PROSODY-SEGMENT INTERACTION IN THE ACOUSTICS OF POLISH PLOSIVES

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ABSTRACT

An acoustic study of voiced and voiceless word-initial plosives sought to establish the nature of the relationship between prosodic positions, accent, and segmental phonetics in Polish. VOT measurements revealed some position-induced effects in the case of voiceless stops. However, the mean differences between prosodic levels were minimal, and significant effects of position were only found for unaccented items with labial and dorsal onsets. For the voiced series, some effects of accent were observed, with pre-voicing longer in accented conditions. In turn, position revealed conflicting effects depending on the level of a given domain. Phrase-initial position appeared to be stronger than utterance-initial position in terms of pre-voicing. These results show little evidence of domain-initial strengthening observed in other languages, which in turn challenges the hypothesis of a universal prosodic hierarchy.

Keywords: Polish, prosody, prosody-segment relationship, phonetics-phonology interface.

1. INTRODUCTION

There is a long tradition of research within the domain of Prosodic Phonology (cf. [18], [12], [2], [21]) which postulates the existence of a universal Prosodic Hierarchy. This hierarchy imposes structural domains on languages and while the theories vary, the most widely agreed-upon domains – moving from smallest to largest – are the syllable, foot, prosodic word, intonational phrase, and utterance.

The Prosodic Hierarchy is argued to manifest itself in small variations with regard to the phonetic realisation of segments at different prosodic levels. There are a number of theories concerning the influence which prosody has on segments. The principle of Polarisation (e.g. [14]), for instance, assumes that the phonetic robustness of both members of a two-way laryngeal contrast will be increased in more prominent prosodic positions. In turn, Feature Enhancement (e.g. [8]) theory claims that prosodic prominence will affect only specified – i.e. marked – features. Yet another theory, known as Uniform Strengthening (e.g. [3]), assumes that phonological contrasts will not be enhanced under the influence of prosodic positions; rather, the acoustic fine-grained details of both members of the contrast will move in the same direction.

There are phonetic studies that provide empirical support for each of those theories. For example, [1] found polarisation effects in Swedish, with longer duration of pre-voicing in voiced plosives and longer VOT values in the voiceless series at larger prosodic domains. Therefore, there were effects of prosody observed in both members of the contrast. However, these results might also be explained by means of the feature enhancement hypothesis: Swedish voiced stops bear the feature [+voice], while the voiceless series is specified for [+spread glottis]. In other words, Swedish appears to be a case of both Polarisation and Feature Enhancement.

Other phonetic experiments appear to provide even more conflicting data. Relevant studies from various languages include the following:

- Voiceless stops in English in general have been shown to have higher VOT values at larger prosodic domains, cf. [7], [10] (e.g. when comparing utterance-initial with utterance-medial ones as in [5]).
- In Taiwanese [11] found more contact in the articulation of oral and nasal stops at higher prosodic domains but little effects were observed on VOT or vowel formant frequencies.
- [6] in their studies on Dutch observed that VOT of /t/ was shorter in stressed syllables and at stronger boundaries and longer at weaker boundaries, which contradicted the findings for English, suggesting the effects of prosody on segmental phonetics were language-dependent.
- In French, prosodic position appears to affect the articulation of stops and lateral consonants, but the effects were subject to much individual variation, cf. [9].
- Contrarily to French, in [4] Korean speakers were shown to be quite consistent in distinguishing at least three different prosodic levels, while [13] found that the degree of aspiration of stops in this language depends upon the prosodic position in which it occurs.

- In [3] Korean plain voiceless stops seemed to be unaffected by prosody, similarly to what [9] noticed in French, but the former was accounted for by the fact that Korean is a language with a three-way laryngeal contrast and longer VOT in plain voiceless stops might reduce the difference between them and the aspirated series which might be undesirable.
- [17] in one of very few phonetic studies on Polish found only minimal effects of prosodic position on the realisation of stop consonant voicing.
- Finally, [16] observed VOT shortening at higher prosodic positions in German and concluded that prosody seems to affect those acoustic parameters which are not highly relevant for expressing phonological contrasts.

