ACOUSTIC ANALYSIS OF LEXICAL TONES IN CONTEMPORARY STANDARD SLOVENIAN

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ABSTRACT

The present investigation into acoustic properties of tones in Slovenian addresses vowel duration, intensity and fundamental frequency. Although no statistical differences were found with respect to vowel duration and intensity, the two lexical tones (or pitch-accents) differed highly significantly in terms of fundamental frequency. Results from the present investigation differ greatly from what has been previously reported. Roughly, the two lexical classes differ on the basis of tone on the stressed and on the final syllable. In the first lexical class, tone is Low on the stressed syllable and High on the final. In the second lexical class, the situation is the reverse; the stressed vowel is High in tone while the final syllable is Low.

Keywords: Acoustic phonetics, tones, pitch-accent, Slovenian.

1. INTRODUCTION

Historically, it has been established that Slovenian has two lexical tones, or pitch-accents, termed *acute* and *circumflex*. The tones are obligatory in some dialects but optional in the standard language. The stress is an independent of tone in Slovenian, indicated by duration [9], vowel quality, spectral tilt [4, 6] and other characteristics, e.g. phonation, cf. [5]. Also, in the non-tonal dialects, stress is marked primarily by a rise in fundamental frequency. — As this investigation is not about phonological properties of the tones in Slovenian, the existence of the two lexical classes shall not be questioned.

Although Slovenian tones have been investigated acoustically since the 1930's, the results of the majority of studies were inconclusive, often contradictory and generally not representative. Studies so far limited the scope of analysis to fundamental frequency. Although duration was mentioned, it was not considered systematically [9].

The first acoustic characterization of Slovenian tones based on actual measurements can be traced to [1]. It was not until two decades later, that a proper acoustic investigation was conducted [12]. Vodušek recorded a limited number of tokens and investigated speakers of different dialectal background, chiefly linguists. He found two different realizations of both tones, dependent on the background (dialect) of the informant. A feature common to both variants is a general Low of the acute tone and a general High of the circumflex tone (stressed vowels only). However, the author also notes that tones may be realized over the stressed and the post-tonic syllable, and that monosyllables are distinctive in some of the examined dialects.

Toporišič [11] sumarized his findings in a similar manner: High vs. Low play a decisive role in Slovenian tones. Based on a much larger corpus of material but only one speaker, he concluded that both tones differ in f_0 of the stressed and the first post-tonic vowel. In acutes, f_0 is Low on the stressed vowel, and High on the post-tonic; in circumlexes the opposite is true. In the final position of the prosodic word, the post-tonic syllable is omitted, such that acute is realized as Low tone, and circumflex as High.

Neweklowsky [8] analyzed tone in Carinthian dialects. He also found significant differences in f_0 (as well as duration). Roughly, f_0 peak was found to be the most indicative of both tones, acute having the peak on the post-tonic while circumflex having it on the tonic syllable.

Srebot Rejec [9] investigated both duration and f_0, and compiled an extensive corpus of sentences from three male speakers from Ljubljana. With regards to prosody, she concludes the following: (i) quantity is no longer distinctive in standard Slovenian, (ii) tone is marginally, but still significantly distinctive, although probably not in the final syllable [10], (iii) tones are typically realized as contours. The tones are ideally realized with a peak in f_0 at about two thirds of the duration of the stressed vowel (Class I) or at the end of the post-tonic syllable. The domain of tone is a foot consisting of two syllables, or a single syllable in the case of final stress. Srebot Rejec's analysis is phonetically the most accurate so far. Similar to Neweklowsky, she took three points of measurement, in the beginning, middle and end of the vowel. Although more recent sources indi-

cate progressive loss of tone in Slovenian dialects ([7], Vera Smole and Roberto Dapit, p.c.), it is still believed that tonal Slovenian is widely spoken. Preliminary results of a perceptual study by the author show that tones are perceived well above the chance levels by the native speakers, contrary to what was reported by Šuštaršič and Tivadar [13].

In this paper, we try to fill in the gaps in acoustics of Slovenian tones. Three acoustic parameters are investigated: fundamental frequency, duration and intensity.

2. METHOD

In order to properly observe tonal phenomena, segmental influences, sentence intonation and speaker variability should be minimized from the outset. In a controlled experiment such as this, the prepared list of words should be compiled carefully. It is known that non-vocalic segments influence f_0, duration and intensity. In the present investigation, minimal pairs in tone were used to minimize these variables. Sixteen minimal pairs of mono- to trisyllables were selected from available dictionaries, a few of the pairs being morphologically related. The following consonant and vowel patterns were observed: CV.CV as a basic tamplate, CVC.CV and CV.CVC as templates with closed syllables, monosyllable CVC and tri-syllables CV.CV.CV. The complete list of words with both tones includes the following minimal pairs: 1 mono-syllable, 12 di-syllables (7 of which only have open syllables) and 3 tri-syllables. All words have word-initial stress. Based on the previous findings (see Sec. 1.), pre-tonic syllables were not analyzed.

