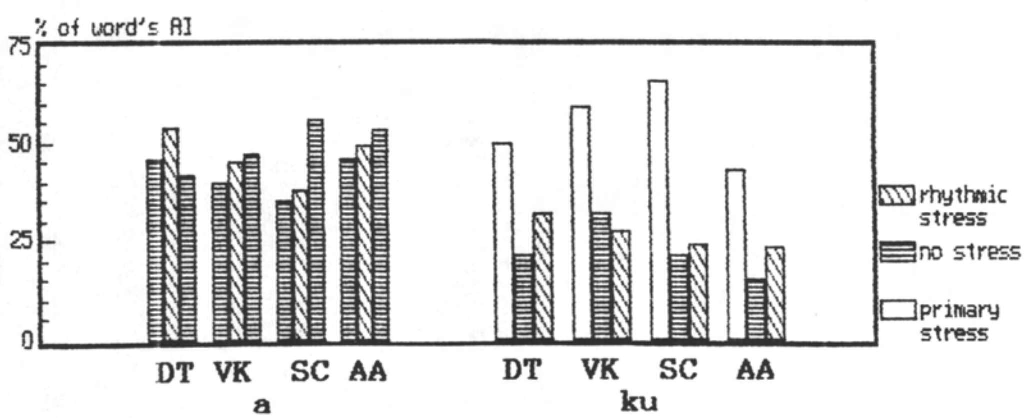


Figure 6

On the left, mean normalised AI of /a/ of /a'kustikan/, /.a/ of /.aku'stikan/ and /a/ of /a.kusti'ka/, in this order; on the right, mean normalised AI of /'ku/ of /a'kustikan/, /ku/ of /.aku'stikan/ and /.ku/ of /a.kusti'ka/, in this order. Values are for each speaker separately.



5.2.3 FUNDAMENTAL FREQUENCY

Fundamental frequency contours of the /xamoγela/ set can be seen in Figures 7-10. Only one set of /akustikan/ test-words, from SC's data, is presented in Figure 11; in the /.aku'stikan/ and /a.kusti'ka/ tokens of the other speakers the pitch tracker could not extract any F0 information about the middle vowels /u/ and /i/ which were very short or whispered (for a discussion see section 5.3).

When searching for evidence for rhythmic stress in F0 patterns, it is essential to consider these patterns in the context of the F0 contour of the sentence the test-word belongs to. As can be seen in Figures 7-10, the contours of all sentences were essentially the same, regardless of the position of the primary stress in the test-word. Each contour is composed of an initial peak, a trough and another peak. The initial peak corresponds to the syllable following the stressed syllable of the carrier phrase and the trough to the following two unstressed syllables. The lowest point of the F0 contour usually coincides with the very beginning of the stressed syllable of the test-word. On this stressed syllable, F0 starts rising, reaching the next peak on the syllable following the stressed one, at which point F0 starts falling again. Thus, each F0 peak is related to one of the first two stressed syllables although it does not coincide with them. (The last stressed syllable, which belongs to the carrier phrase, usually has a much smaller rise, as it is the last stressed syllable in a sentence pronounced with falling intonation.)

The fact that F0 peaks do not coincide with stressed syllables is not surprising. The same phenomenon was observed in the data of Experiment 2, in which it was shown that the F0 peak in /'papa/ coincided with the unstressed final syllable rather than with the stressed initial one, although the F0 rise usually started during /'pa/. If the contours of Experiment 2 are compared to those of Experiment 5, it is clear that they are very similar, allowing for the fact that the contours of Experiment 2 are more fragmented due to the voiceless stops. In both Experiment 2 and Experiment 5, F0 rises from the first stressed syllable to the syllable following it and then starts falling, reaching its lowest value at the beginning of the next stressed syllable. It is not possible to detect any differences between the contours of Experiments 2 and 5, other than those which are due to the fact that in Experiment 2, stressed syllables are separated by two unstressed ones, while in Experiment 5, stressed syllables are separated by three unstressed ones. In other words no differences associated with rhythmic stress are found.

SC's /akustikan/ contours differ somewhat from his /xamoγela/ ones, in that the F0 of the stressed syllables of /a'kustikan/ and /.aku'stikan/ is falling rather than rising. As mentioned in Chapter 2, section 2.4.3, falling contours on stressed syllables sometimes occur in the data of Experiment 2, although in general falling F0 is not very usual on stressed syllables which are not sentence-final. In any case, SC's /akustikan/ contours, like the /xamoγela/ ones, include no F0 perturbations which could be related to rhythmic stress.

An argument against the above assertion could be that although the /.mo/ of /xa.moγe'la/ and the /mo/ of /.xamo'γela/ have falling F0, /.mo/ has higher maximum and minimum F0 values than

/mo/, and thus it can be considered more prominent. However, this is an untenable position because high minimum and maximum F0 values coincide with unstressed syllables following syllables with primary stress. Thus, by this argument, the /xa/ of /xa.moɣe'la/ (which follows the carrier phrase's stressed syllable) must also be considered more prominent than the /.xa/ of /.xamo'ɣela/, since the former has higher minimum and maximum F0 values than the latter.

