

STRESS IN MODERN GREEK: AN ACOUSTIC STUDY

Antonis Botinis

INTRODUCTION

This paper reports an experimental investigation of the contribution of fundamental frequency, duration, and intensity to the construction of word stress and sentence stress in Modern Greek. By word stress is meant the phonetic prominence over a syllable (of the type CONflict-conFLICT) to convey linguistic information. By sentence stress is meant that part of the sentence which carries the most important information; in the terminology of generative grammar, it is the *focus*, referring to the new information in contrast to *presupposition*, the information already shared by the speaker and the listener (Jackendoff 1972). Thus, sentence stress is semantically rather syntactically conditioned.

The paper addresses three basic questions: (1) What is the acoustic manifestation of word and sentence stress in Modern Greek? (2) Which is the most consistent acoustic parameter of word and sentence stress? (3) Are the acoustic parameters equally consistent across the utterance or does their contribution to the construction of stress depend on the position of sentence stress in the sentence?

EXPERIMENTAL PROCEDURE

Fundamental frequency (F_0), duration, and intensity data were recorded from two speakers who produced utterances with word stress and sentence stress. Oscillographic analyses were made of these recordings.

Speech material

Eight meaningful Greek sentences were constructed. All the sentences were declarative, with the same syntactic structure, i.e., subject-verb-adverb. The words composing the sentences were prosodic minimal pairs and the position of sentence stress varied

according to the contextual situation. The first two sentences were pronounced *neutrally*, i.e., the speaker had no contextual information. The remaining six test sentences were elicited as answers to questions formulated in different ways, to make the speaker choose one of the elements of the sentence as the focus and the carrier of the information required by the questioner. The segmental structure of the sentences was composed exclusively of sonorants in order to have a continuous Fo-contour. Below is the list of the test sentences (capital letters indicate sentence stress).

<i>Contextual frame</i>	<i>Test sentences</i>
1. None	<i>i mána múmene móni</i> (Mother was alone.)
2. None	<i>i naná mu méni moni</i> (Nana is single.)
3. <i>pja súmene móni?</i> (Who was alone?)	<i>I MÁNA múmene móni</i> (MOTHER was alone.)
4. <i>pja su méni moni?</i> (Who is single?)	<i>I NANÁ mu méni moni</i> (NANA is single.)
5. <i>ti súkane i mána móni?</i> (What was mother doing alone?)	<i>i mána MÚMENE móni</i> (Mother WAS STAYING alone.)
6. <i>ti su káni i naná moni?</i> (What is Nana doing single?)	<i>i naná MU MÉNI moni</i> (Nana IS STAYING single.)
7. <i>pos súmene i mána?</i> (How was mother?)	<i>i mána múmene MÓNI</i> (Mother was ALONE.)
8. <i>pos su méni i naná?</i> (How is Nana?)	<i>i naná mu méni MONÍ</i> (Nana is SINGLE.)

The test sentences were read in a random order, five times by each speaker. The speakers read the sentences as in everyday speech.

Subjects.

The main subject is a male student, 24 years old, brought up and educated in Athens; he speaks what is considered to be standard Athenian. In addition the present investigator, male, 32 years old,

was recorded. Both subjects speak about the same sociolect.

Dialect.

The dialect investigated is Modern Demotic Greek, a dialect spoken in southern Greece, especially in Athens and Peloponnesos.

Experimental equipment.

The recordings took place in a sound-treated room at the phonetics laboratory, Lund University. The frequency response of the tape recorder was flat within ± 2 dB from 30 Hz to 14 000 Hz and the signal to noise ratio was 63 dB. The microphone was flat within the frequencies 35 to 17 000 Hz. The Fo-contour was extracted by a F-J Electronics pitch extracting device along with a duplex oscillogram and recorded on a Siemens oscilloginc, with a paper speed of 100 mm/sec. Intensity was also recorded using a Fonema analysis unit.

Acoustic analysis.

Oscillograms of the eight utterances were made from the tape recording. From these oscillograms the first and the last repetitions of the test sentences were rejected. From the remaining three, the one which combined the best execution (in the investigator's judgement) and the finest oscillogram display was selected for acoustic analysis.

