

POST-STRESSED SYLLABLES IN BRAZILIAN PORTUGUESE AS MARKERS

Sandra Madureira*, Plínio Barbosa, Mario Fontes*, Karla Crispim*, and Daniela Spina*
 *Pontifícia Universidade Católica de São Paulo and Universidade Estadual de Campinas

ABSTRACT

This study investigates word fundamental frequency contours by examining three-syllable oxytons (stress on the last syllable in the word), paroxytons (stress on the penultimate syllable in the word) and proparoxytons (stress on the antepenultimate syllable in the word) inserted in sentences read by adult male speakers. Analysis of the data revealed that F0 increases (peak displacement) or levels off in post-stressed syllables corroborating the hypothesis that unstressed syllables function as succession markers (in duration contours) as well as durative markers (F0 contours) in defining prominence at phrasal level. Word fundamental frequency contours of pairs contrasting by means of stress placement were found to be systematically differentiated. The results are interesting from the point of view of setting up patterns to reconstruct word fundamental frequency contours based on a phonetically-oriented hierarchical model of intonation for the purpose of synthesis.

1. INTRODUCTION

In a previous pilot study of F0 variations in oxytons, paroxytons and proparoxytons inserted in a carrier sentence, a rising fundamental frequency movement was detected to start at the stressed syllable and continue across post-stressed syllables in proparoxytons. In paroxytons, the rising movement would start either in the pre-stressed or the stressed syllable and would extend to the post-stressed syllable, that is, post-stressed syllables in paroxytons also showed higher values of F0 than stressed ones.

Stress is distinctive in Portuguese. Studies [2 & 3] have pointed two factors as the main acoustic correlates of lexical stress in Brazilian Portuguese: longer duration of the stressed syllable and reduced intensity in post-stressed syllables.

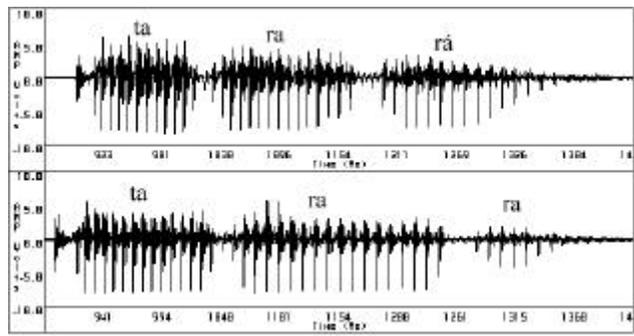


Fig. 1. Wave forms of the oxyton "tarará" and the paroxyton "tarara" in final position in the sentence.

Although duration is the most consistent stress correlate, no perceptual testing has been carried out to evaluate the influence of the stress phonetic parameters. Compare duration, rms and F0 values of the phones in the nouns "áballo" ([ˈabalU]; meaning

someone from a region in India) and "aballo" ([aˈbalU]; meaning riot) inserted in a carrier sentence before a very strong boundary (syntactically NP-VP boundary, initial in the sentence) for speaker **M** in figure 2 and in the verbs "durará" (will last) and "durara" (had lasted) before a strong boundary (syntactically VP-Adv. Phrase at the end of the sentence) for speaker **J** in figure 3.

	Duration	Energy	F0
a'	176 ms	3,1 v	143 Hz
b	67 ms	0,5 v	147 Hz
a	75 ms	2,2 v	157 Hz
l	48 ms	1,5 v	151 Hz
U	56 ms	1,4 v	157 Hz

	Duration	Energy	F0
ˈa	110 ms	1,7 v	137 Hz
b	107 ms	0,3 v	115 Hz
a	176 ms	2,4 v	141 Hz
l	47 ms	1,3 v	162 Hz
U	55 ms	1,3 v	168 Hz

Fig. 2. Duration, rms and F0 values (syllable medial phrase) for a stress contrasting pair of words: proparoxyton and paroxyton.