It seems, then, that the F0 value of a syllable which does not have primary stress depends on this syllable's position in relation to the sentence's primary stresses. That is, the F0 of /.mo/ is higher than that of /mo/ because /.mo/ is closer to the previous stressed syllable than /mo/: compare /θa 'po xa.moɣe'la/ with /'ipe .xamo'ɣela/; similarly the F0 of /xa/ of /xa.moɣe'la/ is higher than that of /.xa/ of /.xamo'ɣela/ because /xa/ is closer to the carrier phrase's stressed syllable. This conclusion is confirmed by Botinis's (1989) data which show that in Greek the F0 contour is composed of peaks and troughs which are determined only by primary stresses. This feature of Greek F0 contours is very pronounced in Botinis's data which have the same basic F0 pattern as the present ones, even when 4 unstressed syllables intervene between 2 primary (or secondary) stresses (see e.g. Botinis 1989:43). In other words, the F0 fall after the peak associated with a primary (or secondary) stress is "spread out" so that F0 reaches its lowest point at the beginning of the next stressed syllable.

In conclusion, the data of Experiment 5 in relation to those of Experiments 2, 3 and 4 show that F0 perturbations are associated only with primary and secondary stress. The F0 values and the F0 pattern of syllables said to have rhythmic stress are not determined by rhythmic stress but by the way in which F0 contours are organised in Greek. Rhythmic stress has no effect on a sentence's F0 contour.

Figure 7

Speaker DT: waveforms and smoothed F0 contours of /xa'moγela/, /.xamo'γela/ and /xa.moγe'la/.

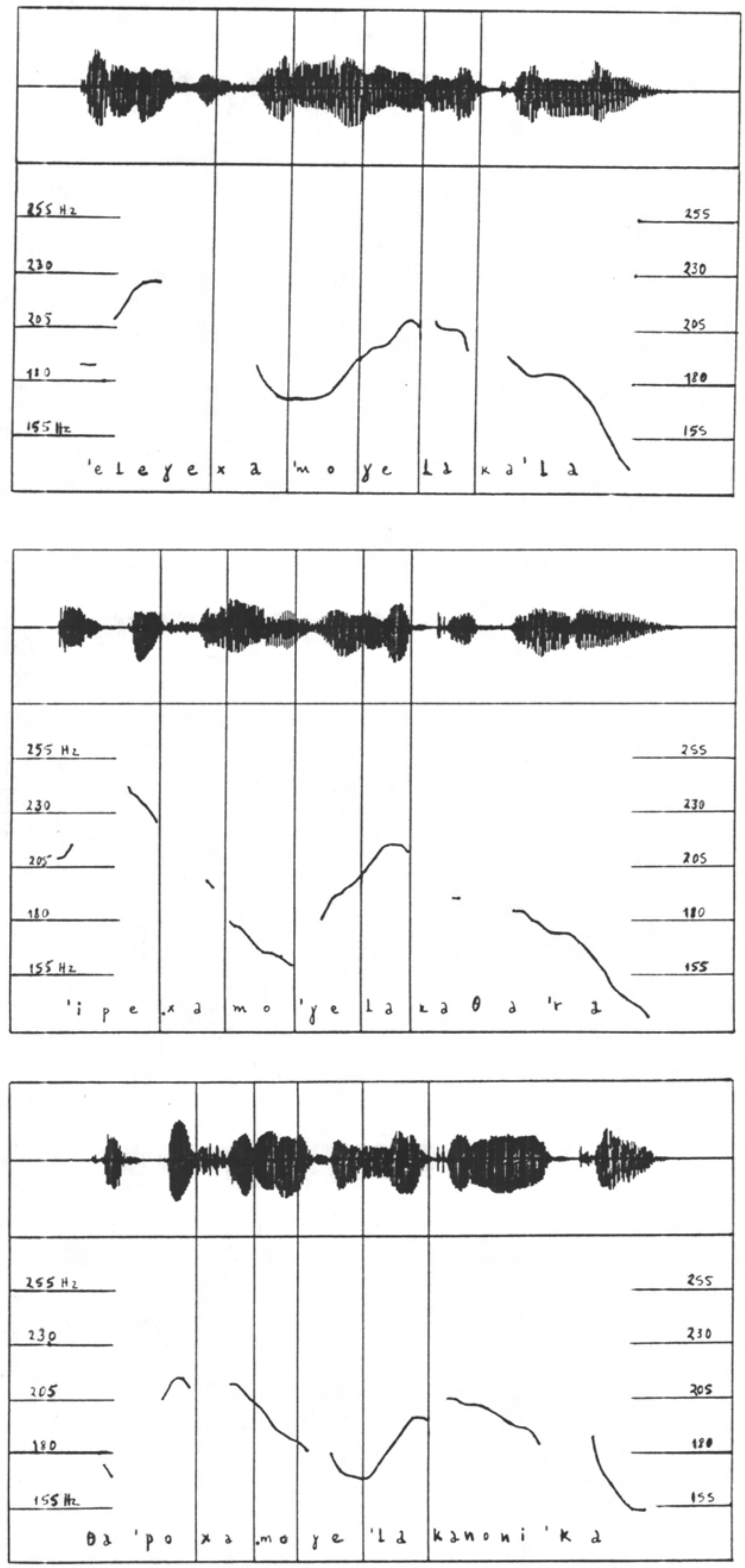


Figure 8

Speaker SC: waveforms and smoothed F0 contours of /xa'moγela/, /.xamo'γela/ and /xa.moγe'la/.

