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PHONETIC INVARIANCE AND PHONOLOGICAL STABILITY: LITHUANIAN PITCH ACCENTS

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ABSTRACT

We argue that phonetically invariant realizations of phonological categories imply the synchronic and diachronic imperviousness of such categories to phonological rules and sound laws. We claim that phonetic invariance is the foundation of phonological stability. The category we discuss in this contribution is the pitch-accent. We provide a parametric phonetic description of this phonological category. By means of a parametrization technique we apply this description to the contrastive pitch-accents of Lithuanian. The statistic differences between acute and circumflex pitch-accents derived by the parametrization provide a basis for the discussion of synchronic and diachronic behavior of the phonetically nonbalanced phonological contrasts.

1. PITCH-ACCENT PARAMETERS

A pitch-accent is a characteristic F_0 shape realized over a stress bearing unit. Languages in which word stress is characterized by specific F_0 contours are called pitch-accent languages. In languages (e.g. Swedish) where a pitch-accent is realized over at most two syllabic nuclei we speak of the syllabic pitch-accent [2]. In languages (e.g. Japanese) where pitch-accent is realized over two units of phonological weight, we speak of moraic pitch-accent languages [10]. In all languages with characteristic intonations (possibly all human languages) pitch-accents are realized over the sentence stress bearing units [13].

Irrespective of the accent bearing unit we use a pitch-accent description as defined by the following set of phonetic parameters [15]:

- ***p***: form of movement ($-1 \leq p \leq 1$)

This is the most important of pitch-accent parameters as it defines the pitch-accent contour. Typical forms of pitch-accent movement are rise (LH, p=1), fall (HL; p=-1) and rise-fall (LHL; p=0)

- ***d***: alignment of accent (in fraction of the stress bearing unit)

Alignment is decisive for the perception of pitch-accent. Typically pitch-accents are aligned with phonological heads of stress bearing units (i.e. syllabic nuclei or head morae). These phonological heads are aligned with phonetic steady states. If, however, the alignment does not correspond with the phonetic steady state but with a transition, pitch-accent is perceived not as a movement (LH; HL) but as a level pitch (L; H) [11].

- ***s***: steepness of movement slope

This parameter defines the span of movement over the accent bearing unit(s) and is particularly important for the perception of accent in cases where accent is spread over two syllables or two morae

- ***l***: accent base (in Hz)
- ***h***: amplitude of movement (in Hz)

These two parameters define the thresholds of pitch perception and they are particularly critical in the perception of consecutive pitch-accents [8].

The parametric model is represented by a polynomial function. When the parameter values *p*=-0.5; *d*=-0.5; *s*=0.8; *h*=30 Hz and *l*=100 Hz are provided, the function defines a pitch-accent like the one in figure 1.

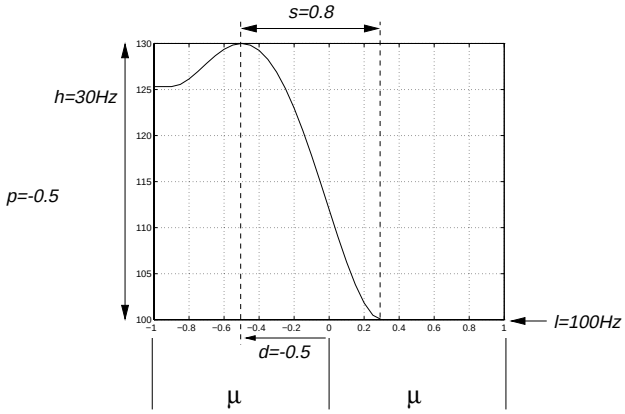

Figure 1: Prototypical pitch-accent representation generated by the parametric model.

The parameter values of the function may be numerically derived from the labelled data of any pitch-accent realization. A detailed description of such pitch-accents approximations characterizing German and English intonation are presented in [14] and [15]. In this study numerical approximations of the perplexing word-level accents of Lithuanian are provided.