	Duration	Energy	F0
dd	15 ms	0,8 v	104 Hz
uu	81 ms	2,6 v	97 Hz
rr	28 ms	0,8 v	96 Hz
aa	132 ms	2,2 v	93 Hz
rr	24 ms	0,8 v	96 Hz
aa	153 ms	2,0 v	97 Hz

	Duration	Energy	F0
dd	65 ms	0,7 v	101 Hz
uu	110 ms	2,75 v	99 Hz
rr	32 ms	1,2 v	96 Hz
aa	198 ms	2,7 v	96 Hz
rr	17 ms	1,2 v	96 Hz
a"	118 ms	1,4 v	107 Hz

Fig. 3. Duration, rms and F0 values for a stress contrasting pair of words: oxyton and paroxyton.

In **M**'s pronunciation of both words, the stressed syllable showed a rising movement (from 129 HZ to 150 HZ in "ábalo" and from 129 Hz to 153 Hz in "abalo"). In the proparoxyton, duration and energy decrease in post-stressed syllables as F0 increases. In the paroxyton, duration and energy decrease in the post-stressed syllable, the pre-stressed syllable being closer in values to the stressed one. The F0 peaks occurred in the post-stressed vowel immediately following the stressed vowel.

In **J**'s pronunciation of the oxyton, the rising movement started at the pre-stressed syllable and culminated in the stressed one. In the paroxyton, the rising movement started at the offset of the stressed syllable and culminated at the medial portion of the unstressed syllable.

The phenomenon of F0 peaks in weak syllables known as peak displacement in the literature has been observed and studied in many languages [6], [7], [9], [10], [11] and [12]. It is mainly reported as a productive process in initial stress groups, revealing consistent correlations with segmental duration, number of consonants in the syllable onset, segmental features at syllable onset and offset, rate word boundaries, syntactic and prosodic boundaries and stress clash.

In our work we are concerned with contrasting F0 variations in oxytons, paroxytons and proparoxytons in Brazilian Portuguese so as to discuss peak displacement as related to language specific constraints. A highly controlled corpus will be used for that purpose. We aim at discussing the role of the productive rising of F0 in post-stressed syllables in a reading style relating its occurrence to constraints imposed by the prosodic patterns of the language.

2. EXPERIMENT DESCRIPTION

A corpus was built containing three-syllable oxytons, paroxytons and proparoxytons inserted in sentences contrasting boundaries of varied strength. Number of syllable was controlled. The sentences were read by six adult male speakers of Portuguese whose F0 ranged from 80 Hz to 180 Hz. They were told to read the sentences at normal speed in a "neutral" way, that is without emphasis. Each sentence, in randomized order, was repeated 12 times. Acoustic recordings were made in studio conditions on DAT-tape. The acoustic signals were digitized at 16 kHz by means of a 16-bit A/D converter. Duration, fundamental frequency and rms intensity of the vowels in pre-stressed, post-stressed and stressed positions were measured.

Boundaries of three different strength were considered: very strong (final in the sentences), strong (coinciding with major syntactic boundaries within sentences) and weak (other positions, usually coinciding with boundaries between constituents belonging to the same syntactic structure).

Nouns and verbs were contrasted: "O NP perturbou a todos na tomada de decisão"; "Fotografei o NP"; "O NP da garota ficará na gaiola"; "O vestido VP bem".

3. FINDINGS

Analysis of the contrasting pairs of words indicate that there is usually a F0 rising movement that characterizes the stressed vowel. This movement can start either start in the pre-unstressed syllable or in the stressed syllable and it is usually the last portion of the stressed syllable, the offset, which exhibits higher values, thus confirming consistent findings mentioned in the literature (See [6] for an overview) that long vowels favour late peaks. The

movement extends to the post-stressed syllable where the peak occurs. However, there are cases in which no rising movement is detected in the stressed vowel and yet the post-stressed vowel gets higher (late alignment) or levels off.