The words were then put in frame sentences, using original contexts of the selected words, based on the text corpus Nova beseda [3]. The sentences were randomized and put into a Power Point presentation which was later read by the subjects.

Next, the subjects were selected. Eight speakers from central Slovenia, all residents of Ljubljana, some originally form different parts of Lower Carniola (2), Upper Carniola (1) and Carinthia (1). All were educated past high school, four of them female and four male. Median age at the time of the experiment was 38 years. Two male speakers were later excluded form the analysis because it was established that they did not seem to speak a tonal variety of Slovenian; their minimal pairs did not differ significantly. Consequently, only the tones of six speakers (four females, two males) are acknowledged. This may cause a typical frequency bias, such that average F0 would be higher than otherwise. However, it is not the absolute values that are at question here, but relative pitch contours.

The subjects were instructed first to read the sentences that appeared on the computer screen. These were cues for contextualizing relevant words (minimal pairs in tone). After reading the sentence, a word changed the color on the screen and then disappeared. The speakers were orally instructed to utter the word in a carrier sentence (Reci [kila] navadno, ne posebno. *'Say* [kila] regularly*, not in a special way.'*). Each such carrier sentence was repeated.

The recordings took place in several sound-proof rooms (usually radio studios, different locations). Recording was digital, with a standard sampling frequency of 44.1 kHz at a 16 bit rate. Recordings were stored on digital storage devices and later transferred to a computer for acoustic analysis. For acoustic analysis, Praat software program [2], was used. Relevant words were segmented manually, and then analyzed using modified scripts. Normally the first utterance of the carrier sentence was analyzed. Duration was measured for all stressed and post-tonic vowels, as well as time-normalized f_0 and intensity contours. For each vowel, 11 points of intensity and F0 were measured. Intensity and F0 themselves were not normalized, as they did not differ significantly from the absolute values. In this manner, 192 words were obtained for analysis, i.e. 96 minimal pairs, or 408 vowels. However, 9 words (4.7%) were excluded from the analysis because of various reasons (e.g. incorrect pronunciation, irregular or non-detectable f_0).

3. RESULTS

3.1. Duration

Durations of individual vowels (not whole syllables nor voiced parts thereof) in the observed words were measured, ratios calculated and averaged. The results are presented in Table 1.

The results indicate that the stressed vowel is slightly longer in Class I words, such that difference is independent of any segmental, (sentence) intonational and even speaker dependent influences. Moreover, it is consistent across all word types. Also, the difference is never statistically significant ($0.1 < p < 0.6$). This leads to the conclusion that no statistically significant differences between both tonal types could be detected.

3.2. Intensity

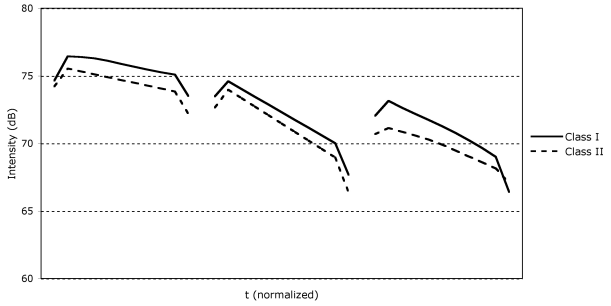
Cross-linguistically, intensity contours are known to complement tonal contours. In Slovenian however, no statistically significant differences ($p > 0.3$) in intonation contours were detected, see Fig. 1. Here, only CVCVCV words are presented, as the results

Table 1: Duration of vowels with respect to tone. Abbreviations: Dur – averaged sum of individual vowel durations in a word, $\%v_1$ – percentage of the first vowel with respect to the sum of durations of all vowels in a word, Ratio II/I – Ratio of average total vowel durations of Class II with respect to Class I words.

Word type	Class I Dur	$\%v_1$	$\%v_2$	$\%v_3$	Ratio II/I
cv.cv	235	51.3	48.7		
cvc.cvc	218	61.0	39.0		
cv.cv.cv	243	35.4	30.0	34.6	
cvc	122				
Word type	**Class II Dur**	$\%v_1$	$\%v_2$	$\%v_3$	**Ratio II/I**
cv.cv	220	52.9	47.1		.937
cvc.cvc	201	61.8	38.2		.921
cv.cv.cv	219	38.6	31.3	30.1	.902
cvc	109				.893

for all word types are similar. Previously, intensity had not been studied in connection to Slovenian. An interesting discovery is that in words with antepenultimate stress, a secondary intensity peak in the final syllable/vowel is found. This may be indicative of secondary stress, also connected to tonal prominence of final vowels (see Sec. 3.3.).

Figure 1: CVCVCV intensity contours (for each vowel).