2. PITCH-ACCENT IN LITHUANIAN

Lithuanian distinguishes three types of accents: the acute accent [´], the circumflex accent [˜], and the grave accent [`]. The grave accent is not contrastive, it is realized on the short vowels only, and its phonetic parameters vary. It will be not considered in this study. The phonetic properties of the other two accents are contrastive and highly invariant. The acute and the circumflex accents are contrastively used on long vowels (e.g. kóse 'porridge' ~ kõse 'to sour'), on diphthongs (áusta 'to cool' ~ aũsta 'to come'), and on short vowels followed by a sonorant (drímba 'lout' ~ drim̃ba 'to fall'). The common phonological property of long vowels, diphthongs and short vowels followed by a sonorant is that they form so-called heavy syllables, i.e. they are all composed of two phonological weight units, the morae. Thus, phonologically Lithuanian is considered as a prototypical example of a stress system where heavy syllables are marked by distinctive pitch - the s.c. "mora-pitch-accent" system.

The phonological difference between the acute and the circumflex accent is attributed to the alignment of the high pitch morpheme of the complex pitch-accent with the accent bearing unit. In case of an acute accent high pitch is assigned to the first (head) element of the heavy syllable e.g. káltas 'chisel' (the first mora [a] is associated with a high pitch morpheme). For circumflex accents the non-head part of the syllable (the second mora) is associated with a high pitch morpheme: e.g. kal̀tas 'guilty'. The result of this phonologically stipulated association and its phonetic implementation is a falling pitch contour [HL] for the acute accent and the rising pitch contour [LH] for the circumflex accent.

Phonetic studies of Lithuanian accent [4] point out that rising vs. falling pitch is not the main correlate of acute-circumflex accent opposition. It is claimed that due to pitch-accent levelling other acoustic parameters take over the contrastive property of the two accents. Still, auditory studies and perception experiments show that pitch declination is perceived as particularly salient in Lithuanian. Given the detailed parametric model of pitch-accent presented in the previous section we are in a position to check if, and in case of the positive result, which of the pitch-accent parameters is responsible for the prosodic salience of Lithuanian accents.

2.1. Parametric Approximation of Lithuanian Pitch-accents

Methods. A database of acoustic tokens instancing the contrast between the acute and the circumflex accents has been recorded at the Department of Lithuanian at the University of Vilnius (courtesy of Dr. Bonifacas Stundzia). The targeted tokens like kóse `porridge' ~ kõse 'to sour'; áusta 'to cool' ~ aũsta 'to come'; drímba `lout' ~ drim̃ba 'to fall'; káltas 'chisel' ~ kal̃tas 'guilty', etc., where placed in a prosodically balanced context (phrase medial position). They were recorded by two female speakers of standard Lithuanian (South-West variant). Each speaker recorded each token five times. Altogether 120 tokens (60 of each accent type) were set for the analysis and for training. The recordings were sampled with 16kHz/16 bit rate and low-pass-filtered using Ariel's ProPort A/D converter. The acoustic analysis of duration, F_0 variation, intensity and spectral structure of the accent bearing units was carried out using the S_TOOLS software. The results are presented in [4].

For the present study a subset of the targeted items were manually segmeted using the ESPS/xwaves software. Both moraic and syllabic segmentations were used. For example, the token like drímba 'lout' was segmented into the its syllabic constituent - [*drim*][*ba*] - as well as into the moraic constituents of the heavy syllable - *dr*[*i*][*m*]*ba*. F_0 values were extracted from the labelled files using the *get_f0* ESPS command. The pitch-accent parameters proposed in section 1 were extracted from these labelled files.

The parameter extraction was achieved by approximating the relevant F_0 values by the polynomial function described in section 1. A Nelder-Meade simplex search algorithm was used for the approximation. The approximation function was normalized for moraic and syllabic segmentations respectively. In this way we arrived at discrete values for the five parameters of the pitch-accent model. The resulting parameter values describe phonetic realizations of the acute and the circumflex accents in both the moraic and the syllabic context.

Results. The results show that the acute accent has a significantly (*t*-test sign. $< 10^{-8}$) higher movement amplitude. The average value of the parameter ***h*** for the acute accent is 79.3 Hz in contrast to 16.0 Hz for the circumflex accent. This means that the acute accent utilizes a much broader pitch range within the accent bearing unit.