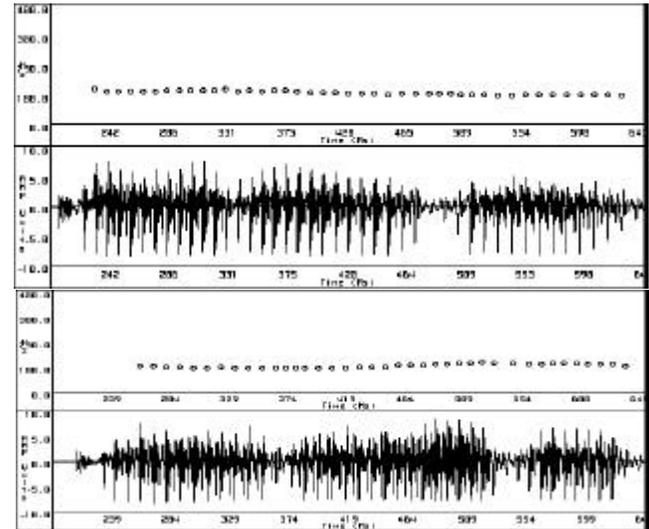


Fig. 4 . F0 tracings and word forms of a oxyton (higher) and a paroxyton (lower).

In all contexts, the unstressed syllable showed higher values. In non-final positions, differences ranging from 15 Hz to 30 Hz have been found. In final position before silence, a software developed by Barbosa has been used to eliminate the declination line effects by entering the highest frequency and its corresponding time instant and the lowest frequency and its corresponding time instant and then the frequency values and time instant for the syllables. In final positions, once declination line effects are excluded the post-stressed syllable was found to be in average 10 Hz higher than the stressed one. Take F0 values of the syllables in speaker **J**' pronunciation of "falára" in sentence final position: 107 Hz (pre-stressed syllable) 85Hz (stressed position) and 86 Hz (poststressed position). The software introduced three values for correction 17Hz, 4Hz and 12Hz which yielded 124Hz, 89Hz and 97Hz respectively.

Peak displacement was found to be highly productive. In our data, it was restricted to the syllable immediately following the stressed. The process affected oxytons followed by an unstressed syllable in cases where there was no prosodic boundaries between them, that is, the boundary would block peak displacement. In figure 4, values for speaker **R** in the boundary NP-PP are given.

	Content Words	Function Word
Oxyton	90 Hz	96 Hz
Paroxyton	112 Hz	98 Hz

Fig. 5. F0 values for speaker **R** taken at the offset of the last syllable of two content words (an oxyton and a paroxyton which are heads of a subject NP) and of the following unstressed syllable (a monosyllabic function word introducing the prepositional phrase used as modifier of the head).

Our results for the NP-VP boundary differ from Listerrí's study [7] as far as the Spanish proparoxytons are concerned. In Spanish the peak would be displaced to the syllable immediately preceding the boundary. In Spanish the lexical stress pattern of the noun preceding the NP-VP boundary was not found to affect the placement of the peak since this occurs in the syllable immediately preceding the boundary independently of the stress pattern of the word preceding the boundary. In the data we have analysed, stress pattern was influential. In figure 5, F0 values of syllable nuclei of oxytons, paroxytons and proparoxytons at NP-VP boundary are given.

SYLLABLE 1			
	Initial in the syllable	Medial in the syllable	Final in the syllable
Oxyton	104 Hz	103 Hz	105 Hz
Paroxyton	98 Hz	96 Hz	94 Hz
Proparoxyton	111 Hz	110 Hz	112 Hz

SYLLABLE 2			
	Initial in the syllable	Medial in the syllable	Final in the syllable
Oxyton	107 Hz	100 Hz	94 Hz
Paroxyton	106 Hz	106 Hz	108 Hz
Proparoxyton	114 Hz	118 Hz	108 Hz

SYLLABLE 3			
	Initial in the syllable	Medial in the syllable	Final in the syllable
Oxyton	93 Hz	100 Hz	105 Hz
Paroxyton	118 Hz	123 Hz	111 Hz
Proparoxyton	104 Hz	102 Hz	102 Hz

Fig. 6. F0 values of syllable nuclei of stress contrasting pairs of words for speaker J at NP-VP boundary.

In sum, the results of the analysis point out to a strong tendency towards displacement of the F0 peak to the right of a lexically accented syllable in proparoxytons and oxytons. Strong boundaries would block the effect in oxytons.