Intensity was calibrated in 5 dB steps and fundamental frequency in 10 Hz steps. Both intensity and fundamental frequency scales were linear. For the segmentation of the utterances, a duplex oscillogram and the intensity contour were used. Intensity was measured at the peak of the intensity contour for each syllable; peak Fo values for the stressed syllables and Fo minima for the unstressed ones were also measured.

RESULTS

The acoustic parameters of Fo, duration, and intensity are shown in Figs. 1, 2, 3, and 4. Figure 1 represents the neutral con-

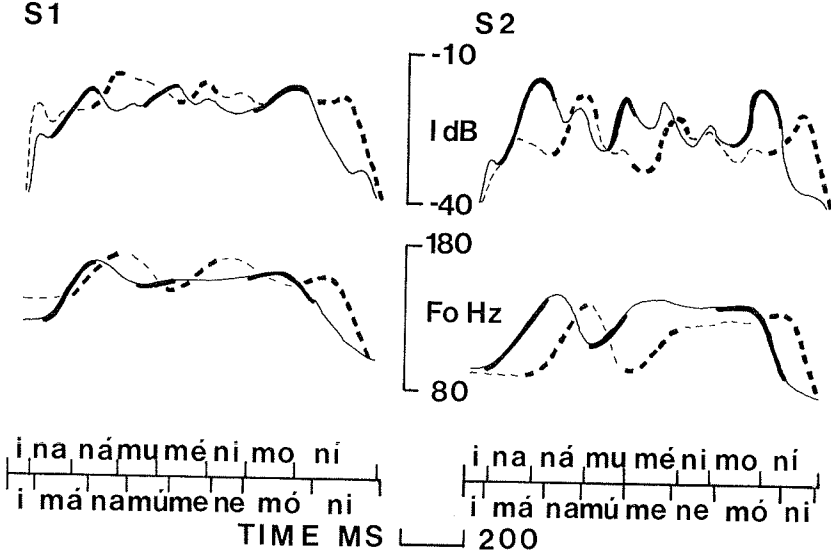


Figure 1. Neutral sentence. Intensity contour (upper), Fo-contour (middle), and duration (bottom) of the sentences *i mána múmene móni* (solid lines), and *i nána mu méni moni* (dashed lines). The thick lines represent the stressed syllables and the thin lines the unstressed syllables, subject 1 on the left and subject 2 on the right.

figuration of the two sentences; the other three figures represent the acoustic manifestation of the sentences with sentence stress located either at the first position, second position or third (final) position, in response to the contextual situation demanded by the question.

In Fig. 1 (the neutral sentence) the Fo-contour rises on each word stress although only moderately on the last stressed syllable (for absolute values see Table I). The Fo-contour of the unstressed syllables is either falling or level. The stressed syllables are longer than the unstressed ones; at the end of the utterances the syllables are longer no matter whether stressed or unstressed. The intensity contours have about the same configuration as the Fo-contours, with the addition of small peaks on the unstressed syllables.

