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# ACOUSTIC DESCRIPTION OF CROATIAN ACCENTS

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This paper presents the descriptive acoustic analysis of Croatian prosodies, i.e. the four lexical accents and the post-accentual length in the pronunciation of twenty young speakers of Croatian (average age 21.6). The total corpus consisting of 900 tokens has been analysed through listening and after that the auditory unambiguous words (52 % of tokens in the corpus) have been analysed according to acoustic dimensions of duration, intonation and intensity. The results of the acoustic analysis indicate that the mean duration of the stressed vowel in the short-falling accent is 123 ms (SD 28), in the short-rising accent 124 ms (SD 24), in the long-falling 190 ms (SD 33) and in the long-rising 185 ms (SD 33). Post-hoc tests of durational differences show that two long accents are significantly longer than the two short accents ( $p < .000$ ). Durational differences between rising and falling accents are small and statistically not significant: LF vs. LR ( $p = .282$ ); SF vs. SR ( $p = .573$ ). In 2/3 of the words the post-accentual phonologically long vowel is perceived as long, and its mean duration is 130 ms (SD 36), that is, 96 % of the total duration of the stressed vowel. Phonologically short post-accentual vowel averagely lasts 95 ms (SD 31), that is, 66 % of the total duration of the stressed vowel. Falling accents have a downward pattern of fundamental frequency in the accented syllable and mostly flat pattern in the post-accentual syllable, while rising accents have a generally flat frequency contour in the accented syllable and a downward contour in the post-accentual syllable. The pitch range (in semitones – ST) within the accented vowel of the long-falling accent is 3.7 ST, of the short-falling accent 2.2 ST, of the long-rising accent 1.4 ST and of the short-rising accent 1.3 ST. The relation between average tone and intensity of the accented and post-accentual vowel indicates that the post-accentual vowel of the falling accents generally has a significantly lower tone and lower intensity than of the rising accents. The pitch level of post-accentual vowel expressed as a ratio of the pitch level of accented vowel in the long-falling accent are –3.8 ST, in the short-falling accent –3.7 ST, in the long-rising accent –1.7 ST and in the short-rising accent –1.2 ST. The intensity level of post-accentual vowel expressed as a ratio of the intensity level of accented vowel (in dB) in the long-falling accents are –8.5 dB, in the short-falling accent –7.6 dB, in the long-rising accent and –7.6 dB and in the short-rising accent –5.5 dB.

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## 1. INTRODUCTION

The Croatian accentual system has the characteristics of both stress accent languages and tone languages and it belongs to so-called pitch accent languages. In pitch-accent systems both the place of stress as well as the pitch level or pitch curve have a lexical function, whereas the accentual distribution is limited. Other languages described as belonging to pitch accent systems are Lithuanian, Swedish and Slovene and their respective accentual systems are typologically comparable to that

of Croatian. The Croatian system of word prosody in contemporary grammars, dictionaries as well as the various works with phonetic and phonological descriptions of standard Croatian (Barić et al. 1997, Anić 2003, Škarić 1991, Jelaska 2004) has been described as a four accent system with two types of long accents (falling and rising) and short accents (falling and rising) as well as the long and short post-accentual vowels. Although in the history of Croatian grammars the number of accents, their phonetic description, names and symbols has constantly been changing (Lehiste and Ivić 1996), this four accent description is based on the prosodic system of the Štokavian dialect that was chosen as the base for standard Croatian and Serbian in the mid 19<sup>th</sup> century. In the 20<sup>th</sup> century Croatian accents were labelled as: long-falling (e.g. *zlâto*), long-rising (e.g. *rúka*), short-falling (e.g. *kůća*) and short-rising (e.g. *žēna*). The post-accentual syllables can be phonologically short (e.g. *rúkā*) or phonologically long (e.g. *slánōst*). In further text these prosodies will be referred to with the following abbreviations: "SF" for short-falling, "SR" for short-rising, "LF" for long-falling and "LR" for long-rising, while the post-accentual length will be marked by the letter "L" at the end of the abbreviation, for example "SFL". Except for these terms there are also other ones in usage, such as "slow" or "weak" for SR as well as "fast", "quick" or "strong" for SF (Barić et al. 1997: 68). The contemporary normative handbooks of Croatian, Bosnian and Serbian have the same description of the repertoire of word accent systems and they set the same rules of distribution (falling accents can only be placed on the initial syllables, rising accents can be placed on all syllables except for the closing syllables of words). This paper is theoretically based on the research related to word prosody in both Croatian and Serbian variety while the measurements of the contemporary word prosody are based on Croatian speech.

Phonetic characteristics of Croatian lexical accents from the perceptive and acoustic viewpoints have been described by numerous authors (Masing 1876, Appel 1950, Rheder 1968, Lehiste and Ivić 1963, 1965 and 1967, Wagner and Matejka 1971, Peco and Pravica 1972, Purcell 1973, Gvozdanović 1980), while the summary and wide critique of all of these descriptions as well as their own detailed descriptions have been given by Lehiste and Ivić (1986). Bakran (1986) measured the duration of accents in contemporary and classic speech, Škarić (1991) proposed a theory concerning the relation between the contours of intensity and tone that is parallel in the falling accents and divergent in the rising accents, Godjevac (2000) examined the relation between the accents of words and information structure in sentence intonation in Serbian, Sovilj (2002) analysed some of the acoustic characteristics of Serbian accents, Pletikos (2003) described the four acoustic dimensions of Croatian classic accents and Smiljanić (2004) described the duration and pitch alignment in four accent types (in broad and narrow focus and in sentence initial and sentence final position) in Two dialects of Croatian and Serbian (the speech of contemporary speakers in Zagreb and Belgrade). The results of the former research vary regarding the statistical differences in the duration of vowels of accented syl-

lables in falling and rising accents and the duration of phonologically short and long post-accentual vowels. Most research results agree on the description of intonation curves of individual accents, according to which the falling accents have falling curves while rising accents have predominantly flat curves with the same or higher fundamental frequency at the beginning of the post-accentual syllable. Falling and rising accents differ in the interpretation of the primary acoustic symbol for the perceptive differentiation of falling and rising accents: is pitch movement, pitch range, pitch alignment or the relation between tone and intensity a relevant cue. Another issue is whether the bi-syllabicity is a characteristic of rising accents (long-rising and short rising) or short accents (short-rising and short-falling).

The Croatian accent system was described in the context of different phonological theories: generative phonology, auto-segmental phonology, metrical phonology and the Optimality theory. The overview of various phonological descriptions (McCawley 1963, Browne and McCawley 1965, Inkelas and Zec 1988, Babić and Josipović 1991, Mihaljević 1991, Gvozdanović 1999, Zec 2005) along with the author's original phonological systematization may be found in texts written by Jelaska (2004).