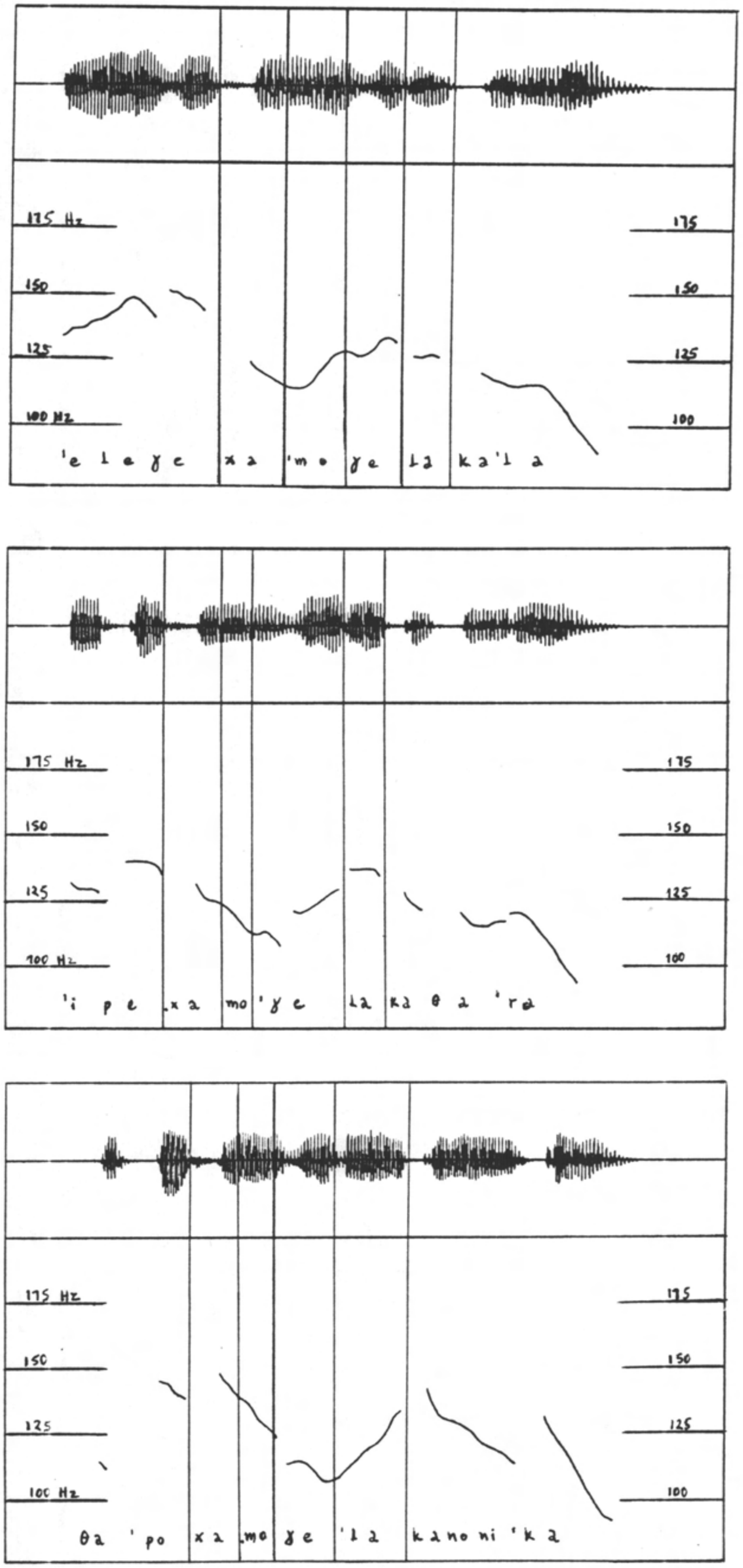


Figure 9

Speaker VK: waveforms and smoothed F0 contours of /xa'moɣela/, /.xamo'ɣela/ and /xa.moɣe'la/.