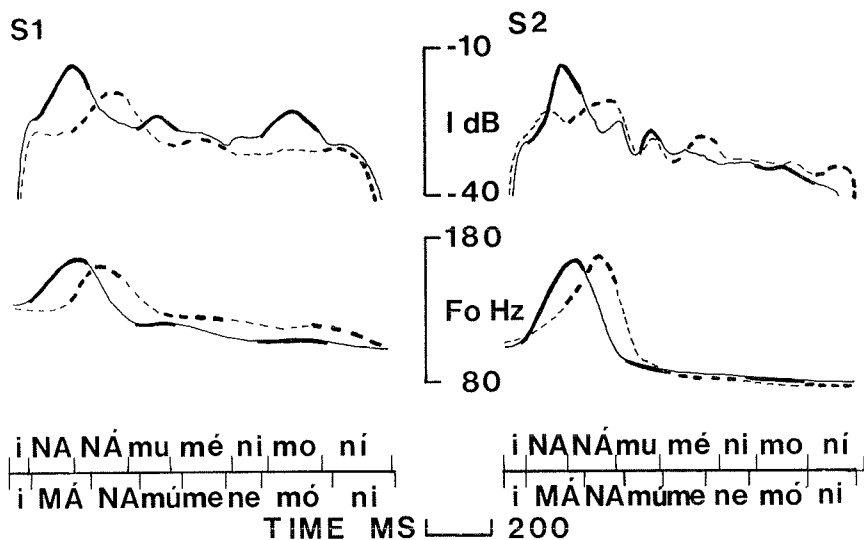


Figure 2. Focus 1 position. Intensity contour (upper), Fo-contour (middle), and duration (bottom) of the sentences *I MĀNA múmene móni* (solid lines), and *I NANÁ mu méní moni* (dashed lines). The thick lines represent the stressed syllables and the thin lines the unstressed syllables. Capital letters indicate focus, subject 1 on the left and subject 2 on the right.

In Fig. 2 (focus on the first position), the Fo-contour rises on the first stressed syllable (carrying the focus of the sentence) and then falls and flattens towards the end of the utterance. Duration preserves the same relations among the stressed and unstressed syllables as in the neutral sentences. The intensity is highest on the focus syllable, fairly high peaks on the other word stresses right to the end of the utterances, in contrast to the Fo-contour which remains low after the focus.

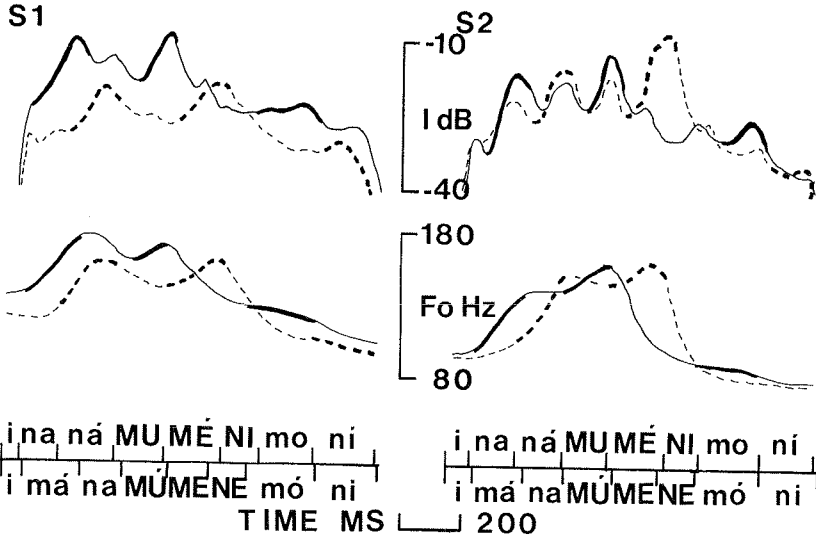


Figure 3. Focus 2 position. Intensity contour (upper), Fo-contour (middle), and duration (bottom) of the sentences *i mána MUMÉNI móni* (solid lines), and *i nána MUMÉNI móni* (dashed lines). The thick lines represent the stressed syllables and the thin lines the unstressed syllables. Capital letters indicate focus, subject 1 on the left and subject 2 on the right.

In Fig. 3 (focus on the second position), the Fo-contour rises on each stressed syllable until the focus syllable and then falls and flattens to the end of the utterances. Duration preserves the same structure as the neutral and the first-focus position sentences. The word stresses have higher intensity peaks than the unstressed syllables and preserve the same relationship to the end of the utterances, though the peak levels are lower after focus. The intensity contour is highest on the focus syllables.