Numerous socio-phonetic research on the attitudes towards Croatian accents (Škarić 1999, 2001, Varošaneć-Škarić 2001, Varošaneć-Škarić and Škavić 2001, Škarić and Lazić 2002, Škarić and Varošaneć-Škarić 2003), the accent type recognition (Magner and Matejka 1971, Vrbanić Zrinski and Varošaneć-Škarić 2004) and the acquirement of specific accents (Mildner 1994) support the thesis according to Croatian accent system has three different accent types (SR and SF are neutralized to SF). Although the short-rising accent exists in the speeches having Štokavian dialectal base (e.g. Osijek or Split), it is not considered to be a universal feature of the general Croatian language, since most of the speeches having Kajkavian and Čakavian base do not have realizations of SR (e.g. Zagreb or Rijeka), while accent system in one part of Zagreb Dialect is reduced to a single stress accent, the so-called "sluggish" accent ("tromi") or "semi-long" (Magner 1966, Šojat 1998, Škarić 1991), phonetically described by Smiljanić (2004). Several research have proved that the distribution rule according to which falling accents are strictly limited to initial syllables no longer operates in the contemporary Croatian speech, but that the falling accents may be found in all syllables of a word (Škarić et al. 1987, Škavić and Varošaneć-Škarić 1999, Škarić 1999, Škarić 2002, Škarić et al. 2004).

This paper examines which accentual forms are being pronounced and the acoustic description of patterns that based on perception may be categorized into four standard accentual types. The paper includes the analysis of the three acoustic dimensions of word prosody: duration, intonation, the intensity of accented and post-accentual vowels in monosyllabic, disyllabic, trisyllabic, quadrisyllabic words spoken in isolation, which are also accentually unambiguous according to position, quality and quantity of accent

## 2. METHOD

The corpus for the analysis of the acoustic parameters consists of 900 tokens, i.e. 45 words spoken by 20 speakers. All speakers have Croatian as their native language and they originate from different parts of Croatia. The average age of a speaker is 21.6 and the majority of them are students. Although this sample is not representative both according to number and origin, the young, urban, highly educated population, may nevertheless indicate the tendencies present in the realization of word prosody in contemporary standard Croatian. According to the estimate of the speakers themselves, their speech is influenced by all three dialects, approximately 16% by the Čakavian, 27% by the Kajkavian and 58% by the Štokavian dialect. Data on individual speakers – age, sex and the origin of the speakers and their parents, as well as their own estimate of the dialect influence may be found in Appendix I. The majority of the speakers have lived in Zagreb for at least past two years.

The speakers were recorded in 2003 with the high-quality equipment on a mini disc recorder in a soundproof booth in the Department of Phonetics at the University of Zagreb. Each speaker read a set of words that were displayed on the screen in random order. The data were transferred to computer at the sampling rate 16 kHz. The list of words consisted of the total of 45 familiar and frequent words with unambiguous accents in terms of their notation in dictionaries (Anić 2003, Deanović and Jernej 1991), having comparable syllabic and sound structures. The following words with the long-falling accent were chosen: *zéc, dívno, dōba, drvlje, būnda, Kárlovac, dněvnica, dājēm, rūdnik*; words with the long-rising accent: *dávno, déblo, dojam, brko, duša, podatak, dīsati, gubítak, metoda, dūbiti, poduzéće, slánost, dižnōst*; words with the short-falling accent: *dāti, dēset, dēvet, diči, dōbar, držak, duġo, dīgnuti, kućica, drškōst, dōgadāj*; words with the short-rising accent: *dānas, dōbro, dūbok, dādilja, dīvljati, dubīna, teškōća, dēšnjāk, kapētān, dīvlji, držāč, rezultāt*.

The acoustic analysis of the recorded material that included the four accentual types was carried out by the two phoneticians skilled in accent listening (authors of this paper) who listened through the material and marked whether the pronounced prosodic patterns correspond to the expected accentual category. The accents on whose estimate the experts did not agree in two listening sessions (disagreements between the first and second listening sessions or mutual disagreements) were registered as indefinite short (for ambivalence SR, SF, short stressed) or as indefinite long (for ambivalence LF, LR, long stressed). The Zagreb stress accent, the so-called "sluggish", "slow" or "semi-long" accent is most frequently categorized as indefinite short or even as SF. The listening sessions do not indicate whether the insufficient perceptive clarity of accents is caused by the reduced accentual system of the speaker idiom or by the marked sentence intonation. Words that have been clearly pronounced with non-falling sentence intonation, words with an unexpected position of accent as well as the words spoken in the accentual category different

from the one marked in the dictionary have also been excluded from the corpus for acoustic analysis. Realized (i.e. audible) and unrealized post-accentual lengths have also been separately analysed.

The acoustic analysis of duration, intonation and intensity has been done in the phonetic program Praat 4.0.49. Words have been segmented and vowels have been taken as the exponents of the word prosody. The obtained numerical data have been statistically analysed through SPSS program. The statistical analyses included mean and standard deviation, One-Way ANOVA (the accent type was taken as the factor) and post-hoc tests (Scheffe).

In order to compare the frequency curves of individual accents of different duration, all the frequency and intensity values have been calculated in normalized time, i.e. every 10% of vowel duration. In order to level out and compare the pitch movement and pitch ranges of twenty speakers (three of which were male speakers having particularly low fundamental frequency), all the frequency values in Hz have been converted into octave relations (whose referential value corresponds to the average frequency of an accented vowel), while the frequency ranges within and between syllables have also been converted into semitones.

## 3. RESULTS AND DISCUSSION

### 3.1. THE ANALYSIS OF THE PRONOUNCED ACCENTS ACCORDING TO THE AUDITORY ESTIMATE

From 900 tokens that constituted the corpus 52.4% of them were correctly pronounced and they may be used for an authentic acoustic description of the four Croatian accents. The remaining words, constituting almost half of the entire corpus, were pronounced with an indefinite accent, non-standard accent or in an inappropriate sentence intonation. Table 1 presents different ways of accent realization, i.e. the extent to which the accents were realized within the expected standard accent types. The accents perceived to be pronounced according to the prescribed standard, i.e. with the accent with which a particular word is labelled in the Dictionary of the Croatian language (Anić 2003) have been labelled as "correct". Among the performances which cannot represent the forms of standard accents are: stress shifted to the next syllable (0.3%), indefinite short accents i.e. perceptive oscillations SF, SR (23.7%), indefinite long accents, i. e. oscillations LR, LF (11.7%) and rising and flat intonations (7.6%). In spite of being pronounced with one of the four typically described and accepted accents, 4.3% of all performances depart from the standard since in the dictionary those words are marked by another accent. The examinees further varied in the number of incorrectly pronounced accents from the minimum of two words (one speaker) to the maximum of all 45 words (two speakers) (see Appendix I).

The analysis of individual accents indicated the frequency of correct pronunciations for each of the accents: the short-falling accent was most frequently correctly pronounced (77.7%), then follow the long-falling (56.7%) and long-rising



accents (45.4%), while the short-rising accents had the lowest incidence of correct pronunciations (33.8%). Such information support the results of the research on auditory recognition of Croatian accents indicating that the falling accents are more readily recognized than the rising accents (Vrban Zrinski and Varošaneć-Škarić 2004). The results also demonstrate that there is a considerable difference between production and perception. More specifically, although the long-falling accent is most easily perceived (86.03%), in this research only 56.7% of the words with the expected long-falling accent (the majority of other accents are not sufficiently falling, so they are accordingly marked as indefinite long or their pronunciation is shortened) passed the verification procedure.

