ARTICULATORY CORRELATES OF SECONDARY STRESS IN POLISH AND SPANISH

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ABSTRACT

Electromagnetic Articulography was used to registrate tongue movements during Spanish and Polish sentence utterances. In Polish no significant differences between secondarily stressed and unstressed syllables could be found. In Spanish the tongue gesture of the secondarily stressed syllable showed a different shape of the movement in comparison with the unstressed case. However, this effect might represent a coarticulatory artifact of the test material.

INTRODUCTION

An alternating secondary stress for Polish and Spanish has been postulated by numerous phonologists although the phonological as well as the acoustic phonetic evidence for an alternating secondary stress in Polish and Spanish is tenous, if not non-existent. There are no phonological processes or rules that would crucially refer to the position of secondary stress. There can't be found clear acoustic correlates of an alternating secondary stress such as F0-, intensity, durational or spectral features differing from the unstressed syllables in both languages either (cf. [6], [3]).

DeJong et al [2] found that in English sentence utterances stress on different prosodic levels was implemented by the same articulatory feature, namely movement size as compared to the unstressed case, but to a different extent: The movement amplitudes of the secondarily stressed syllable showed values just in between the amplitudes of the nuclear stressed and the unstressed syllable. However, Beckman & Edwards [1] suggest that, at least in English, stress on different prosodic levels yields different phonological and phonetic - and articulatory - realisation: They found that nuclear stress was mainly correlated with intonational features whereas at lower prosodic levels like word level stress was correlated with longer syllable duration as well as with articulatory features like greater movement amplitude and greater velocity.

The articulatory realisation of secondary stress in Polish and Spanish has not been investigated before. The purpose of the present study was to find an articulatory correlate of alternating stress in Polish and Spanish sentence utterances and to answer the question wether secondary stress is implemented by the same articulatory feature as primary accent - but to different degrees - or by a principally different kind of feature.

METHODS

In the present experiment the Articulograph AG100 (Carstens Medizinelektronik Göttingen, cf. [9]) was used. The kinematic recordings were made with a sampling rate of 200 Hz. Simultaneously with the recording of the articulatory data the acoustic signal was digitally recorded. Five sensors were placed on upper lip (UL), lower lip (LL), 5mm behind the tongue tip (TT), tongue mid (TM) and tongue dorsum (TD). Different word forms of Polish and Spanish stimulus words were used with one target syllable appearing on three different prosodic levels (primary stress, secondary stress, unstressed). The target words for Polish were: *,hipo'potam* (hipopotamus, nom. sg.), *hipopo'tama* (gen. sg.) and *,hipo,pota'mami* (instr. pl.) with the second po being the target syllable. The words were embedded in a neutral sentence frame: *On powie _ dwa rasy* (He'll say _ twice). The Spanish target words were: *Constan'tino* (Constantine), *constan,tino'pleno* (Constantinople man) and the infinitive form of the verb *cons,tanti,nople'ar* (to hang out in Constantinople) with the syllable *ti* being the target syllable. The Spanish carrier sentence was: *No he dicho _ jamas* (I never said _). Each sentence type was visually presented 8 times in randomized order. The speakers, one native speaker of peninsulan Spanish and one native speaker of Polish (two of the authors, I.R. and G.D.) read the sentences with normal speaking rate.

During the production of the sequence *hipopo* in the Polish sentence the mid tongue performs a continuant back- and downward movement from the high position for the vowel [*i*] over the first *po* to the vocal tract configuration of the 2nd [*o*], during the target syllable turning back for producing the following closure [*t*] (as schematized in Fig.1a).

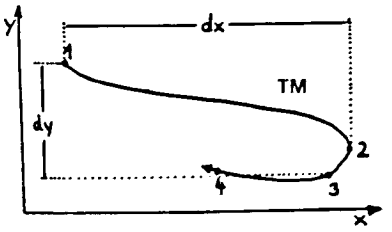

Figure 1a. Schematized mid tongue trajectory during the production of the sequence ipopo in the Polish utterance.

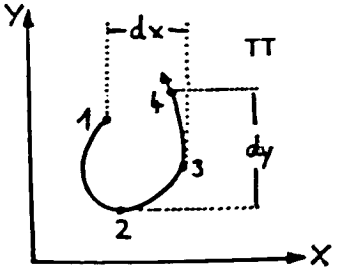

Figure 1b. Schematized tongue tip trajectory during the production of the target syllable ti in the Spanish utterance.

The articulation of the Spanish target syllable is mainly realised by the tongue tip. In the two-dimensional, midsagittal representation the tongue tip performs a circle-like movement from the alveolar closure during the [*t*] over the opening of the vocal tract for the vowel [*i*] to the next alveolar closure for the [*n*] in the following syllable (as indicated in Fig.2a). Across all recorded Polish and Spanish utterances the characteristic articulatory positions (maximum high/front, back and low tongue position) show a certain time alignment with acoustic events (mid of stop consonant closure, onset, mid and offset of the vowel, see the 4 marks in the acoustic signal, cf. Figures 2a, 2b corresponding to the 4 marks in the articulatory trajectory, cf. Figures 2a, 2b). At these characteristic 4 timepoints the x- and y-coordinates of the relevant sensor were calculated. The differences between the extrema on the horizontal and vertical axis (dx, dy) were the basic movement parameters. In addition the following articulatory parameters were derived: the sum dxy = dx + dy as a rough measure for the size of the movement and the quotient dq = dy / dx as a measure for the relation between horizontal and vertical movement and therefore as a rough measure characterizing the shape of the movement. The following durational values were measured in the acoustic signal: for the Polish sentences the vowel duration of [*o*] in the target syllable was extracted as well as the duration of the whole sequence *ipopo*, for the Spanish material the syllable duration of the target syllable *ti* (mid of consonant closure in [*t*] to vowel offset of [*i*]) was measured.