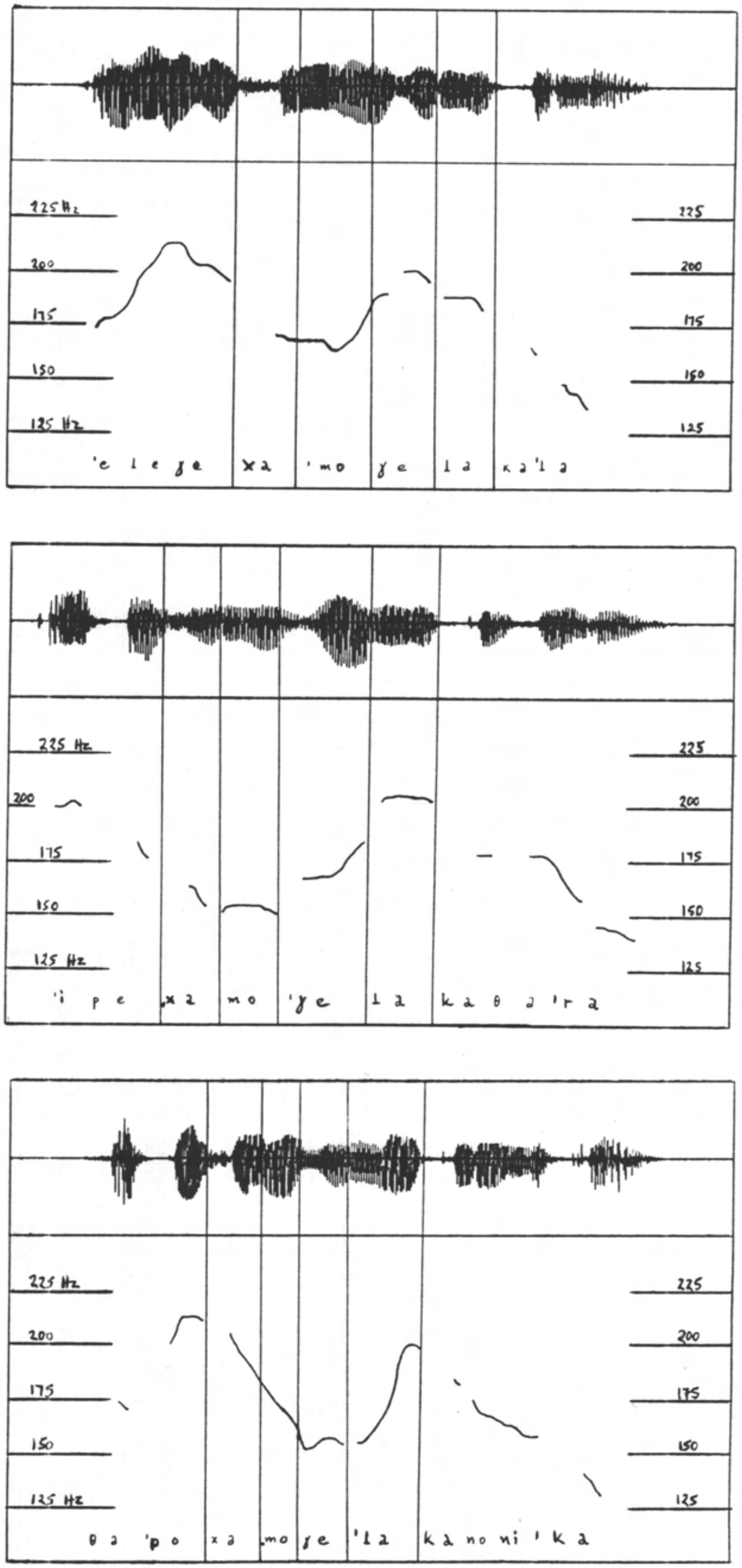


Figure 10

Speaker AA: waveforms and smoothed F0 contours of /xa'moɣela/, /.xamo'ɣela/ and /xa.moɣe'la/.