Table 1. The types of realization of standard accents (according to auditory estimate).

Standard accent types										
	LF		LR		SF		SR		Total	
Number of tokens	180		260		220		240		900	
	%		%		%		%		tokens	%
correct	102	56.7	118	45.4	171	77.7	81	33.8	472	52.4
incorrect	78	43.3	142	54.6	49	22.3	159	66.2	428	47.6
incorrect accents are realized as:										
LF			1	0.4					1	0.1
LR	5	2.8							5	0.6
SF	2	1.1	5	1.9			16	6.7	23	2.6
SR	2	1.1	7	2.7	1	0.5			10	1.1
indefinite long	27	15.0	75	28.8	3	1.4			105	11.7
indefinite short	26	14.4	31	11.9	31	14.1	125	52.1	213	23.7
influenced by sentence intonation	16	8.9	23	8.8	14	6.4	15	6.3	68	7.6
stressed on the second syllable							3	1.3	3	0.3

### 3.2. ACOUSTIC ANALYSIS

#### 3.2.1. DURATION IN FOUR ACCENT TYPES

The prosodic dimension of duration is the basic differentiating dimension for long and short accents and it is therefore appropriately included in the terms used to denote Croatian accents. Although the duration of lexical accents reflects the durations of prosodic units both smaller and bigger than the prosodic word (inherent vowel duration, the influence of neighbouring consonants on the duration of the vowel, the number of syllables before and after stressed syllable, the position of the accented syllable within the intonation unit, tempo, etc.), in this research those conditions were almost identical, so that the obtained values were comparable. The duration, as well as the values of other acoustic dimensions, has been measured on

statistical analysis are presented in Table 2. Except for the absolute values (with a millisecond as the basic unit of measurement), the duration of the post-accentual vowels has also been presented as the ratio of the duration of accented vowels (in percentages). The average duration of the accented vowel in the long-falling accent is 190 ms (SD 33), in the long-rising accent is 185 ms (SD 33), in the short-falling accent is 123 ms (SD 28), while in the short-rising accent the average duration is 124 ms (SD 24). Although the statistical analysis proves that the durations of the accented vowel in four accent types are statistically considerably different (ANOVA:  $F(468) = 180$   $p < .000$ ), the results of the post-hoc tests indicate that the difference in the duration of the accented syllable is statistically significant only between long and short accents, while the differences between the long-falling and long-rising accents ( $p = 0.282$ ) and between the short-falling and short-rising accents ( $p = 0.573$ ) are not statistically significant.

Although the duration of the accented vowel doesn't reflect the differences between rising and falling accents (the results do not confirm the supposition that the rising accent is longer than the falling accent), there are differences in the duration of the post-accentual vowels. More specifically, if we analyse the duration of the first post-accentual vowel in relation to the duration of the accented vowel (see Table 2) we may see that the average duration of the post-accentual vowel with the long-falling accents is 60%, with the long-rising accent is 50%, with the short-falling accent is 77%, while with the short-rising accent the duration is 93%. The results of the post-hoc tests indicate that with the short-rising accent the duration of the post-accentual vowel in relation to the accented vowel (93%) is statistically considerably longer ( $p < .000$ ) than with the short-falling accent (77%). We may conclude that short-falling and short-rising accents have the same duration in the accented vowel and that the short-falling is "faster" than the short-rising accent in the post-accentual vowel. However, long accents in the post-accentual vowel display a reverse tendency of duration differences contrary to short accents. The long-rising accent in the post-accentual vowel is 10% shorter (in relation to the accented vowel) than the long-falling accent. The differences in cuing duration of rising and falling accents in short and long vowels may be interpreted by taking into consideration that duration depends of the pitch curve. Namely, the production of the flat or rising tones requires considerably longer time than the production of falling tones (Ohala 1978), so the rising accent is all together longer than the falling accent in the production of short vowels. In long vowels that duration difference is no longer physiologically conditioned.

If we compare the results of this research (where accents belong to the contemporary Croatian speech which may also be called the Croatian "received pronunciation" or spoken "koine") to the results of former research on the Croatian, Serbian or Bosnian speech or the so-called "classic" idiom or "heroic" (i. e. standard) which has been best presented in the audio recordings accompanying the textbook *Srpski hrvatski jezik* ("The Serbian Croatian language", Ivšić and Kravar 1955), we may

see that the average values of the duration of short accented vowels in the Croatian classic idiom in the speech of contemporary speech-professionals (Pletikos 2003) are similar to the values of this research obtained by "common speakers" of contemporary speech (classic SF = 115 ms, contemporary SF = 123 ms), but that the duration of long accented vowels in the classic variety is much longer (LF lasts 234%, while LR lasts 243% of the total duration of SF) than their duration in the contemporary variety (e.g. LF lasts 155% of the total duration of SF). The measurements performed by Lehiste and Ivić (1986) on the corpus of twelve examinees show the average durations of the accented vowel in different accents: SF = 116 ms, SR = 119 ms, LF = 192 ms, LR = 202 ms. These values are similar to those obtained through this research on contemporary Croatian speech. The measurements of the duration of accented vowels in connected speech of two TV professional speakers (Bakran 1986) of which the results are SF = 77 ms, SR = 78 ms, LF = 99 ms, LR = 96 ms, show the tendency for the equal shortening of all accented vowels, but also the tendency for the difference reduction in the duration of long and short accents. These data indicate that the long accented vowels in connected speech become shorter than the short accented vowels in isolated speech.

Table 2. The duration of vowels in four lexical accents.

Vowel duration (ms)						
Accent type	accented vowel (ms)		1st post-accentual vowel (ms)		2nd post-accentual vowel (ms)	
	mean	s.d.	mean	s.d.	mean	s.d.
LF	190.33	33.17	109.83	33.13	92.92	27.03
LR	185.47	33.31	92.88	30.54	98.18	29.48
SF	122.53	28.04	91.94	29.96	113.65	34.94
SR	124.49	24.48	113.51	37.81	105.35	34.31
ANOVA	F (468) = 180.28 p < .000		F (439) = 12.4 p < .000		F (90) = 1.8 p = .154	
Duration of post-accentual vowels expressed as a ratio of the duration of accented vowels (%)						
Accent type	accented vowel		1st post-accentual vowel (%)		2nd post-accentual vowel (%)	
	set at		mean	s.d.	mean	s.d.
LF	100		59.55	19.41	54.18	16.26
LR	100		50.47	15.12	62.12	11.95
SF	100		77.34	26.57	113.64	41.03
SR	100		93.14	30.28	84.03	28.05
ANOVA			F (439) = 61.37 p < .000		F (90) = 17.1 p < .000	

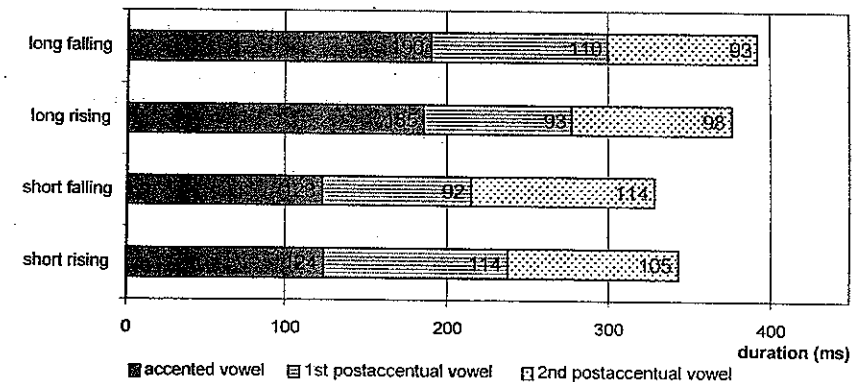


Fig. 1. The average duration of accented and post-accentual vowels in four accent types (in ms).