The data from various languages is, therefore, quite inconclusive. To go even further, recently the universality of Prosodic Hierarchy has been questioned. [15] found that French, Taiwanese, and Korean in fact make different prosodic distinctions as not all languages require the same number of layers in their hierarchies. [19], for example, showed that Vietnamese seems not to have prosodic words, while Limbu exhibits multiple word domains, therefore revealing more layers than predicted by most Prosodic Hierarchy theories. Therefore, different prosodic constituents are emergent, rather than universal, and they seem to develop differently in various languages.

In [20], two opposing mechanisms for the emergence of prosodic constituents are proposed, encompassing different predictions with regard to prosodic strengthening effects. In one system, such effects are predicted to robust, while in the other, they are predicted to be minimal. This paper aims to test the hypothesis that Polish belongs to the latter type.

2. METHOD

2.1. Materials

A data set comprised of twenty four disyllabic target words was created. The words started with a voiced or a voiceless plosive /b,d,g,p,t,k/, counterbalanced for place of articulation and vowel context /a,ɛ,ɔ,ɨ/, and embedded in carrier sentences controlled for the total number of syllables. The vowel preceding the target word was always [ɨ]. The carrier sentences were carefully controlled in terms of prosodic factors. The three prosodic positions of interest were utterance-initial, phrase-initial (i.e. utterance-medial), and phrase-medial. The sentences were then elicited in both accented and unaccented condition. The examples in (1) show the three sentence types for the target word *tyfus* 'typhus' (the target word is underlined, the accented item is bolded).

- Utterance-initial:
  - *Dziś skutecznie go leczymy.* ***Tyfus*** *został już opanowany.* 'Nowadays it is successfully treated. **Typhus** has been contained.' – accented.
  - *Dziś skutecznie go leczymy. Tyfus* ***został*** *już opanowany.* 'Nowadays it is successfully treated. Typhus **has** been contained.' – unaccented.
- Phrase-initial (i.e. utterance-medial):
  - *Choć skutecznie go leczymy,* ***tyfus*** *nadal budzi przerażenie.* 'Although we can successfully treat it, **typhus** still evokes fear.' – accented.
  - *Choć skutecznie go leczymy, tyfus* ***nadal*** *budzi przerażenie.* 'Although we can successfully treat it, typhus **still** evokes fear.' – unaccented.
- Phrase-medial:
  - *W dzisiejszych czasach leczymy* ***tyfus*** *dzięki antybiotykowi.* 'Nowadays we treat **typhus** with antibiotics' – accented.
  - *W dzisiejszych czasach leczymy tyfus* ***dzięki*** *antybiotykowi.* 'Nowadays we treat typhus **with** antibiotics' – unaccented.

With six plosives (three voiceless and three voiced), four vowel contexts, and two accentual conditions, our set comprised 133 sentences.

2.2. Procedure

50 native speakers of Polish were asked to read the sentence list in a sound attenuated booth at a Polish university. They were aged 18-29 (median age: 24) and they were paid for their participation in the study. None of the speakers had completed any phonetic training and they claimed to have little command of any other foreign languages. The sentences were elicited using PowerPoint slides and the order thereof was randomised for each participant. The speakers were recorded directly onto laptop, using a head-mounted microphone and a USB interface.

2.3. Acoustic and statistical analyses

The acoustic analysis was performed in Praat by hand by the first author of the present paper. The acoustic measures with regard to both voiceless and voiced plosives included the duration of the vowel

preceding the target word, the closure, closure voicing (if any), VOT, and the duration of stressed and unstressed vowel. For voiced plosives, many items showed breaks in voicing toward the end of the closure. Negative VOT measures included items both with and without voicing breaks. Figure 1 exemplifies an instance of a voiceless plosive initial target word, while Figure 2 illustrates a voiced-initial one.