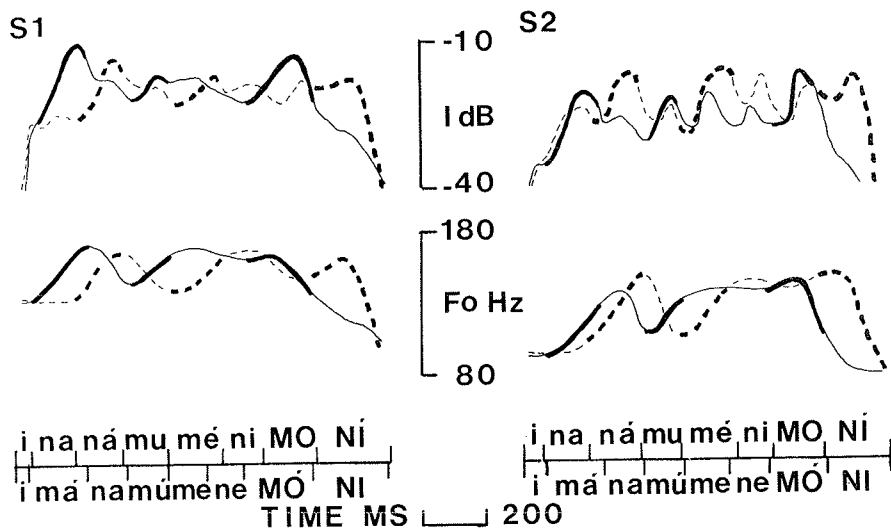


Figure 4. Focus 3 (final) position. Intensity contour (upper), Fo-contour (middle), and duration (bottom) of the sentences *i mána múmene MÓNÍ* (solid lines), and *i nána múmene MÓNÍ* (dashed lines). The thick lines represent the stressed syllables and the thin lines the unstressed syllables. Capital letters indicate focus, subject 1 on the left and subject 2 on the right.

The overall structure of Fig. 4 (focus on the third position) is quite similar to that of Fig. 1 (the neutral sentence). The stressed syllables are marked for Fo, duration, and intensity relative the unstressed ones.

All eight investigated declarative sentences have shown some degree of declination, both for Fo and intensity, which is more evident after focus.

		<u>Subject 1</u>															
		Sentence (a)								Sentence (b)							
		i	má	na	mú	me	ne	mó	ni	i	na	ná	mu	mé	ni	mo	ni
NEUTRAL	Fo	115	160	140	140	145	145	155	100	130	130	165	140	160	160	140	150
	D	70	170	120	130	120	110	210	200	60	130	140	110	150	110	150	250
	I	18	25	22	26	23	21	25	10	22	21	27	24	26	24	26	24
FOCUS 1		I	MA	NA	mú	me	ne	mó	ni	I	NA	NA	mu	mé	ni	mo	ni
	Fo	130	160	112	115	110	105	108	100	120	120	150	120	120	110	108	110
	D	60	190	140	140	130	110	210	200	50	130	160	130	180	100	160	220
FOCUS 2		i	má	na	MU	ME	NE	mó	ni	i	na	ná	MU	ME	NI	mo	ni
	Fo	128	180	150	170	130	120	115	100	112	112	150	130	150	110	105	100
	D	60	170	130	140	120	120	210	200	50	120	170	160	180	110	170	190
FOCUS 3		i	má	na	mú	me	ne	MÓ	NI	i	na	ná	mu	mé	ni	MO	NI
	Fo	128	175	135	160	165	150	150	100	130	130	160	130	155	160	140	155
	D	40	170	120	130	120	110	210	230	50	130	150	130	170	120	160	230
FOCUS 3	I	17	30	25	26	24	22	28	16	18	20	28	23	25	23	24	24
		<u>Subject 2</u>															
		Sentence (a)								Sentence (b)							
		i	má	na	mú	me	ne	mó	ni	i	na	ná	mu	mé	ni	mo	ni
NEUTRAL	Fo	95	135	105	125	135	128	132	80	95	95	135	95	120	120	125	135
	D	60	190	120	130	150	130	200	120	60	140	160	130	160	100	150	190
	I	13	27	22	24	23	20	26	6	11	18	25	17	22	20	17	22
FOCUS 1		I	MA	NA	mú	me	ne	mó	ni	I	NA	NA	mu	mé	ni	mo	ni
	Fo	100	150	95	90	85	85	83	80	100	120	160	90	85	85	85	85
	D	60	180	120	120	130	130	180	140	60	130	150	140	180	110	150	170
FOCUS 2		i	má	na	MU	ME	NE	mó	ni	i	na	ná	MU	ME	NI	mo	ni
	Fo	95	130	130	150	95	90	90	80	95	100	142	135	152	85	80	80
	D	70	160	130	150	130	130	190	180	60	140	150	140	180	110	170	170
FOCUS 3		i	má	na	mú	me	ne	MÓ	NI	i	na	ná	mu	mé	ni	MO	NI
	Fo	90	118	102	120	125	125	135	80	90	90	135	100	130	135	130	140
	D	60	170	120	120	120	120	190	190	50	140	160	120	170	110	160	190
FOCUS 3	I	8	22	18	22	22	19	25	6	6	20	25	20	26	25	22	25