### 3.2.2. THE DURATION OF THE POST-ACCENTUAL LENGTH

The post-accentual lengths in contemporary Croatian speech are less and less frequently realized and they are becoming increasingly shorter. If we analyze all the words with the four standard accents and separate them in two groups, 1) the group with words in which the first post-accentual syllable is phonologically long and 2) the group with words in which the first post-accentual syllable is phonologically short (without the auditory estimate of whether the length has been phonetically realized or not), the results indicate that in the group with post-accentual lengths (N = 96) the average duration of the post-accentual vowel is 116 ms (SD 36), i.e. 86 % of the total duration of the accented syllable. In the group without phonological lengths the average duration of the post-accentual vowel is 95 ms (SD 31), i.e. 66% of the total duration of the accented vowel. Although the post-hoc test shows the statistical significance of the difference between these two groups ( $p < .000$ ), i.e. that the phonologically long post-accentual vowel is statistically considerably longer in the phonetic realization as well, the average duration difference of 20 ms borders on perceptibility.

If we analyze the duration according to the auditory estimate of whether the post-accentual lengths have been realized or not the results indicate that the phonologically long vowels have been realized as short vowels in one third of the words and that their average duration is only 90.5 ms (SD 17), that is, 67% of the total duration of the accented vowel which is at the same time shorter than the duration of the phonologically short post-accentual vowels (95.0 ms, SD 31). In two thirds of the words in which the phonologically long vowel is perceived as long, its duration is 130 ms (SD 36), that is, 96% of the total duration of the accented vowel (see Figure 3 and Table 2). The post-accentual syllables are subject to two phonetic principles: 1) if the syllable has a final position in a phonetic word it should contain the cue for the word boundary (which means that it is under the final lengthening), 2) if the post-accentual syllable immediately follows the accented syllable it should

make a contrast to the accented syllable (so that due to this position the syllable is under the influence of shortening). The results indicate that the influence of the contrast to the accented vowel has greater force than the cuing phonetic word boundary.

Table 3. The duration of accented and post-accentual vowels in phonologically long and short post-accentual syllables.

1st post-accentual vowel	Auditory estimate:	Vowel duration (in milliseconds)					
		accented vowel (ms)		1st post-accentual vowel (ms)		2nd post-accentual vowel (ms)	
		mean	s.d.	mean	s.d.	mean	s.d.
phonologically long	Audible as long	148.82	47.98	129.92	36.17	132.38	26.93
	Audible as short	144.74	38.4	90.5	17.24	106.29	40.36
phonologically short		154.67	43.83	94.83	31.21	104.09	32.63
		Duration of post-accentual vowels expressed as a ratio of the duration of accented vowels (%)					
		accented vowel		1st post-accentual vowel (%)		2nd post-accentual vowel (%)	
				mean	s.d.	mean	s.d.
phonologically long	Audible as long	100		95.91	35.33	110.07	29.23
	Audible as short	100		66.83	20.9	87.81	23.1
phonologically short		100		65.59	24.63	90.03	42.9
ANOVA				F (439) = 34.27 p < .000			

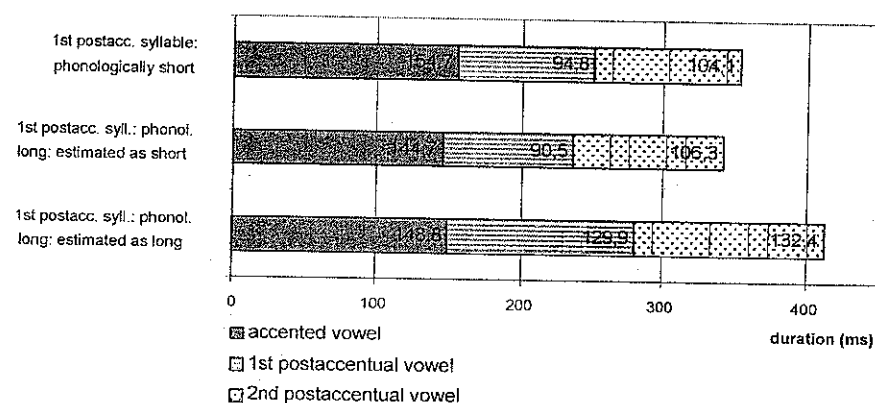


Fig. 2. The average duration of accented and post-accentual vowels in phonologically long and short post-accentual vowels (in ms).

In comparison to former research related to the Croatian classic idiom this research indicates that the relation of duration of phonologically long post-accentual vowels to the accented vowel is twice as shorter and it amounts to 96% (cf. Pletikos 2003, 181%). From the data obtained by Ivić and Lehiste (1986) it is possible to calculate that the duration of long post-accentual vowels amounts to 112% of the duration of the accented vowels, which is somewhat longer (for 18%) compared to the results of the measurements in contemporary Croatian speech.

### 3.2.3. INTONATION PATTERN (PITCH CONTOUR AND PITCH RANGE)

The results, i.e. the average curves of pitch movement in Croatian accents (see Figure 3) indicate that the rising and falling accents differ in the accented and the first post-accentual vowel, while in the second post-accentual vowel the frequency in all accents is equally low. The basic characteristic of the long-falling accent is a downward curve of a broad range in the accented vowel as well as the low and flat fundamental frequency in the post-accentual vowel. As opposed to the long-falling accent, the short-falling accent has a downward curve with a narrower range in the accented vowel, but in the initial part of the post-accentual vowel the frequency continues to decrease so that in the second part of the post-accentual vowel the short-falling accent reaches equally low level of tone as the long-falling accent. Rising accents have a very similar predominantly flat pitch curve in the accented vowel, while in the post-accentual vowel the curve is downward (although, contrary to falling accents, the curve of rising accents stays at a much higher pitch level). The difference between the long-rising and short rising accent is prominent in the post-accentual syllable in which the short-rising accent begins with a higher and the long-rising accent with a lower pitch than the pitch at the end of the accented vowel.

The difference between the accents may also be noticed in the variability of the pitch movement that is expressed as the value of one standard deviation in each of the time-points of the average fundamental frequency (see Appendix II, Figures 1a, 2a, 3a, 4a). Rising accents have a low variability of the pitch movement in the accented vowel. Falling accents have a low variability in the initial part of the accented vowel that increases towards the end of the vowel. In the post-accentual vowel only the short-rising accent has a low variability (0.1 to 0.15 of the octave), although it is considerably higher than in the accented vowel. All the other accents in each time-point vary to approximately 0.3 octave. The second post-accentual syllable has the highest variability. A lesser dispersion of data related to the average pitch movement in rising accents (as well as in the stressed vowels of all four lexical accents) indicates control of the movement, while a greater dispersion in falling accents (as well as in time-points increasingly distanced from the stressed vowel) indicates a ballistic articulation movements.