Figure 1: An example of annotated target word *tyfus* 'typhus'

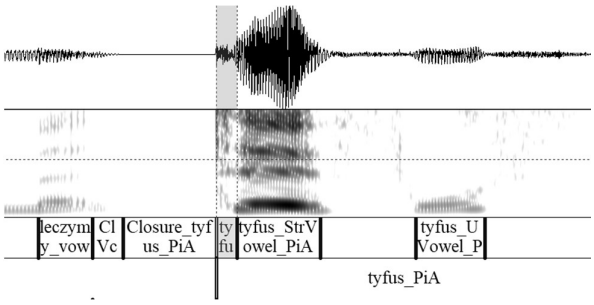
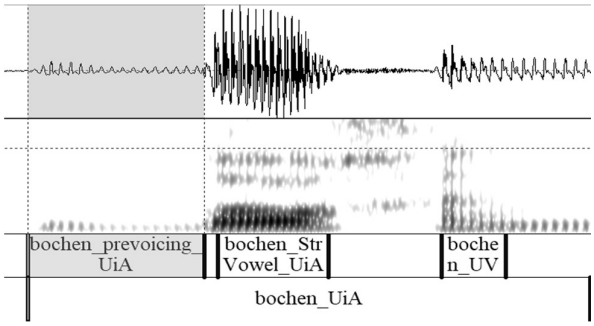


Figure 2: An example of annotated target word *bochen* 'a loaf'.



The acoustic measures were subsequently extracted using a Praat script and a statistical analysis was conducted for both series of stops by the second author of the paper. Generalised Mixed Models were run in SPSS with VOT duration as the dependent variable, Accent * (Prosodic)Position * Consonant-place as fixed factors, and Speaker and Vowel as random factors.

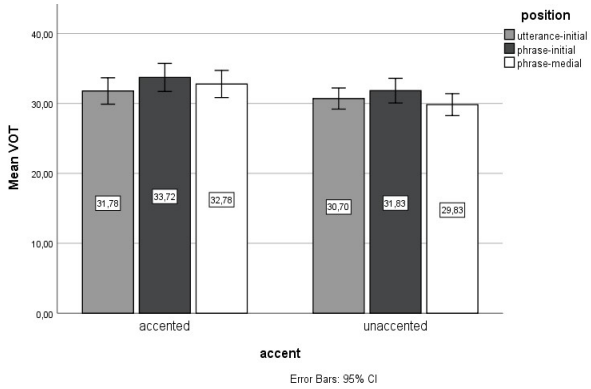
3. RESULTS

3.1. Voiceless plosives

For the purposes of the present paper we have been able to annotate and analyse the data on /p, t, k/ from 20 speakers out of 50 recorded. After all exclusions, which included hesitations or errors, we ended up with 1381 items: 457 utterance-initial, 465 phrase-initial, and 459 phrase-medial ones.

For the accented condition the mean value for utterance-initial plosives was 31 ms (SD=14), phrase-initial 33 ms (SD=15), and phrase-medial 32 ms (SD=14). For the unaccented condition the mean value for utterance-initial plosives was 30 ms (SD=1 11), for phrase initial 31 ms (SD=13), and for phrase-medial ones was 29 ms (SD=12). These results are summarised in Figure 3.

Figure 3: Mean values for the accented and unaccented conditions for all three prosodic positions.



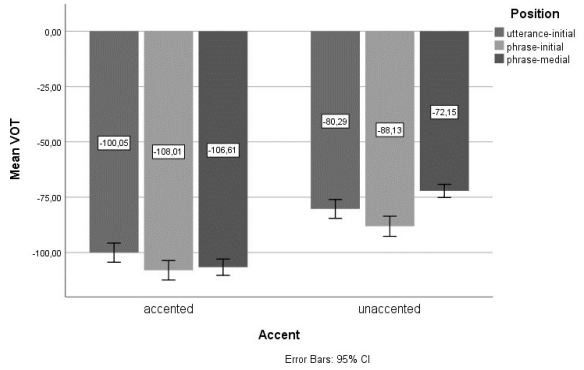
Significant effects of prosodic position were found only in unaccented items. For labial onsets there was difference between utterance-initial and phrase-medial stops ($p<.05$; contrast estimate of 2 ms). Dorsal onsets exhibited difference in phrase-initial and phrase-medial plosives ($p=.01$, contrast estimate of 2.57 ms).

3.2. Voiced plosives

The analysis of /b, d, g/ also included data from 20 speakers. The number of obtained tokens was 1346, out of which 450 was utterance-initial, 440 phrase-initial, and 456 phrase-medial.

