UDC 811.163.6'342.41

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FORMANT FREQUENCIES OF VOWELS IN TONAL AND NON-TONAL STANDARD SLOVENIAN

The article presents formant frequencies of Standard Slovenian (SS) vowels as spoken by five tonal and five non-tonal speakers in citation form. The results and subsequent analysis of variance indicate two types of differences between both groups. In the tonal SS, [+ ATR] mid vowels have higher F1, and short [a] has considerably lower F1. Secondly, acute, circumflex, and short vowels of all phonemes are more dispersed in the tonal SS, the differences being statistically significant in most cases. This is a by-product of fundamental frequency and intensity distinctions in the two tones, and of duration/centralization effects in quantity contrast. These phenomena do not occur in the non-tonal SS.

V članku so predstavljene formantne frekvence samoglasnikov standardne slovenščine, kot jih govori pet tonemskih in pet netonemskih govorcev v izoliranih besedah. Rezultati in statistična analiza kažejo na dve vrsti razlik med obema skupinama: (1) pri tonemskih govorcih imata srednja visoka samoglasnika višji F1, kratki [a] pa precej nižjega (je centraliziran). (2) Pri tonemskih govorcih se akutirani, cirkumflektirani in kratki samoglasniki posameznega fonema v večini primerov statistično različni. V akustičnem smislu je to predvsem posledica razlik v osnovni frekvenci in jakosti, deloma pa tudi trajanja oz. fonetične redukcije. Tega v netonemski standardni slovenščini ni.

Key words: acoustic phonetics, formant frequencies, suprasegmentals, tone, Slovenian
Ključne besede: akustična fonetika, formanti, formantne frekvence, nadsegmentne lastnosti, ton, tonem, slovenščina

1 Introduction[1]

Phonetic studies of lexical tones in pitch-accented languages usually include acoustic analyses of fundamental frequency, intensity (or amplitude), duration, and phonation types. Spectral characteristics, most prominently formant frequencies, are considered non-significant or only marginally affected, and thus left aside, when tone is in question. On the other hand, formant frequencies, formant bandwidths, and spectral balance are the primary indicators of vowel quality (e.g., correspondence between openness and F1), and also prone to phonological and phonetic influence of stress (cf. Sluijter and Van Heuven 1996). The dependence of formant frequencies on vowel duration, phonetic reduction, or undershoot effect, speaking rate and style (e.g., Lind-

[1] The author wishes to thank Vesna Mildner, Mateja Blas and the speakers for their valuable contributions to this work. Any remaining errors are the author's. Earlier versions of the article (or parts thereof) have been presented at Between Stress and Tone Conference in Leiden (June 16–18, 2005) and the International Conference of Language Variation in Europe in Amsterdam (June 23–25, 2005). The ZRCola font, used in this text, was developed by Peter Weiss at The Scientific Research Centre of the Slovenian Academy of Sciences and Arts in Ljubljana (http://www.zrc-sazu.si).

blom 1963, Gay 1978, Tuller idr. 1982, Miller 1989, Engestrand 1988, Bakran 1989, Fourakis 1991, Van Son and Pols 1992, Moon and Lindblom 1994, Fourakis idr. 1999, Pitermann 2000, Erickson 2002, and Jurgec 2005c, for Slovenian), speaker's gender and fundamental frequency (Murry and Singh 1980, Assmann and Nearey 1987, Childers and Wu 1991, Wu and Childers 1991, Simpson 2001, and Jurgec 2005b) have been researched extensively. Moreover, studies of formant frequencies in pitch-accented languages usually represent each prosodic combination individually, cf., vowel charts of Croatian in Bakran 1989, or Lehiste and Ivić 1963: 84.

In the present study however, the interaction between tonal features (i.e., phonological features primarily encoded as fundamental frequency oscillations) and formant frequencies is addressed. The hypothesis is that in tonal languages, formant frequencies can be affected by tonal differences to a certain degree. This can be viewed primarily as a by-product of fundamental frequency and intensity. In respect to tonal features, Slovenian has two types of dialects, pitch-accented[2] and stress-accented, and is therefore very appropriate for this task. Furthermore, in contemporary Standard Slovenian (SS) both tonal and non-tonal varieties are permitted.

In Slovenian,[3] the majority of central dialects, i.e., those of the Upper and Lower Carniola regions, are tonal. Additionally, Carinthian dialects in Austria and Italy are tonal, as well as the Littoral dialects of Ter, Nadiža, and Upper Soča Valley. In Rovtarsko dialects, only Horjul and parts of Tolmin dialects are tonal. Tonal speech is found in Bela Krajina as well. Other dialects (most of the Littoral dialects, all of Styrian and Pannonian dialects, and Carinthian dialects in Slovenia) are non-tonal (cf. Rigler 1968). Srebot Rejec (1988) disputed the tonal contrast in educated speech of Ljubljana, believed to be the most important in contemporary standardization processes. She concludes: »The lexical (phonological) function of the two accents is on the wane, while the phonetic characteristics, the sing-song effect, is retained.« (Srebot Rejec 2000: 66.) Relatively recent tone loss has also been documented in Eastern Haloze (Lundberg 2003). – Slovenian has two lexical tones, acute and circumflex. For acoustic analyses of tones in Slovenian, see Vodušek 1961, Toporišič 1967, 1968, Neweklowsky 1973, and Srebot Rejec 1988, 2000. Phonetically, the acute is realized as a rising tone (or low on the stressed and high on the post-stressed/final syllable), the circumflex as the opposite. Phonologically, both tones can occur only in traditionally (i.e., diachronically) long vowels, while short vowels are considered circumflex (unmarked) in SS. In contrast to phonological limitations of better known pitch-accent languages, like Swedish and Serbo-Croatian, the contrast is preserved also in words with final stress (e.g., *pot* /ˈpoːt/ – acute 'path', circumflex 'sweat'). A total of less than 100 morphologically non-related minimal pairs in tone exist (e.g., *kila*, *kura*, *mula*, *šibica*, *šalica*), while morphologically related pairs are abundant.