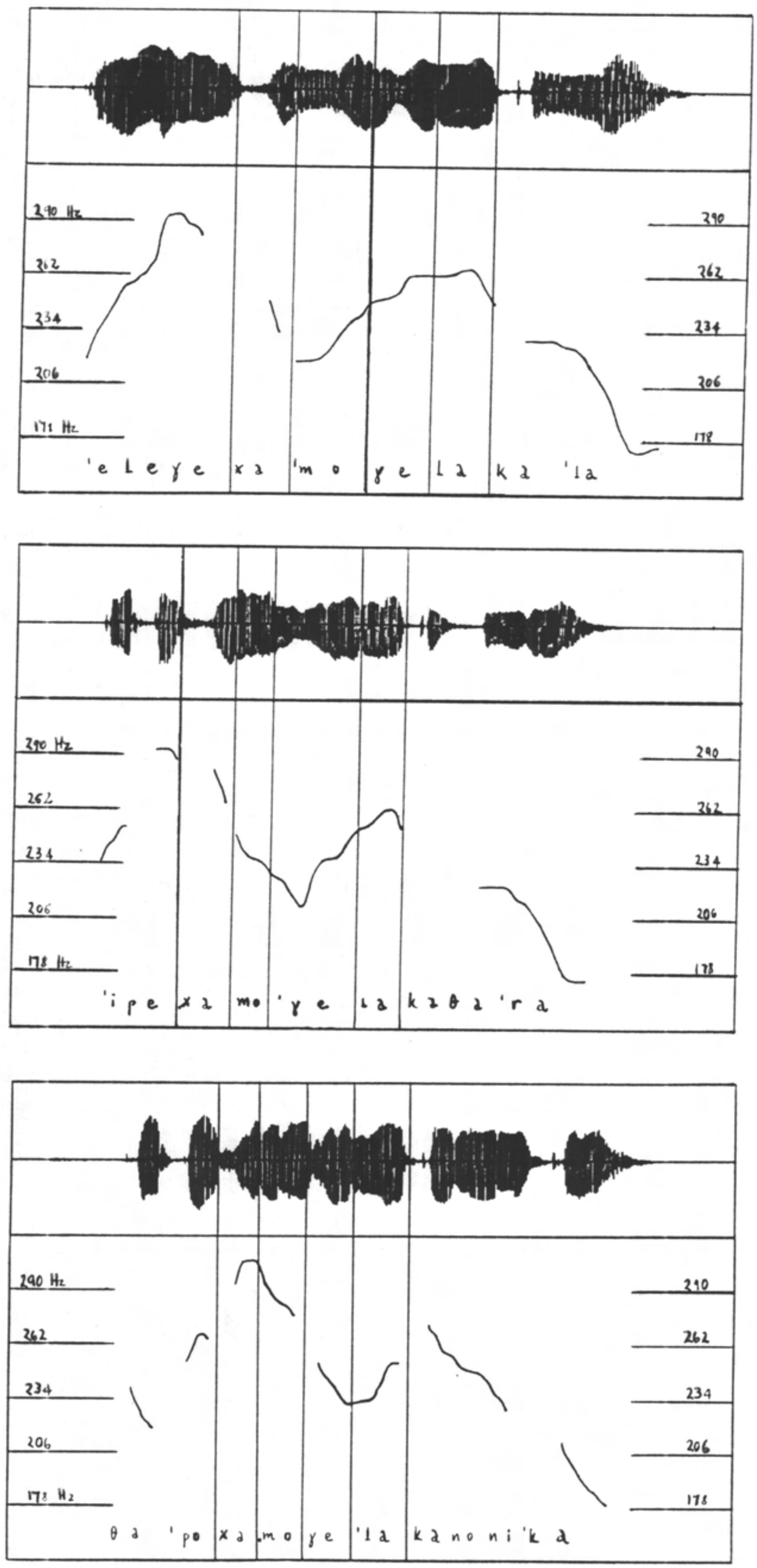
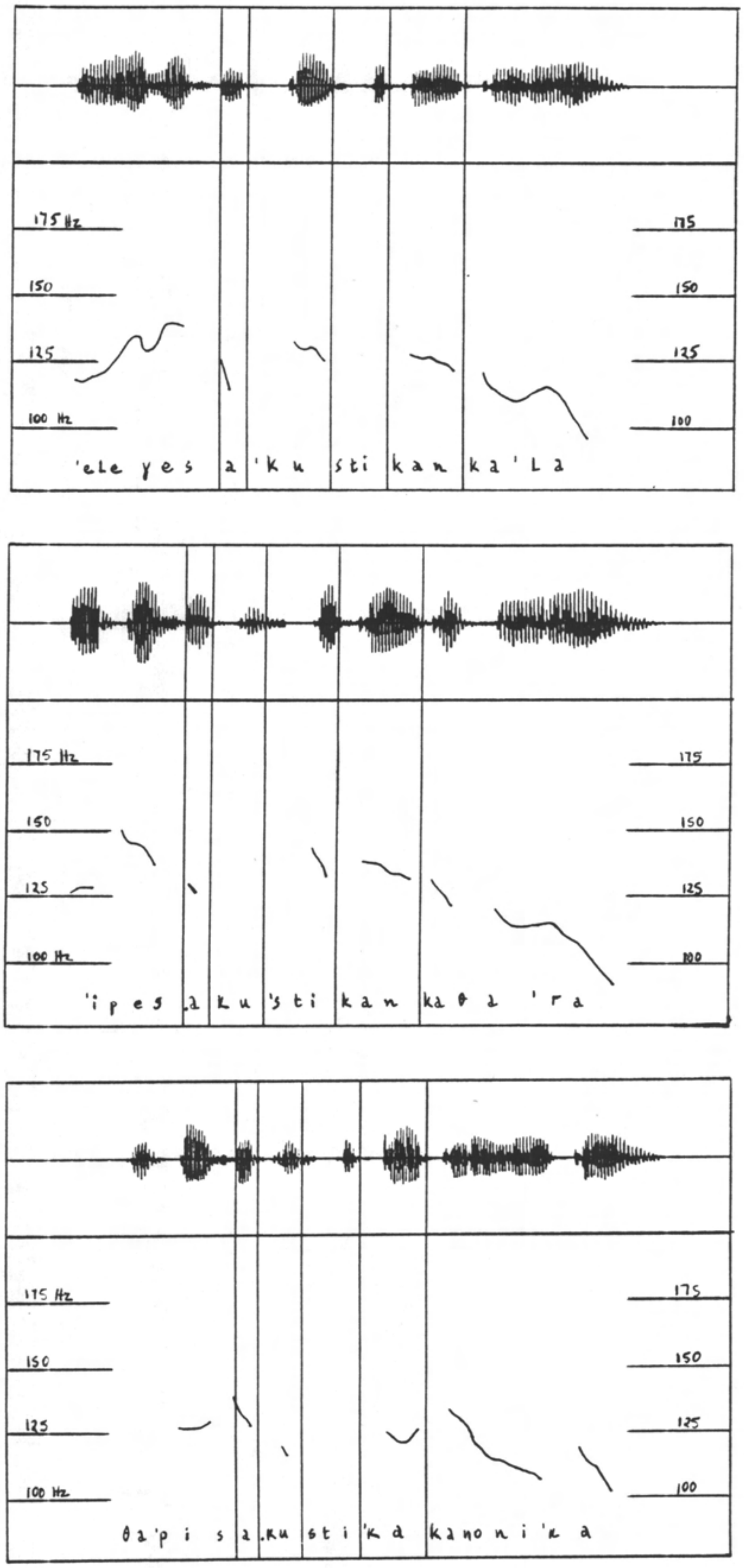


Figure 11

Speaker SC: waveforms and smoothed F0 contours of /a'kustikan/, /.aku'stikan/ and /a.kusti'ka/.



5.3 DISCUSSION

Experiment 5 presents very little evidence for rhythmic stress. First, syllables with rhythmic stress are acoustically much less prominent than syllables with primary stress, which have longer duration and higher AI than syllables with rhythmic stress and are associated with F0 perturbations. Second, rhythmically stressed syllables are acoustically very similar to unstressed syllables, with the exception of a small number of cases in which syllables with rhythmic stress have higher amplitude integral than unstressed syllables, due to higher RMS. These results corroborate those of Experiment 4 which showed acoustic similarities between rhythmically stressed and unstressed syllables, and considerable acoustic and perceptual differences between syllables with secondary and rhythmic stress.