4. DISCUSSION

These findings can lead to the interpretation that in Brazilian Portuguese post-stressed syllables play a role in highlighting prominence within a stressed interval. Some arguments can be made to support such an interpretation: among them, diacronic trends, perceptual salience and results from the analysis of rhythmic patterns of Brazilian Portuguese data.

One argument against explaining the fact that the unstressed vowel which is reduced in intensity and duration (final lengthening

excluded) bears the F0 peak due to merely dynamic overshoot (another possible production related explanation) is that a stressed vowel followed by an unstressed in the same prosodic group behaves differently from a stressed vowel followed by an unstressed vowel belonging to another prosodic group (no rising or leveling off of movement having been found). The lack of peak displacement over boundaries discards dynamic overshoot as the sole inducer of the process.

4.1 Diacronic trends

First of all, we must consider the influence of stress on the formation of the lexicon in Romance Languages. French favours a greater number of oxytons, Italian and Romanian a greater number of proparoxytons and Spanish and Portuguese a greater number of paroxytons [4]. As mentions Albano [1], penultimate stress is considered canonic in Portuguese as it accounts for about 55% of the vocabulary.

As Latin evolved into Portuguese, unstressed vowels tend to be less resistant than stressed ones. Unstressed vowels fell, weakened and underwent several changes. However, as Cavacas [5] mentions, the final unstressed vowel in a word in Portuguese was considerably more resistant than in medial or initial positions in the word. There must be a prosodic motivation for this event.

The falling of the medial unstressed syllable which took place diacronically is also productive synchronically. In the pronunciation of proparoxytons such as "óculos" (glasses), "chícara" (cup) and "veículo" (vehicle) the medial syllable often falls yielding [ɔklUs] instead of [ɔkulUs], [ʃikrø] instead of [ʃikrø] and [veiklU] instead of [veikulU]. Also note that in the special case of the word final "e" which fell in a lot of cases, the vowel was preceded by a consonant (usually [+continuant]) which remained closing the syllable and adding duration to the oxyton. Some examples: poenale -> penal; luce -> luz e amore -> amor.

The productivity of paroxytons can be related to the use of the unstressed vowel as a lexical boundary marker. As in metaphony, a kind of assimilation process in which the unstressed vowel acts as an inducer, the unstressed vowel has a role in the lexical phonology.

Comparison among pre-stressed, stressed and post-stressed vowels in Brazilian Portuguese show the former two to be phonetically more alike. In this sense, the post-stressed condition would favor contrast and could be thought as well as adding to the prominence of the stressed syllable.¹

If the domain right to the lexically accented syllable is favoured, then the post-stressed syllable can be thought of playing a role in the prosodic patterns in Brazilian Portuguese. That role would be of a marker.

4.2 Saliency

Second, as pointed out by Barbosa [3], if post-stressed syllables constitute a domain where stress culminates, the greater perceptual prominence of proparoxytons over paroxytons and oxytons and paroxytons over oxytons pointed out by Moraes [6] can be explained. In fact, comparison between proparoxytons and paroxytons in our data show that the increase in F0 values in the syllable immediately following the stressed one tend to be greater in proparoxytons than in paroxytons.

In our data, sentences in which the three-word verb was followed by an adverb of manner, the adverb was found to be more

salient after the oxyton than the paroxyton. What is more comparison of oxytons and paroxytons before the unstressed function word "da" (translation equivalent to "of") within the same prosodic group reveal that, only after the oxyton, the function word will have a higher F0 value behaving as the post-stressed syllable in the paroxyton. Subjects asked to evaluate the function word after oxytons reported it as more salient than the function word after paroxytons. In the latter the post-stressed vowel will be considered as more salient than the function word.

4.3 Rhythm

Viewing the unstressed syllables as signaling prominence in F0 contours is compatible with the view of unstressed vowels bearing the role of beat counters as proposed by Barbosa's model of rhythm for Brazilian Portuguese [3]. If unstressed syllables are taken to be markers for pitch prominence in Brazilian Portuguese, oxytons and paroxytons should be differentiated when followed by other unstressed vowels in the same prosodic group. In fact our data confirm this since peak displacement affects oxytons in that it extends to the unstressed syllable following them.