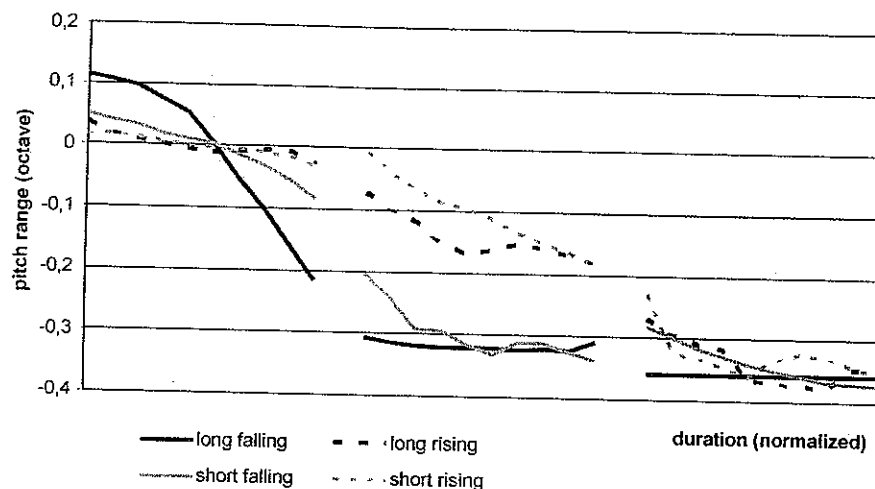


Fig. 3. The average pitch movement of the four Croatian accents (in the accented and two post-accentual vowels).

The average value of the pitch level of the accented vowel (LF = 187 Hz, LR = 190 Hz, SF = 197 Hz, SR = 195 Hz) is not relevant for the differentiation of the four Croatian accents (ANOVA:  $F(447) = 1.5$   $p = 0.204$ ), but the average pitch level in the post-accentual vowel (LF = 158 Hz, LR = 179 Hz, SF = 167 Hz, SR = 185 Hz) may be interpreted as the average pitch level that constitutes the difference since it is statistically relevant (ANOVA:  $F(352) = 6.2$   $p < .000$ ). However, the pitch movement in the accented vowel (the direction and range of the pitch curve) and the relation of the average pitch level of the post-accentual vowel to the accented vowel are supposed to be the most important elements for the differentiation of the lexical accents. The results of the statistic analysis (see Table 4) indicate that the pitch range in the accented vowel statistically considerably varies between the accent types (ANOVA:  $F(447) = 77.42$   $p < .000$ ). The pitch range in the accented vowel of the long-falling accent is 3.7 ST (ST = semitone), of the short-falling accent is 2.2 ST, of the long-rising accent is 1.4 ST and of the short-rising accent is 1.3 ST. In the post-accentual vowel the pitch range varies between 1.4 ST (in the long-falling accent) to 2.4 ST (in the short-rising accent), but in spite of the contradictory tendencies of the range size in relation to the accented vowel, these differences are not statistically relevant.

The total decrease in the pitch level of the post-accentual vowel in relation to the average pitch level of the accented vowel (ratio) within rising accents is somewhat lesser (SR = -1.2 ST, LR = -1.7 ST) than within falling accents (SF = -3.7 ST, LF = -3.8 ST) and this difference is statistically relevant (ANOVA:

$F(343) = 16.55$   $p < .000$ ). The second post-accentual vowel is generally about four semitones lower in all the accents and it is outside the domain in which the lexical accent is realized.

The results of the research on the classic idiom analysed on the speech of three professional speakers (Pletikos 2003) indicate that the average range of the downward pitch curve in the long-falling accent is 5 – 7 semitones, and 2 – 4 semitones in the short-falling accent. The range of the fundamental frequency (which moves both upwards and downwards) in rising accents is 1 – 2 semitones. It may be concluded that the oppositions between the accents in terms of both duration and tone are more prominent in the pronunciation of speech professionals than in the pronunciation of average speakers. The results of extensive research by Lehiste and Ivić (1986) demonstrate the tendencies in the frequency range in the accented and post-accentual vowels that are more similar to the tendencies demonstrated in this paper. Nevertheless, the great differences in the description result from the methods of measurement. Unlike Lehiste and Ivić in whose research the  $f_0$  contour is described in three time-points: at the beginning,  $f_0$  peak and the end of the vowel, in this research the  $f_0$  contour has been described throughout the entire vowel at every 10 % of its total duration. Therefore, the initial parts of intonation curves have not been interpreted as being differentiating, but as the result of the influence of consonants. More specifically, Lehiste and Ivić (1986: 42) hold that “the fundamental frequency of the accented syllable in words with the accent commonly called the short falling accent is not consistently falling (...), the peak is reached at approximately the middle of the duration of the syllable nucleus. The accented syllable in words with the accent commonly called the short rising accent is indeed predominantly rising”. This paper demonstrates that the words with falling accents have the average falling  $f_0$  contour, while the words with rising accents have the average flat (even falling)  $f_0$  contour within the accented syllable and falling  $f_0$  within the first post-accentual syllable. In all accent types the post-accentual vowels have the same predominantly falling contour, but the  $f_0$  level of the post-accentual syllable which follows after the rising accent is considerably higher than when it follows after the falling accent. The pitch peak alignment in the four accent types hasn't been meas-

Table 4. The pitch range within accented and post-accentual vowels.

Accent type	N	Pitch range (in semitones)					
		Accented vowel (st)		1st post-accentual vowel (st)		2nd post-accentual vowel (st)	
		mean	s.d.	mean	s.d.	mean	s.d.
LF	102	3.7	1.7	1.4	1.8	2.9	3.5
LR	118	1.4	0.6	1.8	1.8	2.7	4.1
SF	171	2.2	1.4	2	1.9	1.4	0.8
SR	80	1.3	0.9	2.4	1.2	2.5	3.4
ANOVA		$F(447) = 77.42$ $p < .000$		$F(358) = 4.2$ $p = .006$		$F(61) = 1.4$ $p = .270$	

ured because of the assumption that the pitch peak alignment of the syllable structure is a cue more relevant for the sentence intonation. Within one word the pitch peak is influenced by segmental structure. Lehiste and Ivić (1963) have found that in the falling accents within the vowels preceded by voiceless stops the peak occurs immediately after the onset of voicing.

Table 5. Pitch level of the post-accentual vowels.