Nevertheless, Experiment 5 has shown that in some cases, rhythmically stressed syllables are more prominent than unstressed ones. Do these cases provide sufficient evidence for rhythmic stress to justify taking it into account in a phonological representation of Greek rhythm? To answer this question, the acoustic evidence must be put into perspective. First, only speaker DT makes relatively consistent use of RMS to show rhythmic stress: in her data 3 of the 4 syllables which could carry rhythmic stress have higher RMS than unstressed syllables. AA, the other speaker who showed some evidence for rhythmic stress, used it only in 1 of the 4 possible cases. In short, out of 16 possible instances of rhythmic stress (4 speakers x 4 words) only 4 were realised, most of them by the same speaker. When considering the rarity of rhythmic stress in these data, one must bear in mind that the material consisted of simple sentences with the same overall stress pattern; that is, the conditions were likely to encourage a rhythmic reading of the sentences, and thus they were likely to maximise the occurrence of rhythmic stresses.

In addition, if it is accepted that rhythmic stress exists in Greek, then it must also be accepted that this type of stress is qualitatively distinct from primary and secondary stress. Primary and secondary stress share the same acoustic features: they are accompanied by longer duration, higher AI and F0 perturbations. The difference between them is one of degree. In contrast, the only possible acoustic correlate of rhythmic stress is average amplitude. The idea that rhythmic stress may be conveyed by amplitude disagrees entirely with the generally accepted view that rhythmic patterns are temporal: rhythmic stress in Greek is clearly not associated with longer duration as in other languages, Swedish for example (Bruce 1983)[4] .

Moreover, Experiment 2 has shown that RMS is a rather weak acoustic correlate even of primary stress. Botinis's (1989) data show that RMS is also a weak perceptual cue to stress. Botinis used synthesis-by-analysis to create stimuli from natural tokens of the words /'nomo/ *law* and /no'mo/ *county*. He found that in postnuclear position, where F0 was flat and the stress cues could only be amplitude and duration, changing average amplitude (i.e. the amplitude envelope of

[4] In my opinion rhythmic patterning is not necessarily created by temporal differences; for instance, in pitch accent languages, like Japanese, F0 is likely to be the major contributor to rhythm (for a discussion see Chapter 6, section 6.4). However, Greek has stress accent, and as the acoustic correlates of primary and secondary stress show, it does use duration to create rhythm.

the test-word) changed the identification rate of the stress pattern from 70% (natural stimulus) to 52% for /'nomo/, and from 90% to 76% for /no'mo/[5] . In prenuclear position, where F0 is the most robust stress cue, changing only average amplitude did not have any effect on stress judgements, while the change of the F0 contour from that of one test-word to that of the other shifted the stress judgements by 100%. These results suggest that speakers of Greek are not as sensitive to amplitude changes in the speech they hear as their use of amplitude in production implies they would be.

The weak role of amplitude in stress perception could also explain why Greek native speakers are not aware of rhythmic stress. The fact that rhythmic stress is not perceived by listeners is a powerful argument against the phonological representation of rhythmic stress; metrical theory relies on the assumption, inhereted from generative phonology, that the stress patterns it postulates are perceptible, if not always present in the acoustic signal. For instance, Hayes (1981:16) states: "[i]f the reader wonders, then, just what PHONETIC reality the trees in this thesis represent, the answer is essentially none: the trees depict the mental representation of the relative prominence of syllables and words in an utterance." Although Hayes does not mention who these "mental representations" belong to, it must be assumed that he implicitly refers to native speakers. It is precisely this assumption that the stress patterns postulated by metrical phonology have psychological reality that is the strongest argument against rhythmic stress in Greek: native speakers of Greek, with the notable exception of Malikouti-Drachman, do not seem to have "mental representations" of rhythmic stress, let alone adequate phonetic means of expressing it.

The fact that Greek speakers are unaware of stresses other than primary and secondary ones has been observed by other researchers as well. Dauer (1980a:5), for instance, says: "Drachman and Malikouti-Drachman [...] in their phonological analysis assign 'secondary stress' to every other syllable before the main stress in a word [...]: this word would then have to be /propáralíγusa/ [*antepenultimate*]. Nevertheless, none of my informants ever felt that a syllable to the left of the accented one in a word is stressed."

And later on (Dauer 1980a:340): "[...] Drachman and Malikouti-Drachman [...] have a phonological rule which assigns secondary stress 'to alternate syllables to the left of the main stress' [...]. None of my informants assigned stress in continuous texts according to this principle, and there is no acoustic evidence for it."

Dauer (1980a:5), accepting her informants' judgment, states: "Thus, although a compound word like /xartopetséta/ (χαρτοπετσέτα 'paper napkin', χαρτί 'paper') may have phonetic prominence on the first syllable (because of the inherent sonority and length of /a/) as well as the fourth, this syllable is not considered to be stressed by a naive speaker of Greek [...] and will not be considered stressed here. As a native speaker of English, I sometimes felt that the initial syllable was prominent in long words such as /simvoleoγráfos/ (συμβολαιογράφος 'notary

[5] In this experiment Botinis also manipulated amplitude integral, i.e. interchanged both the durations and the amplitude envelope of the two test words. This change fared much better: the identification rate of /'nomo/ dropped from 70% to 30%, while the identification rate of /no'mo/ dropped from 90% to 37%.

public', συμβόλαιο 'contract') or /krevatokámara/ (κρεββατοκάμαρα 'bedroom', κρεββάτι 'bed'); in English we need another stress in a word of that many syllables, and we generally prefer one towards the beginning of the word. These syllables are not considered to be stressed in Greek [emphasis added]".

Although in my opinion these arguments are sufficiently strong to support a phonological representation of Greek which makes no reference to rhythmic stress, it is worth considering whether there are any reasons why the acoustic evidence for rhythmic stress is so slim, and also whether there are any other means by which alternating rhythm can be achieved in Greek.

