

The Relation between Stress and Tonal Peaks

Antonio Pamies Bertrán & Mari Cruz Amorós Céspedes

University of Granada, Spain

E-mail: apamies@supercable.es, mcamoros@terra.es

ABSTRACT

Experiments dealing with the stress acoustic cues have produced very different results. The main contradictions between such results are related to the tonal nature that intonation theories attribute to stress. Such disparity is due to the huge methodological differences between these studies. This can be proven by applying the two main methods to the same corpus, which produce results that are completely opposite.

1. INTRODUCTION

The phonetic realization of stress - the prominence of the stressed syllable with respect to the surrounding unstressed syllables - is of a syntagmatic nature ([1], [34] p.230, [18] p.312, [15] p.4, [19] p.63). Its phonological relevance or distinctive function, however, is of a paradigmatic nature. Thus, a stressed vowel is 'horizontally' in opposition to its neighboring vowels in the discourse, but also 'vertically' in opposition to its own unstressed counterpart in the system. Although there is some consensus about such postulates, the disparity of the results of experimental research on the acoustic mark of stress is related to a certain underestimation, and even confusion, regarding the autonomy of the vertical versus the horizontal contrast. Whereas some researchers in experimental phonetics conclude that duration is the cue of stress ([20], [21], [28], [9] p.158), others are more inclined to say it is loudness or pitch ([13], [8], [5], [27],[26]). Other authors conclude that none of the three factors is satisfactory ([16] p.101,[23]), and that only a complex interaction between two or three factors can serve as a stress marking cue ([15]; [19] p.67; [23], [30]). It has also been stated that a large number or stresses are not realized in speech ([14], [12], [23]). Yet, the two main trends in intonation studies agree on the tonal nature of phonological stress for both English and Spanish ([32]).

2. OBJETIVES AND METHODS

We believe it is necessary to apply both horizontal and vertical studies to the same corpus to observe the realizations of stress. Our aim is to control morphological variables (paroxytone, oxytone and proparoxytone words) and syntactic-intonational ones and analyze the three acoustic parameters (loudness, duration and pitch) in the realization in each position ([2]). To this end, we designed a

'laboratory' corpus with series of sentences where the same stressed and unstressed vowel /e/ was found in identical contexts except in the prosodic element to be studied. We thus isolated the possible effects of the vowel's metrical position. We inserted the vowel into a syllabic structure [voiceless dental consonant_n] in keywords which occupied all the positions in the sentence (1st, 2nd or 3rd stress in affirmative sentences, and 3rd stress in interrogative sentences). In order to double the data, we included two series ([θen] and [ten]), which produced 6 keywords in four intonational positions. This figure, multiplied by 6 informants, amounts to 144 sentences. The informants were 3 mixed pairs of young people with middle to high social and educational level. They represented monolingual Spanish speaking regions (Granada, Madrid and Salamanca). We measured the duration, loudness and fundamental frequency of the vowels /é/ and /e/ and those of the surrounding syllables. We also converted the absolute data into relative data looking at the maximum-minimum range for pitch and loudness, and at the speech rate in the case of duration. Any difference below the J.N.D threshold, and therefore imperceptible, was considered irrelevant so as to avoid a negative result caused by excessively 'demanding' criteria. The criteria used were +6% for pitch (the threshold verified by [25] is +9% [or +1,5#]) and +10% for duration (the threshold verified by [24] even exceeds +30%). In the case of loudness, we accepted a 1dB contrast since it is a perceptible unit. The recordings were made in a anechoic booth in Barcelona and Granada with DAT. They were segmented and measured with Speech Analyzer.