5. CONCLUSION

The finding that F0 increases in post-stressed syllables both before continuative and non-continuative boundaries (once declination line effects are excluded) has interesting implications for the designing of the prosodic module of the text-to-speech synthesis system being developed for Brazilian Portuguese since rules on word level would apply and adjustments imposed by the global hierarchically higher elements would yield the output.

The finding also corroborates a hypothesis raised by Barbosa elsewhere that unstressed syllables act as succession markers (duration contours) as well as durative markers (F0 contours) in defining prominence at phrasal level.

The results, though partial, present evidence in favour of considering post-stressed syllables as durative markers in defining prominence at phrasal level in Brazilian Portuguese.

ACKNOWLEDGEMENTS

This work is partially financed by a grant from the Conselho Nacional de Desenvolvimento Científico e Tecnológico-CNPQ. We would also like to thank Eduardo V. Kawanishi, Leila H. Marreiro and Ernesto Foscai for the technical support and to all subjects for their voices, specially Antonio Carlos Silva Junior.

NOTES

¹Fewer vowel contrasts are allowed in that position (only /i/, /a/ and /u/) as opposed to pre-stressed (/i/, /e/, /a/, /o/ and /u/) and stressed (/i/, /e/, /ɛ/, /ɔ/, /o/, /u/, /a/). Note that /i/ and /u/ being higher vowels have intrinsic higher values of F0 and that the allophone of /a/ in post-stressed conditions is [ɐ] a variety higher than [a] which productively characterizes pre-stressed positions in non-emphatic speech.

REFERENCES

[1] Albano, E., Moreira, A., Aquino, P., Silva A., Kakinohara, R. 1995. Segment frequency and word structure in Brazilian Portuguese. *Proceedings ICPhS 95*; vol. 3, 346-349.

- [2] Massini, G. 1991. A Duração no estudo do acento e do ritmo em Português. Master Thesis, IEL, UNICAMP.
- [3] Barbosa, P. A. 1996. At least two macrorhythmic units are necessary for modeling Brazilian Portuguese duration. *Proceedings of the 1st ESCA Tutorial and Research on Speech Production Modelling & 4th Speech Production Seminar*, 85-88.
- [4] Barbosa, P. A. & Madureira S. 1999. Toward a hierarchical model of rhythm production: evidence from phrase stress domains in Brazilian Portuguese. *These Proceedings*.
- [5] Cavacas, A. A. 1992. (reprint, 1917) A Língua Portuguesa e sua Metafonía. Rio de Janeiro, Editora Lucerna.
- [6] Ladd, D. R. 1996. *Intonational Phonology*. Cambridge: Cambridge University Press.
- [7] Llisterri, J., Marin, R., de la Mota, C. & Rios, A. 1995. Factors affecting f0 peak displacement in Spanish. *Proceedings of the 4th ESCA European Conference on Speech Communication and Technology*, 2061-2064.
- [8] Moraes, J. A. 1986. Acentuação lexical e acentuação frasal em português. Um estudo acústico-perceptivo. Conference presented at the II Encontro Nacional de Fonética e Fonologia, Brasília, Brasil.
- [9] Prieto, P. van Santen, J. & Hirschberg, J. (1995) Tonal alignment in English, *Phonetica*, Vol. 23, pp 429-45.
- [10] Silverman, K. & Pierrehumbert, J. 1990. The timing of prenuclear high accents in English. In Kingston, J. & Beckman (Eds) *Papers in Laboratory Phonology*. Cambridge: Cambridge University Press
- [11] Wichmann, A., House, J. & Rietveld, T. (1997) Peak displacement and Topic Structure. *Proceedings of an ESCA Workshop on Intonation: Theory, Models and Applications*, 329-332.
- [12] Xu, Y. & Wang, Q. E. 1997. What can tone studies tell us about intonation? *Proceedings of an ESCA Workshop on Intonation: Theory, Models and Applications*, 337-340.