Some effects of accent were found, with the accented items displaying higher overall negative VOT values. The mean value for utterance-initial plosives in the accented condition was -100 ms (SD=30), for phrase-initial -108 ms (SD=33), and for phrase-medial -106 ms (SD=28). In the unaccented condition, the mean value for utterance-initial ones was -80 ms (SD=32), -88 ms (SD=33) for phrase-initials, and -72 ms (SD=32) for phrase-medials. Figure 4 summarises these data.

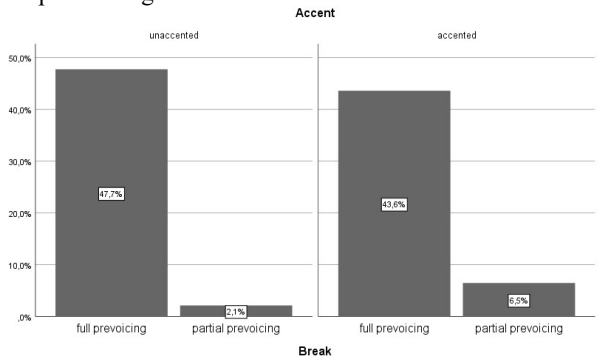
Figure 4: Mean values for the accented and unaccented conditions for all three prosodic positions.



Longer pre-voicing was found between accented utterance-initial and phrase-medial plosives, with pre-voicing values higher for the former (p=.009). In the unaccented condition, the difference between these two positions was approaching significance (p=.059).

There were a number of /b, d, g/ realisations where a break in pre-voicing was found. Figure 5 illustrates the percentage of items with a break in pre-voicing in the accented and unaccented conditions.

Figure 4: Percentages of items with full and partial pre-voicing in accented and unaccented conditions.



The results suggest that the break in pre-voicing leads to higher values of negative VOT which is shown in Table 1. No significant effects of position or place of articulation were observed.

Table 1: Mean VOT durations sorted for accentedness and the nature of pre-voicing.

utterance initial	accented	full pre-voicing	-96 ms
		partial pre-voicing	-123 ms
	unaccented	full pre-voicing	-78 ms
		partial pre-voicing	-120 ms
phrase initial	accented	full pre-voicing	-105 ms
		partial pre-voicing	-123 ms
	unaccented	full pre-voicing	-85 ms
		partial pre-voicing	-126 ms
phrase medial	accented	full pre-voicing	-103 ms
		partial pre-voicing	-127 ms
	unaccented	full pre-voicing	-71 ms
		partial pre-voicing	-127 ms

4. DISCUSSION

The acoustic study provides a perspective on the phonetic variation induced by prosodic positions. This subsection will attempt to interpret the reported data.

First of all, we may note that in both /p, t, k/ and /b, d, g/ the phrase-initial plosives had slightly greater – positive and negative, respectively – VOT values than utterance-initial ones. This direction is quite unexpected if we consider the basic conjectures of Prosodic Hierarchy. What we find in Polish, instead of the values changing in a systematic way in accordance with the postulated hierarchy, is that a smaller prosodic boundary, the phrase, yields longer VOT values than larger utterances.

Moreover, going back the three hypotheses mentioned in Section 1 which attempt to account for the relationship between prosody and segmental realisations, we may note that the apparent lack of effects of position on the phonetic realisation of the voiceless series and the inconclusive results observed in the voiced series do not support any of them, provided we employ the traditional feature theory that would specify /p, t, k/ as [-voice] and [b, d, g] as [+voice].

While the voiced series of plosives did show some strengthening effects between different prosodic positions, it was observed that pre-voicing was often interrupted. If we consider longer negative VOT as strengthening, but that strengthening has a break in the middle, it actually appears to be simultaneously fortition and lenition of the feature [+voice].

The results appear compatible with the typology put forward in [20], which divides languages into ‘submersion’ and ‘adjunction’ systems, and hypothesizes that Polish belongs to the latter. Adjunction systems place initial and non-initial segments at the same representational level. As a result, minimal strengthening effects should be expected – utterance-initial stops are no ‘higher’ than phrase-initial or phrase-medial segments.

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