3. RESULTS AND DISCUSSION

3.1. Horizontal axis: The analysis of the results shows three kinds of relation between stressed and unstressed vowels: positive prominence of the stressed vowel with respect to the surrounding unstressed vowels on both sides; negative prominence (if the contrast is inverted in favor of at least one of the unstressed vowels) and zero prominence (if there is a 'tie' between the stressed vowel and at least one of its neighbors). Zero prominence is equivalent in practice to negative prominence, since there is no prosodic contrast that is favorable to stress in either case. **Table 1** shows the appearance of horizontal contrast. In a breakdown depending on the position of stress in the sentence, the positive prominence rates of the stressed vowel can be seen in **Table 2**. In both series, none of the three parameters confirms that there is a higher value in the stressed vowel.

The most spectacularly negative example is precisely that of pitch. It has an average reliability of 8% for the 2nd stress in the sentence (5% and 11% in each series). This is true despite the fact that the internal stress is theoretically a more 'favorable' position for prominence, since it is not subjected to the effect of cadence before a pause or energy impulse in the utterance onset. If we look at the results depending on the position of stress in the word, **Table 3** shows the cases where the prominence of each factor is positive. Even though oxytone words obtain better results than paroxytones and proparoxytones, morphological position does not seem to alter the behavior of the 3 parameters, which are far from being reliable cues of stress.

Table 1.

prominence	intensity		pitch	
	[ˈθen]	[ˈten]	[ˈθen]	[ˈten]
+	35%	47%	21%	24%
-	18%	20%	29%	33%
0	47%	33%	50%	43%
	average (+) 41%		average (+) 22,5%	
prominence	duration			
	[ˈθen]	[ˈten]		
+	36%	29%		
-	38%	56%		
0	26%	15%		
	average (+) 32,5%			

Table2.

	intensity			pitch		
	ˈθen	ˈten	average	ˈθen	ˈten	average
1° st. aff.	56%	50%	53%	17%	12%	15%
2° st. aff.	33%	44%	39%	5%	11%	8%
3° st. aff.	33%	61%	47%	27%	27%	27%
3° st. int.	17%	33%	25%	33%	44%	38%
average	35%	47%	41%	21%	24%	22%
	duration					
	ˈθen	ˈten	average			
1° st. aff.	33%	23%	28%			
2° st. aff.	17%	17%	17%			
3° st. aff.	44%	44%	44%			
3° st. int.	50%	33%	42%			
average	36%	29%	32%			

3.2. Vertical axis: The 'vertical' analysis is a radically different method. The aim is no longer to compare each stressed vowel with its two unstressed neighbors, but rather to compare stressed and unstressed vowels in general. This is done here by studying the same vowel, stressed and unstressed, in the same consonantic context and metrical position in different sentences.

When all the absolute values of the stressed and unstressed vowels are added up and the respective average is calculated, we lose sight of the contrastive/culminative perspective, but this is offset by the advantage of comparing only [ˈθen] and [θen] or [ˈten] and [ten] in 144 stressed and 672 unstressed syllables (816 syllables in all).

The results obtained are shown in **Table 4**. With this kind of analysis, our data now show results that are much more 'favorable' to stress in the three acoustic parameters and even exceed those of other 'vertical' experiments carried out with a real corpus (e.g. [31], [29]).

Table 3.

	oxytone			paroxytone		
	ˈθen	ˈten	average	ˈθen	ˈten	average
int.	33%	58%	46%	29%	25%	27%
pitch	34%	42%	38%	21%	12%	17%
dur.	58%	63%	61%	13%	13%	13%
	proparoxytone					
	ˈθen	ˈten	average			
int.	27%	25%	50%			
pitch	21%	12%	12%			
dur	13%	13%	25%			