Table I. The acoustic parameters Fo, duration, and intensity of the sentences *i mána múmene móni* and *i nána mu méni*. The neutral sentences as well as the three focal positions for both subjects are shown.

DISCUSSION

Before interpreting the results given in Table I, the main points will be recapitulated. First, word stress is realized differently before and after focus. Before focus, as well as in the neutral statements, all the three parameters contribute to a stressed syllable; after focus only duration and intensity are present in word stress. Second, sentence stress is realized as a relative increase of F_0 and intensity in comparison with an unfocused word stress in the same position of the sentence; the structure of the words bearing sentence stress is the same as those without focus as far as duration is concerned. Lastly, the effect of downdrift, the tendency of human languages to decline in pitch from the beginning to the end of an utterance (Breckenridge 1977, Bruce and Gårding 1978, Collier 1972, Thorsen 1978), is quite apparent in the majority of the utterances analysed.

It is convenient to discuss sentence stress first. The word *mána* in focal position (Fig. 2) will be compared with the same word without focus (Fig. 3 and 4) in order to isolate the sentence stress component. It is easy to be led astray by the absolute acoustic values (Table I). For instance, in sentence (a), subject 1, when the word *mána* is in focus, F_0 rises to 160 Hz on the stressed syllable. When *mána* is not focused, F_0 rises to 180 and 175 Hz (the neutral sentence not considered). If the stressed syllable is instead compared with the unstressed one, the F_0 difference for *mána* in focus is found to be 48 Hz whereas the differences for the unfocused *mána* are 30 and 40 Hz. The other acoustic parameters can be examined in the same way. Differences in duration are found to be almost constant, no matter whether the word is in focus or not, while intensity is 11 dB higher for the stressed syllable in focus position, 4 and 5 dB higher in non-focal position. Thus, rising F_0 and higher intensity are acoustic elements characterizing sentence stress for subject 1. The same holds true for subject 2. Duration does not seem to contribute to the acoustic structure of sentence stress.

When the word *mána* is compared with *naná* in pre-focal position, we see that the stressed syllables have noticeably higher values than the unstressed syllables, for all three acoustic parameters, for both subjects. Fo is always realized as a rise to denote word stress in Modern Greek (Botinis 1979). Hyman (1977) has observed that in other languages word stress can be realized both as rising and falling Fo. This has been reported for Swedish as well (Gårding et al. 1970, Hadding-Kock 1961). Thus, Fo, duration, and intensity are present on the word stress in pre-focal and focal position.

The acoustic pattern of the post-focus stressed syllables is quite different from the structure of the pre-focus stressed syllables. The most striking difference is that variations of Fo are reduced to a minimum, about 10 Hz. Bruce (1977) and O'Shaughnessy (1979) have reported similar data for Swedish and English respectively. Although these small variations are above the perceptual threshold (Lehiste 1970), it seems highly questionable whether they contribute to the perception of a post-focal word stress distinction.

Duration and intensity run parallel to each other in post-focus stressed syllables, both increase in the majority of the utterances. Durational differences are only at a minimum in one sentence (focus in second position) by subject 2, see Fig. 3. Although the durational difference in this case is 10 msec. (above the perceptual threshold, Lehiste 1970), and although there is a 10 Hz Fo difference, the dominant acoustic factor in this position seems to be relative intensity. The final syllable *-ni* (of both *móni* and *moní*, i.e., both stressed and unstressed) has lower intensity than *mo-*. This may be due to the general difference in intrinsic intensity between /i/ and /o/ and to the contribution of the final juncture. But the intensity difference is much larger in *móni* (12 dB) than in *moní* (5 dB). This is probably the decisive factor for the perception of this stressed syllable.