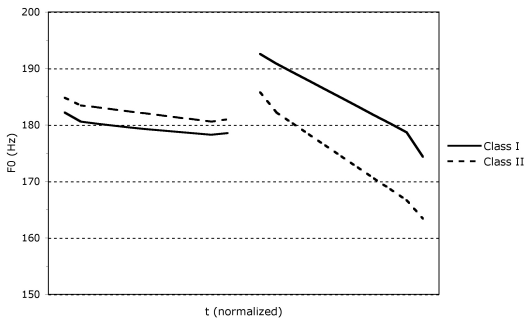


3.3. Fundamental frequency

Previous studies have already established that Slovenian tones differ primarily in f_0. However, they disagree on how this difference is realized and on how it should be interpreted phonologically.

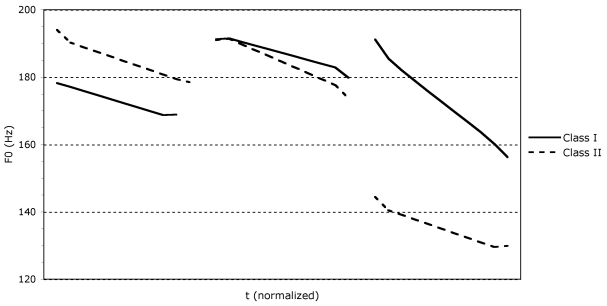
An average CV́CV word was realized as presented in Fig. 2. As evident from the graph, stressed syllables do not differ in f_0 (at least not significantly), whereas post-tonic syllables have higher f_0 in Class I words, and both contours are falling. Difference in the post-tonic syllable is statistically highly significant ($p < 0.005$). The situation is somewhat different in closed syllables, but still significant (figure not reproduced here).

Figure 2: CVCV f_0 contours (for each vowel).



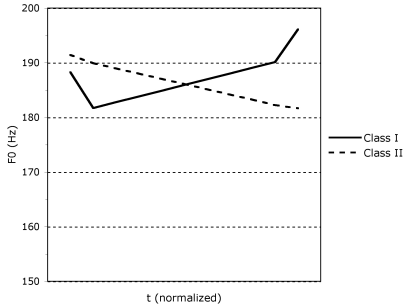
Tones in trisyllables also differ highly significantly ($p < 0.001$). The distinction is limited to stressed (antepenultimate) and the final syllables, the former having lower f_0 in Class I tone, and the latter being considerably higher, see Fig. 3. This is a surprising find as acoustic phoneticians have so far only considered stressed and immediately post-tonic syllables in Slovenian, not the rest of the prosodic word.

Figure 3: CVCVCV f_0 contours (for each vowel).



Monosyllables differ only marginally significantly ($p = 0.042$), although a clear tendency is visible in Fig. 4: Class I has a rising contour, while Class II has a falling one. This seems to be in accordance with the findings in [9, 10, 12]: in the speech of Central Slovenia, tonal differences are neutralized in monosyllables. The question, whether this is phonological proper (l.c.), effectively neutralizing all tonal contrast in final-stressed words, positionally phonological or just phonetic, remains beyond the scope of this article. The results should be interpreted with caution: only six tokens were analyzed for each tone, of which only one was a monosyllabic word (as monosyllabic minimal pairs are rather rare).

Figure 4: CVC f_0 contours (for the vowel).



4. DISCUSSION AND CONCLUSION

The results of the experiments can be summed up as follows: there is no significant difference in neither duration nor intensity between both tones, while fundamental frequency is highly distinctive. In disyllables with initial stress, the post-tonic syllable is usually phonetically distinctive. In trisyllables with initial stress, it is the final syllable that is the most distinctive. Monosyllables also differ in tone. The stressed and all post-tonic syllables constitute the domain of the tone. Contemporary Standard Slovenian, as spoken by educated speakers in Ljubljana, is tonal.

All these findings are connected to the questions (not) addressed in the acoustic investigations of Slovenian tones in the 20th century. For example, vowels two or more syllables after the stressed vowel were never taken into account. The present findings suggest that it is not the immediately post-tonic syllable, but rather the final syllable, that is actually phonetically (and phonologically) relevant. (Native Slovenian roots do not permit pre-antepentultimate stress, but it can surface in the derivation or inflection.) Now it is also clear, that Slovenian tones do not simply translate into High or Low tone (as suggested by [11]) on the stressed vowel, and that all other tonal information is predictable, viz., phonetic. Actual realizations are much more complex (Table 2). The acoustic data from the antepenultimates cannot be explained by any of the previous phonological descriptions of Slovenian. Instead, High vs. Low is distributed on the head of the prosodic word (i.e. the stressed vowel) and the right edge of the prosodic word.

Further investigation is needed to account, for example, for sentence intonation. From a broader perspective, European tone (or pitch-accent) languages are vastly under-described, and much work is yet to be done. The same is true for the majority of Slovenian dialects.

Table 2: Prosodic notation, most consistent with the findings.

Stress	Class I		Class II	
Final	pŏt	‘sweat’	pôt	‘path’
Penult	ˈkìlâ	‘hernia’	ˈkílâ	‘kg’
Antepen	ˈʃàlítsâ	‘joke-dem’	ˈʃálítsà	‘cup’

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