Table 4

media	intensity (dB)				duration (ms)			
	[ˈθen] ~ [θen]	[ˈten] ~ [ten]	[ˈθen] ~ [θen]	[ˈten] ~ [ten]	[ˈθen] ~ [θen]	[ˈten] ~ [ten]	[ˈθen] ~ [θen]	[ˈten] ~ [ten]
1° aff.	13	10	14	10	60	55	63	56
2° aff.	8	9	11	9	56	49	58	54
3° aff.	8	7	8	7	70	49	78	55
3° int.	7	7	8	8	68	50	74	55
media	pitch (hz) men				pitch (hz) women			
	[ˈθen] ~ [θen]	[ˈten] ~ [ten]	[ˈθen] ~ [θen]	[ˈten] ~ [ten]	[ˈθen] ~ [θen]	[ˈten] ~ [ten]	[ˈθen] ~ [θen]	[ˈten] ~ [ten]
1° aff.	190	133	161	134	237	225	238	219
2° aff.	153	141	155	136	232	231	226	213
3° aff.	126	121	164	153	190	205	198	190
3° int.	150	133	161	140	219	207	203	201

4. CONCLUSIONS

a) In spite of the careful design of the experiment, the result of comparing the stressed vowel with the two unstressed vowels that are in contrast with it in the discourse does not show the stressed vowel to have any superiority. It is rather the opposite. The results are negative for the three parameters, in all the morphological and intonational positions. The analysis of the individual results, not featured here for lack of space, does not show dialectal variations of this trend other than the fact that the trend is even greater in the two informants from Granada. The tonal nature that intonation theories usually attribute to stress is especially questionable, since the smallest number of cases of prominence favorable to the stressed vowel concern pitch.

b) If we compare the same stressed vowels with their unstressed counterparts in the same syllabic and intonational position, we reach the opposite result, that is, a superiority of the stressed vowel in the three parameters. This surprising finding is paradoxical insofar as it confirms and denies many of the main postulates about stress at the same time. However, it helps explain one of the causes of such disparity: the contradictory results may refer to

different things. Clearly, the differences in methodological approach must have been responsible for the disparity of results to a large extent, since they can totally invert the interpretation of such results.