Accent type	Pitch level of the post-accentual vowels expressed as a ratio of the pitch level of accented vowels (in semitones)			
	1st post-accentual vowel (st)		2nd post-accentual vowel (st)	
	mean	s.d.	mean	s.d.
LF	-3.8	3.6	-4.1	3.1
LR	-1.7	2.3	-3.9	2.9
SF	-3.7	3.6	-3.8	2.8
SR	-1.2	1.3	-4.4	2.7
ANOVA	F (343) = 16.55 p < .000			

### 3.2.4. INTENSITY PATTERN

Intensity is the acoustic characteristic that mostly follows the movement of the fundamental frequency. The results indicate that the curve of the intensity movement mostly follows the curve of the pitch movement (see Appendix II, Figures 1b, 2b, 3b, 4b). Namely, the fundamental frequency decreases with the falling accents in the accented vowel and the intensity decreases correspondingly. With rising accents in the accented syllable the tone remains at a single level and intensity follows it, so although it decreases, it does so in a narrower range than in the falling accents (see Table 6). The average intensity in the accented vowel is approximately 75 dB in all four accents, in the first post-accentual vowel the intensity is 67 dB to 71 dB (rising accents have an averagely higher intensity), while in the second post-accentual vowel the intensity is approximately 65 dB. In the short-rising accent in the post-accentual syllable the intensity, as well as the tone, remains higher at the beginning, i.e. it remains closer to the values of the accented vowel, but its curve is also downward. The relation between average intensities in accented and post-accentual vowels (see Table 7) demonstrates tendencies similar to those of the fundamental frequency. The post-accentual vowel of the long-falling accent is approximately 8.5 dB lower than the accented vowel, of the long-rising and of the short-falling accents it is 7.6 dB lower, and in the short-rising accent the post-accentual vowel is 5.5 dB lower than the accented vowel.

The analysis of the classic pronunciation of the four accents (Pletikos 2003) demonstrates higher ratios of the differences in intensity, i.e. the post-accentual vowel after the long-falling accent is approximately 8 dB lower, with the short-

falling accent it is 13 dB lower, with the long-rising accent it is 6 dB lower, with the short-rising accent the intensity is 4 dB lower. Lehiste and Ivić (1986: proved through the measurements of the intensity peaks of the accented and post-accentual vowels that the post-accentual vowels with the falling accents are averagely 6.7 dB weaker, while with the rising accents those vowels are 1.8 dB weaker than the intensity peak of the accented vowel. The theory that the relation between the contours of the frequency and intensity curves with the falling accents is parallel, while with the rising accents intensity and tone qualities diverge (Škarić 19321-322) has not been supported in this research which proves that the contour movement of intensity is followed by the contour of the movement of fundamental frequency.

Table 6. The intensity range within accented and post-accentual vowels.

Accent type	N	The intensity range within accented and post-accentual vowels (dB)					
		Accented vowel		1st post-accentual vowel		2nd post-accentual vowel	
		mean	s.d.	mean	s.d.	mean	s.d.
LF	N=92	8.7	4.7	7.3	5.3	7	3.3
LR	N=115	5.8	2.8	7.5	4.4	6	5.5
SF	N=156	7.5	4.5	7.7	4.7	4.6	5.3
SR	N=79	6.0	5.1	9.0	5.4	5	5.7
ANOVA		F (441) = 10.0 p < .000		F (363) = 1.7 p = .159		F (85) = 0.8 p = .508	

Table 7. Intensity of the post-accentual vowels.

Accent type	Average intensity of the post-accentual vowels expressed as a ratio of the average intensity of accented vowels (dB)			
	1st post-accentual vowel		2nd post-accentual vowel	
	mean	s.d.	mean	s.d.
LF	-8.5	2.3	-11.4	3.1
LR	-7.6	3.2	-11.3	2.5
SF	-7.6	3.9	-9.2	3.1
SR	-5.5	4.1	-13.2	2.2
ANOVA	F (343) = 15.25 p < .000		F (57) = 18.16 p < .000	

## 4. CONCLUSIONS

The analysis of the acoustic characteristics of the four standard Croatian accents indicates to the following conclusions:

1) Duration. Long accents have a longer duration of the accented vowel than short accents (LF = 190 ms, LR = 195 ms > SF = 123 ms, SR = 124 ms), nevertheless there is no statistically relevant difference between rising and falling accents.

The difference between rising and falling accents occurs throughout the duration of the post-accentual vowel, which when expressed as a ratio of the duration of accented vowel is longer within SR than within SF (post-accentual SR = 93% > post-accentual SF = 77%), while it is shorter within LR than with LF (post-accentual LR = 50% < post-accentual LF = 60%).

2) Tone. The average pitch movement in falling accents is downward in the accented vowel and flat or initially downward in the post-accentual vowel. Rising accents have a flat pitch curve in the accented vowel and a downward curve in the post-accentual vowel. The average pitch ranges in the accented vowel are: LF = 3.7 ST > SF = 2.2 ST > LR = 1.4 ST > SR = 1.3 ST. Rising accents further differ from falling accents in a generally higher pitch level of the post-accentual vowel in the relation to the accented vowel (pitch level of the post-accentual vowels expressed as a ratio of the pitch level of accented vowels in semitones: LF = -3.8 ST, SF = -3.7 ST, LR = -1.7 ST, SR = -1.2 ST).

3) Intensity. The curve of the movement of intensity mostly follows the curve of the tonal movement. The relation of the total intensity of the accented and post-accentual vowel follows the relation between average pitch levels, except for the cases with the long-rising accent (the average intensity of the post-accentual vowels expressed as a ratio of the average intensity of accented vowels is: LF = -8.5 dB, SF = -7.6 dB, LR = -7.6 dB, SR = -5.5 dB).

4) Post-accentual length. The phonological post-accentual length is realized considerably less than in the classic idiom. According to the auditory estimate the length is not at all realized in one third of the tokens and even in words where length is realized it is greatly reduced. Post-accentual phonologically short vowels averagely last 95 ms (66% of the duration of the accented vowel), while post-accentual phonologically long vowels (which are also perceived as long vowels) averagely last 130 ms (96% of the duration of the accented vowel).

It may be concluded that Croatian accents are only partially realized in the categories that can be perceived as the clear categories of the four accents (52.4 %). In relation to the classic idiom, the differences between four lexical accents are reduced, but they are still nevertheless acoustically very clearly defined. The tonal difference between rising and falling accents is similarly encoded in long and short forms, except that short accents are partly realized at the beginning of the post-accentual vowel.

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## APPENDIX I

The data on the subjects  
and the percentage of the accurately pronounced word accents.