Concerning the first point, it could be argued that the reason why such acoustic evidence is so weak is that there are not enough unstressed syllables between stresses in the present data for the speakers to add a rhythmic stress. In other words, it could be argued that the minimal lapse in Greek must contain more than three unstressed syllables. Obviously, the data of Experiment 5 cannot provide evidence against this argument. Yet, it must be borne in mind that both M-DD and NV (1989) argue that a minimal clash in Greek, as in English, contains three unstressed syllables and is eliminated by the addition of a rhythmic stress. In this respect M-DD and NV share the opinion of many phonologists who maintain that rhythmic patterns are ideally binary and that the maximum number of consecutive unstresssed syllables that can be tolerated is two (e.g. LP, Hayes 1981, Selkirk 1984). Therefore, even if in Greek rhythmic stresses appear in sequences of more than three unstressed syllables, the fact remains that the data disagree with phonological descriptions of rhythm in general, and of Greek rhythm in particular, since they show that Greek rhythm does not follow a binary pattern.

Concerning the second point, one must examine whether there are in Greek means other than acoustic ones which can be used to create alternating rhythm. The use of such means, which may be related to stress, is well-known in English in which a three-way distinction is made between stressed syllables, heavy but unstressed syllables and unstressed syllables with reduced vowels. The presence of this three-way distinction allows the creation of alternating patterns[6] . For example:

(1)

```
      /\
     /  \
    /    \
    w     s
   /\    /\
   s w  s  w
   A la ba ma
   æ lɚ bæ mɚ
```

[6] This is of course a very simplified view of English stress patterns merely to illustrate the point that heavy syllables may be metrically strong, while reduced syllables are always metrically weak.

In Greek this is not a possible option as the language has only 5 vowels which all have the same phonological weight (see Chapter 1, section 1.5). Moreover, although most studies of Greek stress, including the present one, do not study spectral differences, it is fairly certain that unstressed vowels are not phonetically reduced, in the sense of becoming centralised. Studies that deal with spectral differences find no evidence for centralisation of unstressed vowels; for instance, Dauer (1980b) reports that in Greek even whispered unstressed vowels have the same basic formant structure as their stressed equivalents.

On the other hand, in Greek the high vowels /i/ and /u/ can be considerably reduced or altogether elided when they are in unstressed syllables. The phenomenon has been studied both phonologically and phonetically. For instance, Theophanopoulou-Kontou (1973) discusses high vowel reduction from a phonological point of view, while Dauer (1980b) presents a comprehensive acoustic study of high vowel reduction in Greek. Dauer observes that phonetic context and, to a lesser extent, stress pattern play a major part in regulating high vowel reduction. A high vowel is more susceptible to reduction when it is preceded and/or followed by voiceless consonants, in particular /s/, and when it is in a syllable immediately following a stressed one. In contrast, a vowel surrounded by voiced consonants or immediately preceding a stressed syllable is least likely to be reduced. From an acoustic point of view, Dauer observes that there are various stages of high vowel reduction in Greek, ranging from very short vowels (up to 30 ms) with full formant structure following nasals and laterals, to voiceless and usually fricated periods "with energy in the region of the second and third formants which clearly identifies the vowel as /i/ or /u/" (Dauer 1980b:18). When high vowels are elided the duration of the syllable remains virtually intact. This is why the term *reduction* rather than *elision*, the term favoured by Dauer, is used here.

Reduced vowels could play a part in creating alternating rhythmic patterns by making the unstressed and unreduced vowels surrounding them more prominent, and thus rhythmically strong. If this hypothesis is correct, then high vowels should be reduced when their reduction helps create alternating rhythm, but not when they are in a syllable which can carry rhythmic stress. Thus, high vowels should be reduced more often immediately before and after stressed syllables, and when they are an odd number of syllables away from the primary stress. This hypothesis is not confirmed by the general characteristics of vowel reduction in Greek, as described by Dauer (1980b). For example, the fact that the most unlikely position for reduction is the syllable preceding the stressed one is the reverse of what a hypothesis of vowel reduction for rhythmic purposes predicts.

The present findings support Dauer's observations on vowel reduction. As mentioned, the reason for using the /akustikan/ set of test-words was to see what the effect of rhythmic stress would be on /u/. If one of the purposes of reduction is to facilitate an alternating rhythm, then /ku/ should be reduced more often in /.aku'stikan/, where its reduction would make the initial /a/ more prominent, than in /a.kusti'ka/ where it is the only syllable that can carry rhythmic stress.

As unstressed /u/ is very short in the present data, to test this hypothesis I considered reduced only vowels which appear as friction in the waveform or are whispered (there are no elided vowels). The data do not support the above hypothesis: in the 24 tokens from all subjects, there is a total of 8 reductions of /u/ in an environment in which reduction could create an alternating pattern (/.aku'stikan/), and a total of 6 reductions in an environment in which /u/ can carry rhythmic stress (/a.kusti'ka/). Dauer's observation that vowels are reduced more often in post-stressed syllables is borne out by /i/ of /a'kustikan/ which is reduced in a total of 15 tokens out of 24[7] . In contrast, in /a.kusti'ka/, where /i/ precedes the stressed syllable, and where by being reduced it would make /.ku/ more prominent, /i/ is reduced in only 7 out of 24 tokens. No explanation for the different reduction patterns of pre- and post-stress high vowels can be offered, although they certainly do not point towards an alternating rhythm. As mentioned, a tendency for alternating rhythm would require that the syllable preceding the primary stress be short rather than long in order to make the syllable before it more prominent, hence rhythmically stressed.