REFERENCES

- [1] ALARCOS LLORACH, E. (1994): *Gramática de la lengua española*. Madrid: Real Academia Española / Espasa Calpe.
- [2] AMORÓS, M.C. & PAMIES, A. (2001): “Acerca de la relación entre acento y entonación”, en Díaz García, J. *Actas del II Congreso Nacional de Fonética Experimental*. Sevilla: Universidad. (pp. 91-95).
- [3] AMORÓS, M.C. (2002): “Intensidad, entonación y acento”, en Gutiérrez, Salvador (ed.): *V Congreso Nacional de Lingüística General*. León: Universidad. (Actas en prensa).
- [4] AMORÓS, M.C. (2003): *La relación entre entonación y acento en español*. Tesis doctoral, (inédita).
- [5] BOLINGER, D. (1964): “Around the Edge of Language: Intonation” en *Harvard Educational Review*, vol. 34, nº 2, (pp 282-293).
- [6] BOLINGER, D. (1972): *Intonation*. London: Penguin.
- [7] CANTERO, F.J. (2002): Teoría y análisis de la entonación. Barcelona: Universitat.
- [8] CONTRERAS, H (1963): “Sobre el acento en español” en *Boletín de Filología* (Chile), XV, 223-237.
- [9] CUTLER, A. (1991): “Linguistic rhythm and speech segmentation” en Sundberg, J., Nord, L. & Carlson, R. (eds): *Music, Language, Speech and Brain*. London: McMilan.
- [10] DELATTRE, P. (1965): *Comparing the Phonetic Features of English, German, Spanish and French*. Heidelberg: Julius Groos.
- [11] GARDE, P. (1968): *L'accent*. Paris: P.U.F.
- [12] GARRIDO, J.M. (1991): *Modelización de patrones melódicos del español para la síntesis y el reconocimiento del habla*. Barcelona: Universitat Autònoma.
- [13] HODAPP, M. & BOLINGER, D. (1961): “Acento melódico, acento de intensidad” en *Boletín de Filología* (Chile), XIII, pp. 33-48.
- [14] KULLOVA, J. (1988): *Modulaciones de la cadena hablada en español*. Praha: Univerzita Karlova.
- [15] LADD, R. & CUTLER, A. (1983): “Models and Measurements in the Study of Prosody” en Cutler, A. & Ladd, D.R. (eds): *Prosody: Model & Measurements*. Berlin: Springer.
- [16] LEHISTE, I. (1991): “Speech research: An overview” en Sundberg, J., Nord, L. & Carlson, R. (eds): *Music, Language, Speech and Brain*. London: McMilan.
- [17] LIBERMAN, M. (1975): *The Intonational System of English*. Tesis doctoral, Cambridge (Massachusetts): MIT.
- [18] MARTINET, A. (1980): *Eléments de linguistique générale*. Paris: Armand Colin.
- [19] MARTÍNEZ CELDRÁN, E. (1989): *Fonología general y española*. Barcelona: Teide.
- [20] NAVARRO TOMÁS, T. (1921): “Historia de algunas opiniones sobre la cantidad silábica” en *Revista de Folología Española*. VIII, pp. 30-52.
- [21] NAVARRO TOMÁS, T. (1946): *Estudios de fonología española*. New York: Syracuse University, [Reed. Madrid: Guadarrama, 1974].
- [22] NAVARRO TOMÁS, T. (1935): *El acento castellano*. Madrid: C.S.I.C.
- [23] PAMIES, A. (1997): “Consideraciones sobre la marca acústica del acento fonológico” en *Estudios de Fonética Experimental VIII*. Universidad de Barcelona, pp. 11-49.
- [24] PAMIES, A.; FERNÁNDEZ PLANAS A.M. (2002) “La percepción de la duración vocálica en español”, en Gutiérrez, Salvador (ed.): *V Congreso Nacional de Lingüística General*. León: Universidad. (Actas en prensa).
- [25] PAMIES, A.; FERNÁNDEZ PLANAS A.M.; MARTÍNEZ CELDRÁN, E.; ORTEGA ESCANDELL A.; AMORÓS CÉSPEDES, M.C. (2001): “Umbrales tonales en español peninsular”, en Díaz García, J. *Actas del II Congreso Nacional de Fonética Experimental*. Sevilla: Universidad, pp. 272-278.
- [26] PIERREHUMBERT, J. (1980): *The Phonology and Phonetics of English Intonation*. Tesis doctoral, Cambridge (Massachusetts): M.I.T.
- [27] QUILIS, A. (1971): “Caracterización fonética del acento español” en *Travaux de Linguistique et de Littérature*, (Strasbourg), vol IX, num 1.
- [28] ROMERA, L. (1999): “La interacción del Fo y la duración en el reconocimiento automático del acento en español” en *Actes del I Congrès de Fonética Experimental*, Tarragona: Universitat Rovira i Virgili & Universitat de Barcelona (pp. 309-316).
- [29] RUBIO AYUSO, A. & MILONE, D.H. (2001): “Información prosódica y acentual para el reconocimiento del habla”, en Díaz García, J. *Actas del II Congreso Nacional de Fonética Experimental*. Sevilla: Universidad. pp. 56-77.
- [30] TOLEDO, G.A. (1997): “Prominencia melódica y temporal: la colisión acentual en español” en *Estudios de Fonética Experimental*, IX (Universidad de Barcelona), pp. 201-220.
- [31] TOLEDO, G.A. (2001): “Acentos tonales en discursos”, en Díaz García, J. *Actas del II Congreso Nacional de Fonética Experimental*. Sevilla: Universidad, pp.78-88.
- [32] TOLEDO, G.A.; FERNÁNDEZ PLANAS, A.M.; ROMERA, L.; ORTEGA, A. & MATAS, J. (2001): “Tiempo y tono en español peninsular”, en Díaz García, J. *Actas del II Congreso Nacional de Fonética Experimental*. Sevilla: Universidad, pp 318-323.
- [33] TRUBETSKOY, N.S. (1939): *Grundzüge der Phonologie*. Paris: Klincksieck. [Reed. 1970] [trad. esp. 1973: *Principios de fonología*. Madrid: Cincel 1987].