Speakers profile							Subjects self-estimate of dialectal influence			Accurate production of four accents	
Nr.	Code	Gender	Age in 2003	City of education (age 6-18)	Origin of speaker's mother	Origin of speaker's father	ča %	kaj %	što %	n=45	%
G-01	A. F.	f	21	Ivanić grad	Ivanić grad	Ivanić grad	0	10	0	27	60
G-02	A. B.	f	21	Slavonski brod	Ploče	Slavonski brod	2	0	98	29	64.4
G-03	I. C. K.	f	22	Trogir	Hvar	Zenica	65	0	35	29	64.4
G-04	D. M.	f	22	Petrinja	Slavonski Brod	Slavonski Brod	0	0	100	41	91.1
G-05	D. N.	m	22	Mostar	Zenica	Sarajevo	0	0	100	38	84.4
G-06	D. S.	m	23	Buzet	Banja Luka	Rijeka	60	10	30	31	68.9
G-07	D. T.	f	21	Split	Split	Split	30	5	65	43	95.6
G-08	H. S.	f	22	Ogulin	Ogulin	Ogulin	30	10	60	19	42.2
G-09	I. V.	f	22	Varaždin	Varaždin	Samobor	0	75	25	38	84.4
G-10	K. P.	f	21	Grude	Grude	Grude	0	0	100	26	57.8
G-11	A. K.	f	22	Zagreb	Zagreb	Zagreb	0	80	20	0	0.0
G-12	M. G.	f	22	Nova Gradiška	Nova Kapela	Nova Kapela	0	0	100	41	91.1
G-13	M. M.	f	22	Čabar	Čabar	Čabar	0	90	10	12	26.7
G-14	M. P.	f	23	Zagreb	Šibenik	Šibenik	40	30	30	15	33.3
G-15	P. V.	f	21	Metković	Metković	Metković	0	0	100	28	62.2
G-16	R. K.	m	23	Karlovac	Karlovac	Karlovac	0	75	25	7	15.6
G-17	T. Č.	f	26	Zagreb	Ljubuški	Kiseljak	0	20	80	15	33.3
G-18	T. T.	f	20	Rovinj	Nova Gradiška	Sanski most	60	0	40	19	42.2
G-19	T. O.	f	17	Bjelovar	Bjelovar	Tuzla	0	15	85	14	31.1
G-20	N. G.	f	18	Pula	Nova Gradiška	Osijek	10	0	90	0	0
Average		m = 15% f = 85%	21.6%				16%	27%	58%		52.4%

## APPENDIX II

The average pitch movement (a)  
and the relation between the contours of tone  
and intensity (b) in four croatian accents

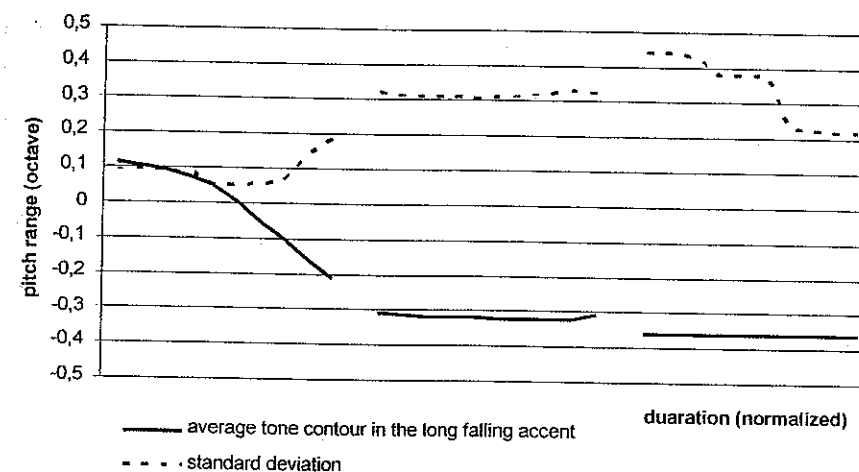


Fig. 4. The average pitch movement in the long-falling accent.

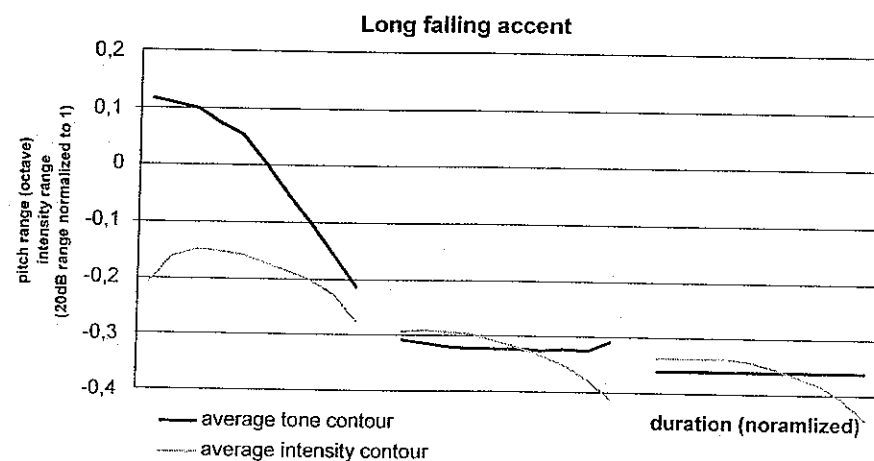


Fig. 5. The relation between the movements of tone and intensity in the long-falling accent.

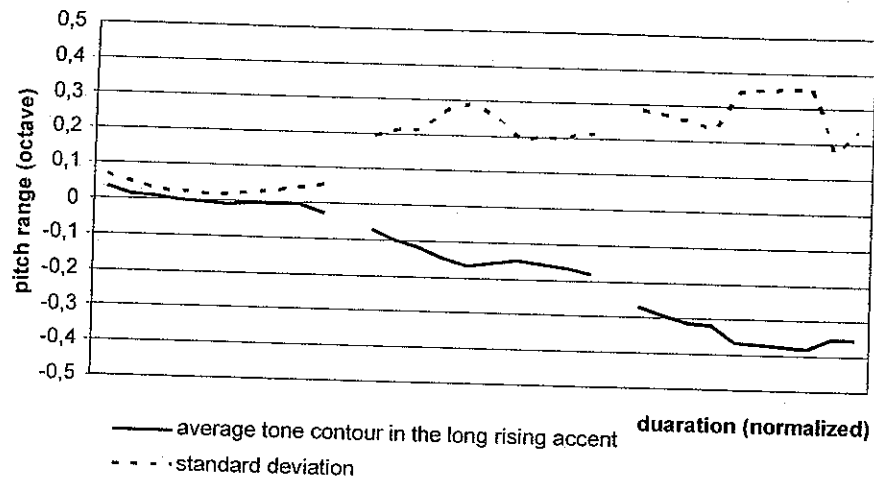


Fig. 6. The average pitch movement in the long-rising accent.

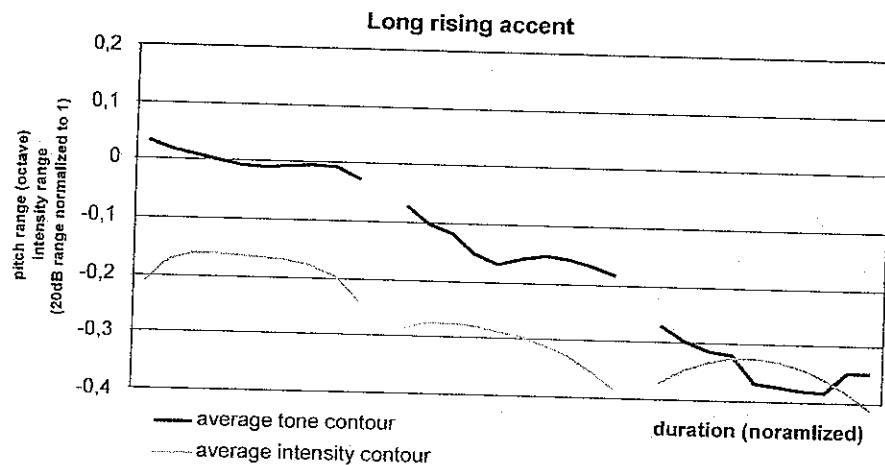


Fig. 7. The relation between the movements of tone and intensity in the long-rising accent.