The present data confirm Dauer's observation that high vowel reduction is regulated by phonetic parameters, such as the lack of voicing in the surrounding consonants, rather than rhythm. The data on vowel reduction also suggest that the rhythmic effect of this process is not to make one of the unstressed syllables more prominent than others, and thus create alternating rhythm; rather, it seems that the effect of vowel reduction is to reduce the temporal interval between successive stresses. Even this effect of vowel reduction on rhythm is limited, however. First, although /i/ is quite frequent, /u/ is particularly rare in Greek. Moreover, due to the influence of stress pattern and phonetic context, not all /i/s and /u/s can be reduced; e.g. reduction would be nearly impossible for an /i/ which is in the syllable preceding the stressed one and/or is preceded or followed by voiced consonants, e.g.

(2) /amiγδa'lja/ *almond tree,*

(3) /etimiγo'ria/ *verdict,*

(4) /eristi'kos/ *quarrelsome.*

Second, Greek native speakers are little aware of vowel reduction, especially of /i/ reduction (/u/ reduction is rather more stigmatised and thus speakers are somewhat more aware of it). Even linguistically sophisticated native speakers of Greek express surprise when confronted with waveforms which show no trace of /i/, as they are certain they can hear the reduced vowel when they listen to the relevant token. A possible explanation for this auditory impression of listeners is that they can recover the elided vowel from the quality of the preceding and following consonants which are palatalised or velarised when /i/ or /u/ respectively are being elided from between them. Regardless of reasons, however, the fact that the elided vowels can be recovered diminishes the effect of vowel reduction on rhythm.

In short, it can be said with certainty that there is no convincing evidence for rhythmic stress in Greek to the extent of justifying its inclusion in the phonological representation of the

---

7 The same criteria as for /u/ were used to define reduction in /i/.

language. Although rhythmic stress can occur, it cannot be considered the norm, as it is acoustically present only in the speech of some speakers, and is not recognised by the listeners. Vowel reduction is another strategy which may have a rhythmic effect. However, only two of the five Greek vowels can be reduced, and many words contain neither of them, or contain them in environments in which reduction is not possible. Moreover, vowel reduction is more frequent in environments in which it cannot create binary rhythmic patterns, and it is not blocked when its effect disrupts rhythmic alternation. Finally, reduction, especially of /u/, can be hindered by sociolinguistic considerations.

It is possible that acoustic prominence (by means of RMS) and vowel reduction are used to a greater extent in longer words, as Joseph & Warburton (1987) predict (see Chapter 1, section 1.6). However, everything points to the fact that Greek does not require alternation of strong and weak syllables, i.e in Greek there does not seem to exist the same strict requirement for the elimination of stress lapses observed in English and other languages. The strongest argument against rhythmic stress remains the fact that it is not perceived by native speakers of Greek, whether they are phonetically sophisticated or not.

Greek is not the only language in which there is so slim acoustic evidence for rhythmic stress. Similar findings for Italian rhythmic stress are reported by Farnetani & Kori (1990). The authors compared the durations of the initial vowels (in the following examples, the vowel /a/) in two-word noun phrases (e.g. /'mani 'korte/, /'nɔve 'mani/), compound words (e.g. /mani'kure/), and polysyllabic simplex words (e.g. /ma'nipolo/, /mani'kɔmjo/, /manife'stare/). Compound words in Italian are said to have secondary stress on their initial syllable (/.mani'kure/), while polysyllabic words may have rhythmic stress on a syllable preceding the primary stress (e.g. /.mani'kɔmjo/), in a way similar to that postulated for Greek. Farnetani & Kori found that only one of their three speakers had a durational difference between unstressed vowels and vowels with rhythmic stress, and even then only for some words in the corpus. The evidence for secondary stress was equally weak. Moreover, when durational differences between rhythmically stressed and unstressed vowels were present they were of a smaller scale than those reported by Bruce (1983) for Swedish. In other words, syllables which did not have primary stress had very similar durations. On the basis of these data, Farnetani & Kori propose that Italian does not have binary rhythm and that sequences of unstressed syllables are acceptable and probably favoured in this language. The results of Farnetani & Kori are very similar to the Greek ones and strongly suggest that not all languages have strict binary rhythm as phonologists postulate.

5.4 CONCLUSION

The purpose of Experiment 5 was to see which are the acoustic correlates of rhythmic stress, if any. The acoustic evidence for rhythmic stress in the present data is very slim. Syllables with rhythmic stress are of the same duration and have the same F0 patterns as unstressed syllables, but sometimes they have higher amplitude integral, due to higher RMS. Only some speakers use rhythmic stress, and even they do not use rhythmic stress in every possible environment. Another phenomenon, vowel reduction, was also examined to see whether reduced vowels help create alternating rhythmic patterns by making the unstressed syllables that surround them rhythmically prominent. Although it was observed that vowels are reduced when they can help create alternating rhythm, it was also shown that it is common for the vowels of syllables which can carry rhythmic stress to be reduced as well. It was suggested that the effect of vowel reduction is to shorten the time interval between successive stresses, rather than make unstressed syllables rhythmically strong. Both the acoustic and the phonological evidence suggests that Greek rhythm does not rely on alternating patterns and that sequences of at least 3 unstressed syllables are not felt to disrupt rhythm.