The ***p*** parameter, which depicts the form of the accent, is highly invariant for the acute accent in the moraic segmentation. Its mean is at a value -0.81 with a low standard deviation ($\sigma = 0.20$). This means that the form of the acute accent is clearly falling. In contrast to the invariant form of the acute accent, the circumflex accent shows a very large variation in the form parameter ***p***. This means that its form can not be described. The only tentative conclusion to be drawn from the approximation is that all but one ***p***-values for the circumflex accent are positive, which speaks for the at least partially rising pitch curve.

The alignment parameter ***d*** can only be reasonably calculated for the acute accent. The low range (parameter ***h***) and the inconsistent form (parameter ***p***) of the circumflex prohibit further analysis of its alignment. The same holds true for the steepness parameter **s**, which can not be modeled for accents of very low range. For the acute accent we found that the pitch movement starts in the middle of the first mora (***d*** = -0.65) and ends in the middle of the second mora (***d***+***s*** = 0.61).

The fifth parameter ***l***, which represents the floor of the pitch movement is relevant for the modeling of intonation but it is irrelevant for the analysis of the pitch-accents and has been, therefore, not investigated in this study.

The representation of the acute accent as approximated by the model is given in figure 2.

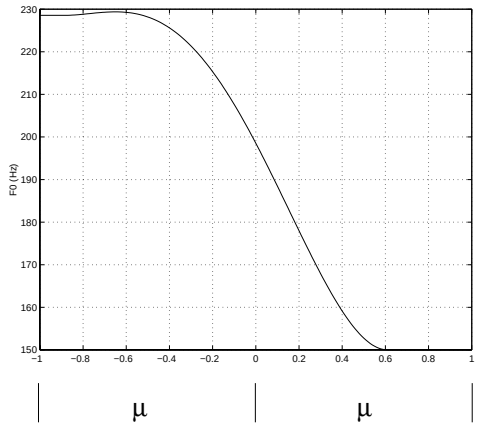

Figure 2: The representation of the acute accent as approximated by the model.

Discussion. The results of the approximation of the polynomial function on Lithaunian pitch-accents show that the acute accent can be quite precisely approximated given the set of five parameters whereas the circumflex accent defies such an approximation.

The statistical analysis of the parameters shows that the acute accent can be consistently described with the ***p***,***d***,***s***,***h*** parametrization within the moraic context. Hence, it may be defined as a crisp mora-pitch-accent.

The accentedness of the mora and the syllables associated with the circumflex accent apparently does not depend on its pitch characteristics. The variation of the accent form (***p***), its alignment (***d***), and steepness (***s***) is very large, irrespective of the syllabic or the moraic context from which the parameters are being extracted.

The difference between the two accents is, hence, not between the falling (acute) and the rising (circumflex) pitch, as it was stipulated in the phonological analyses of this phenomenon [1]. The difference can also be hardly attributed to the distinct auditory properties of the two accents. In traditional accounts of Lithuanian accents the acute accent was described as a *Stoßton* or *gestoßener Ton* ‘thrust tone’ and the circumflex accent as a *geschliffener Ton* ‘dragged tone’[6]. The difference can not be attributed to the accent bearing category either. The circumflex accent does not show any stable pitch-accent characteristics neither as a feature of the accent bearing syllable nor of the accent bearing mora.

The difference between the two accents is that between salience and variance. The acute accent is a distinctive mora-pitch-accent with crisp and clearly defined phonetic parameters. Its main characteristics is the invariance of form, alignment, steepness across speakers and contexts and its high F_0 amplitude. The circumflex accent, if it can be classified as a pitch-accent at all, it can not be described by a set stable phonetic parameters. The difference between salience and variance, which is a basis of the phonological contrast, has very far reaching phonological consequences, which in the case Lithaunian can be quite precisely traced.