RESULTS

Durations - Polish and Spanish

For both languages the durational values showed a significant difference between main stressed and unstressed syllables but no significant difference between the unstressed syllable and the one with supposed secondary stress (*ANOVA*, alpha=.05). That is, in the present sentence utterances primary stress was realized by longer (vowel/syllable) durations in comparison to the unstressed case whereas secondary stress did not.

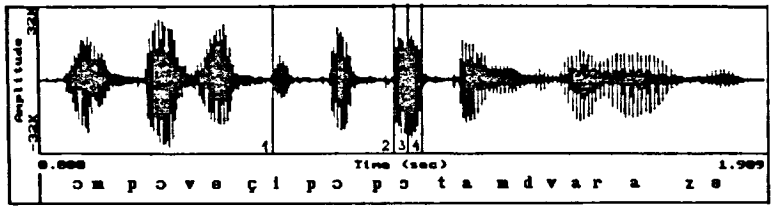

Figure 2a. Acoustic signal of one Polish test sentence with 4 measurement points marked: 1: Vowel onset [i], 2: Vowel onset of 2nd [o], 3: Mid of vowel of 2nd [o], 4: Vowel offset of 2nd [o].

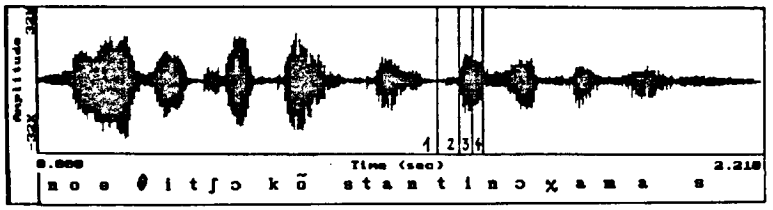

Figure 2b. Acoustic signal of one Spanish test sentence with 4 measurement points on the target syllable marked: 1: Mid of stop consonant closure of [t], 2: Vowel onset [i], 3: Mid of vowel [i], 4: Vowel offset of [i].

Articulatory data - Polish:

In the case of Polish the primary stressed syllables showed significant larger movement amplitudes as compared to the unstressed case but the secondary stress condition did not differ significantly from the no stress case, neither with respect to movement size nor to movement shape (alpha=0.05 in *MANOVA*).

Articulatory data - Spanish:

Figure 3 shows the horizontal and vertical tongue tip movement amplitudes during the production of the syllable *ti*: In both dimensions larger amplitudes were registrated on the target syllable with primary stress than on the secondary stressed or unstressed syllable. The secondary stressed and the unstressed syllable did not differ in movement size. However, they differed slightly with respect to the relation between the two dimensions of the movement: the unstressed syllables showed a small tendency to larger values on the vertical dimension and the syllables with (supposed) secondary stress showed slightly larger horizontal movements. Principal component analysis revealed movement *size* and movement *shape* as the two relevant factors which differentiate between the three accent categories. Post hoc tests showed that the size effect of the primary accent as well as the shape

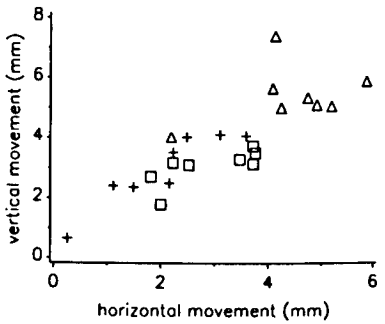

Figure 3. Maximum amplitudes of the tongue tip movement on the horizontal and vertical dimension during the production of the target syllable ti (each symbol represents the measured value of the target movement of one sentence). Primary stress: triangles, secondary stress: squares, no stress: crosses.

effect of the secondary accent were significant ($p<.05$) whereas the difference in movement size between secondary stressed and unstressed syllables did not reach significance ($p>.1$).

DISCUSSION

In the present study longer (syllable) durations and larger articulatory movements of syllables with primary stress as compared to unstressed syllables were measured for both Polish and Spanish sentence utterances. This confirms previous results on articulatory correlates of stress in English (cf. [1], [2], [5]). The assumption that alternating secondary stress would be implemented in the same way as primary stress but to a lower degree could not be confirmed for the material of the present study. For the Polish utterances no articulatory correlate of secondary stress could be found. This negative result might be due to the extremely limited data of the present study with respect to number of speakers and utterances as well as articulatory parameters so that it can't be claimed that secondary stress in Polish does not exist at all.

In the case of Spanish an effect of movement shape on the secondary stressed syllable could be observed. However, since the segmental content of the three target words was not absolutely identical (*Constantino, constantino-pleno, constantinoplear*) it cannot be excluded that the observed small shape effect was caused by the different segmental context rather than by the secondary accent. Nevertheless the strong hypothesis would be the following: Whereas primary stress is implemented by larger articulatory movements secondary stress in Spanish affects the movement shape. This result would push the idea formulated by [1] that stress on different levels might yield different phonetic - and articulatory - implementation. To verify this hypothesis it is necessary to use reiterant speech in future experiments to exclude effects of different contexts and different word length.

Whereas the effect of primary stress on movement size has been explained by greater sonority which may be achieved by e.g. larger downward movements of the jaw (cf. [4]) an explanation for a shape effect of secondary stress is not obvious. One - admittedly very vague - idea might be that a rhythmic variation of movement shape is used as a sort of economization strategy, possibly interpretable as an application of the Obligatory Contour Principle *OCP* of nonlinear phonology (cf. [7]), which does not allow two adjacent identical elements, on the level of articulation.

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