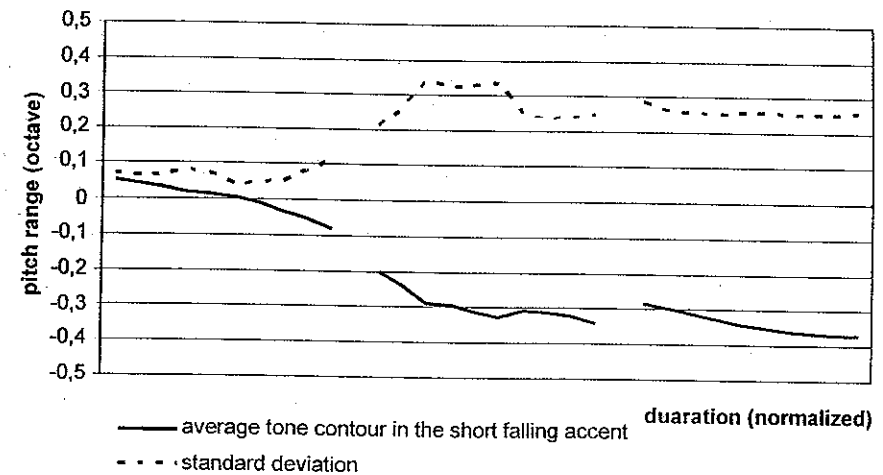


Fig. 8. The average pitch movement in the short-falling accent.

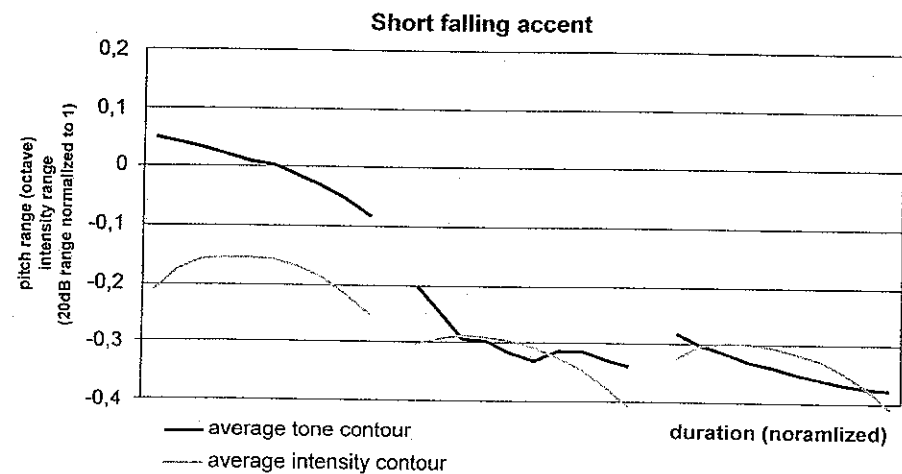


Fig. 9. The relation between the movements of tone and intensity in the short-falling accent.

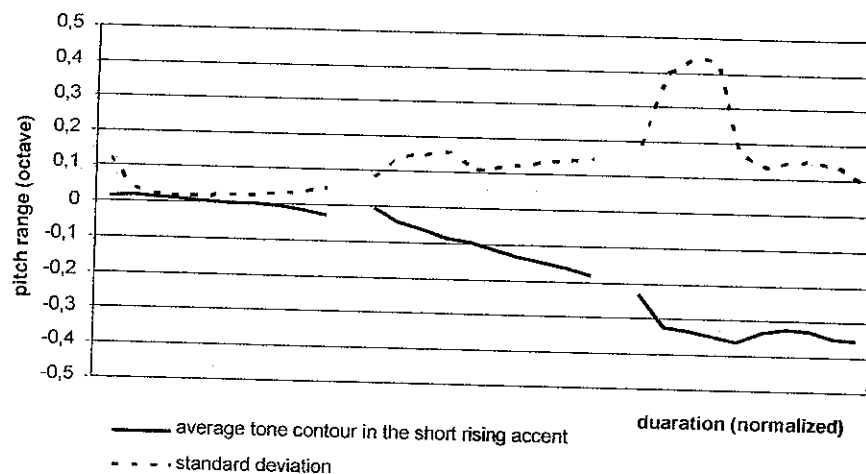


Fig. 10. The average pitch movement in the short-rising accent.

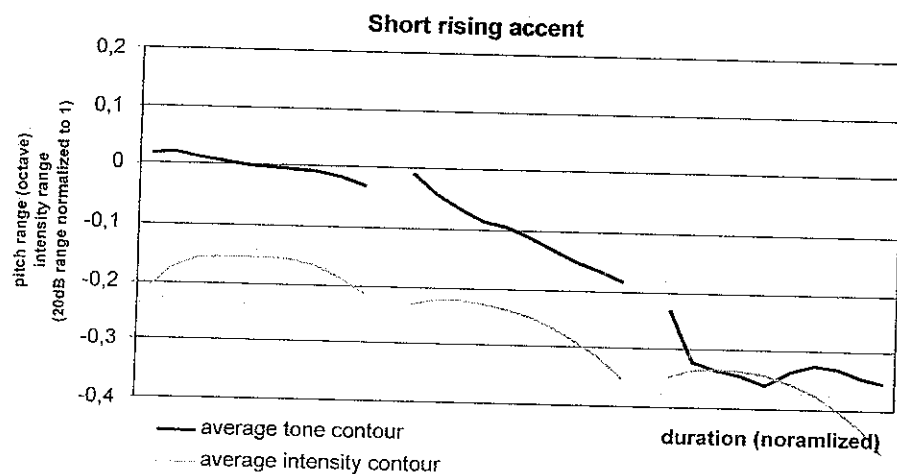


Fig. 11. The relation between the movements of tone and intensity in the short-rising accent.

## AKUSTYCZNY OPIS AKCENTÓW W JĘZYKU CHORWACKIM

## Streszczenie

W artykule przedstawiono opis chorwackich prozodemów we współczesnej wymowie młodych Chorwatów z perspektywy audytywnej i akustycznej. Na podstawie korpusu zawierającego 900 powiedzi, ustalono, że analiza słuchowa była dwuznaczna dla 52% z nich, w związku z czym badano je pod kątem podstawowych parametrów akustycznych.

Ustalono, że różnice czasowe w długości samogłosek w zależności od typu akcentu statystycznie istotne i wynoszą 123-124 ms dla rosnącego i opadającego akcentu krótkiego oraz -190 ms dla rosnącego i opadającego akcentu długiego. Dla 2/3 wyrazów z fonologicznie długą głoseką poakcentowaną, jej iloczyn wynosi przeciętnie 130 ms, co stanowi około 96% czasu trwania samogłoski akcentowanej. Natomiast dla analogicznych samogłosek krótkich, ich czas trwania wynosi 95 ms, czyli tylko 66% akcentowanej samogłoski. Wyznaczono także stosunek poziomu intensywności dla akcentów krótkich i długich.