2.2. Phonological Record of Lithuanian (Pitch-)accents

Since the very out of linguistics Lithuanian word prosody has been exceedingly well studied. The reason for this is that Lithuanian accentual system has always been considered to be close to the accentual system of the indo-european proto-language (Proto-Indo-European) [7],[16],[17],[9]. The reconstructed PIE shares with Lithuanian a property of having a *lexical accent system*. In a lexical accent system, morphemes (roots, derivational affixes and inflectional desinences) are all accentually marked by inherent prosodic properties. One of such properties depends on the ability to receive and preserve accent in a morphological paradigm. For example, in a declination paradigm of a noun *výras* ‘man’ the initial acute accent is preserved in all case forms. Consider the paradigm below:

- NOM. SG. výras PL. výrai
- GEN. SG.výro PL. výru
- DAT. SG. výrui PL. výrams
- ACC. SG. výre PL. výrus
- INST. SG. výru PL. výrais
- LOC. SG. výre PL. výruose

The property of preserving accent in a derivation is not characteristic of all strong (i.e. accent receiving) roots in Lithuanian. The derivation of the noun *vadõvas* ‘leader’ presented immediately below is parallel to the derivation of vyras presented above. However, in accusative singular {ACC. SG.}, instrumental plural {INST. PL.} and locative plural {LOC. PL.} the accent is advanced from the root morpheme to the affix. Consider the derivation below:

- NOM. SG. vadõvas PL. vadõvai
- GEN. SG. vadõvo PL. vadõvu
- DAT. SG. vadõvui PL. vadõvams
- ACC. SG. vadõva PL. **vadovùs**
- INST. SG. **vadovù** PL. vadõvais
- LOC. SG. **vadovè** PL. vadõuose

The grammatical morphemes ACC. SG.; INST. PL.; LOC. PL. belong to the class of the so-called “dominant” affixes. In lexical accent languages like PIE, Russian, Lithuanian, the dominant suffixes have an ability to exert influence upon the accentual properties of other morphemes in the same word. Usually the dominant

affixes attract accent to their own designated syllable (like in the declination of *vadõvas* given above), but they are capable of even more complex accentual shifts (see [18] for details, and [5] for a comprehensive summary). However, if the stem is underlyingly marked with an acute accent (like in the case of výras presented above), the morpho-lexical strength of the dominant affixes vanishes.

The mystifying relation between the lexical prosodic properties of Lithuanian morphemes (like dominance and strength) and the phonetic properties of Lithuanian accents (acute, circumflex) has been already noticed in the previous century. Fortunatov and de Saussure formulated a famous sound law [3;149-152] according to which a grave or a circumflex accent may be removed from the designated morpheme if the morpheme following it is capable of bearing an acute accent. Root morphemes marked with an acute accent are impervious to any accentual shifts.

The motivation of Saussure/Fortunatov law is mainly diachronic, and Saussure formulated the law explicitly for Lithuanian. However, the impact of the law can be observed in diachronic processes of many branches of the Indo-European, and the law has been shown to operate synchronically in Lithuanian dialects. Although the diachronic and synchronic implications of the law have been so fruitfully explored, the phonetic basis of the law has never been explicitly discussed.

3. GENERAL DISCUSSION

Our modeling results show that the main difference between the acute and circumflex accents in Lithuanian is that between salience and variance. The acute accent is a highly invariant pitch-accent with clearly definable form, alignment point within a mora and a precisely defined slope. Moreover, it is characterized by a large F_0 amplitude. We have arrived at this description of the acute accent not by the considerations of its theoretical import but by a parametrization of phonetic data. We have been much less successful with applying our pitch-accent approximation function to the circumflex accent. Low F_0 amplitude and highly variant contour and alignment, force us to consider circumflex accent as a very indeterminate representative of pitch-accent as a phonetic category.

Given the linguistically established correlation between the acute accent and the Saussure/Fortunatov sound law, we argue that this correlation has its basis in the invariant phonetic properties of this accent. In particular we claim that morphemes capable of carrying acute accent naturally attract it due to its phonetic salience. Moreover, we argue that acute accent is impenetrable to general phonological rules due to its phonetic invariance. In general we would expect that all phonological contrasts which may be characterized by unbalanced phonetic invariance to behave in a similar way.

Invariant phonetic shapes tend to be protected by sound laws.

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