This modern Greek data suggests that it would be too simple to

set a hierarchy of acoustic cues to describe stress (Fry 1955, 1958). Rather, it is my opinion that the different acoustic parameters contribute in different ways across the syntagm. The different combinations to denote the same phonetic concept, stress, show that they can be independent of each other; moreover, there seem to be no solid grounds to support a view of a one-to-one mapping between phonetic features and the acoustic signal (Bailey and Summerfield 1980).

CONCLUSIONS

Finally, I shall try to answer the questions posed at the beginning. It is difficult to generalise as the present study has been limited to a small number of speakers and utterances¹.

Firstly, while all three acoustic parameters (Fo, duration and intensity) contribute to the structure of word stress, only duration and intensity are present after focus; on the other hand, relative intensity and Fo both contribute to the sentence stress. Secondly, of the three acoustic parameters examined, relative intensity differences are always present for both word and sentence stress. Lastly, the three acoustic parameters do not make a constant contribution across the syntagm but their relative contribution depends on the position of sentence stress.

1. I am planning both perceptual and physiological experiments related to the relative importance of the physiological and acoustic parameters for the perception of stress.

BIBLIOGRAPHY

- Bailey, P. & Summerfield, Q. (1980) Information processing in speech: Observations on the perception of s-stop clusters. *Journal of Experimental Psychology: Human perception and Performance* 6: 536-563
- Botinis, A. (1979) Stress and stress degrees in Modern Greek. Unpublished paper, Phonetics Laboratory, Department of General Linguistics, Lund University

- Bruce, G. (1977) Swedish word accents in sentence perspective. *Travaux de l' Institut de Linguistique de Lund XII*. Lund: Gleerup
- Bruce, G. & Gårding E. (1978) A Prosodic Typology for Swedish Dialects. In Gårding, E. Bruce, G. & Bannert, R. (Eds.) *Nordic Prosody*, 219-228. *Travaux de l' Institut de Linguistique de Lund XIII*, Department of Linguistics, Lund University
- Breckenridge, J. (1977) The declination effect. *Journal of the Acoustical Society of America* 60: S90
- Collier, R. (1972) From pitch to intonation. Ph.D. thesis, University of Louvain
- Fry, D. (1955) Duration and intensity as physical correlates of linguistic stress. *Journal of the Acoustical Society of America* 27: 765-768
- Fry, D. (1958) Experiments in the perception of stress. *Language and Speech* 1: 126-152
- Gårding, E. Bruce, G. & Bannert, R. (Eds.) *Nordic Prosody*. *Travaux de l' Institut de Linguistique de Lund XIII*. Department of Linguistics, Lund University
- Gårding, E., Fujimura, O. & Hirose, H. (1970) Laryngeal control of Swedish word tone: A preliminary report of an EMG study. *Annual Bulletin of the Research Institute of Logopedics and Phoniatrics* 4: 45-54, Tokyo
- Hadding-Kock, K. (1961) Acoustico-phonetic studies in the intonation of Southern Swedish. *Travaux de l' Institut de Linguistique de Lund III*. Lund: Gleerup
- Hyman, L. (Ed.) (1977) *Studies in stress and accent*. Southern California Occasional Papers in Linguistics 4
- Hyman, L. (1977) On the Nature of Linguistic Stress. In Hyman, L. (Ed.) *Studies in stress and accent*. Southern California Occasional Papers in Linguistics 4
- Jackendoff, R. (1972) *Semantic Interpretation in Generative Grammar*. Cambridge, Mass.: The MIT Press
- Lehiste, I. (1970) *Suprasegmentals*. Cambridge, Mass.: The MIT Press
- O' Shaughnessy, D. (1979) Linguistic features in fundamental frequency patterns. *Journal of Phonetics* 7: 119-145
- Thorsen, N. (1978) Aspects of Danish intonation. In Gårding, E. Bruce, G. & Bannert, R. (Eds.) *Nordic Prosody*, 23-32. *Travaux de l' Institut de Linguistique de Lund XIII*, Department of Linguistics, Lund University