In comparing the tonal and the non-tonal varieties of SS, other issues, such as inherent phonetic distinctions in vowel height, not limited to a certain prosodic feature,

[2] In the present article, the term tonal (language) is used in reference to lexical tones, i.e., in this meaning of the pitch accent (as opposed to non-tonal). The term tonal is preferred to the term pitch-accented.

[3] This paragraph and the corresponding references do not appear in the Slovenian version of the article.

may arise. These are to be acknowledged as well, although these are not the main aim of the study. The sole nature of the linguistic material used (see section 2 for further details) renders it impossible to exclude such variables.

2 Method

The present study of SS vowels is based on the extensive corpus of 241 one-, two-, and three-syllable words, compiled according to the suprasegmental criteria (stress, tone, duration).[4] The list was exported to PowerPoint program and randomized manually, so that each word appeared twice non-consecutively. Speakers were instructed to read the words in citation form as they appear on the computer screen. 10 native speakers of Slovene were chosen, representative by sex (5 female and 5 male), tone contrast (5 non-tonal in origin, and 4 tonal), and age (35 years on average). The geographical criteria (i.e., the origin of the speakers) were in favour of central Slovenia. Recordings took place in the studio of the Department of Phonetics in Zagreb (Croatia) in April 2004 and in the studios of Radio Slovenia in June 2004 (1 speaker only). Sampling frequency was 44.1 kHz, at a 16-bit rate. F1–F4 of the total of 5,960 vowels were measured using *Praat* LPC-analysis software (ver. 4.2–4.2.14) under default settings. Typically, the individual formant steady state was measured, if possible. Alternatively, the central point or averaged value of the transient formant was measured. Altogether, 21,220 readings (of stressed and unstressed vowel formants) were acknowledged, and 4.59 % of the readings were discarded. Data were averaged and analyzed statistically (ANOVA) separately for both groups of speakers. – For a more detailed description of the speakers, method, procedures and more general results see Jurgec 2005b.

3 Results

The measurements of formant frequencies were grouped into prosodic combinations (or accent types), i.e., acute, circumflex and short vowels,[5] separately for both tonal and non-tonal SS. For each, mean value, standard deviation (SD), sample size, and confidence interval were calculated. One needs to note that sample size varies considerably, which is a consequence of (1) phonological distribution or constraints, (2) lexical realization, and (3) discharged cases due to nature of pronunciation. These data are presented in Table 1–2 below. Here, F1–F4 values are presented, while in the rest of the article only F1 and F2 are discussed.

Generally, several types of differences between the tonal and the non-tonal speakers can be observed. Mean values of individual phonemes differ substantially in high-mid vowels /e/ and /o/, which have lower F1 in the tonal SS, while /ɛ/ has somewhat higher F1. Short [a] is considerably centralized (i.e., has lower F1) for the tonal speakers, and this phenomenon is much higher than in other vowels. In /u/, the mean values of F1 are only slightly lower for the tonal speakers.

[4] The complete list of words can be obtained from the author.

[5] For discussion on this matter and its implications to the traditional grammar (e.g. Toporišič 2000 and the predecessors), see Jurgec 2005b: 128–131.

	/i/			/e/			/ɛ/			/a/			/ə/			/ɔ/			/o/			/u/		
F1																								
Acute	274			357			564			731			492			587			393			304		
	31.92	120	5.71	32.97	80	7.23	60.91	68	14.48	77.64	110	14.51	41.22	50	11.43	67.01	58	17.24	41.84	90	8.65	54.78	90	11.32
Circumflex	274			373			573			725			500			608			411			304		
	26.57	120	4.75	41.48	120	7.42	69.34	108	13.08	75.35	120	13.48	39.19	118	7.07	56.52	80	12.38	41.49	120	7.42	42.66	119	7.67
Short	283			/			591			661			/			623			/			327		
	37.85	50	10.49				66.97	60	16.95	97.13	50	26.92				45.10	60	11.41				47.80	20	20.95
F2																								
Acute	2317			2310			1969			1262			1383			1004			769			827		
	248.19	114	45.56	244.61	75	55.36	311.36	68	74.00	110.42	110	20.63	118.48	50	32.84	83.10	58	21.39	92.00	90	19.01	141.08	90	29.15
Circumflex	2293			2318			1850			1233			1350			1020			803			890		
	274.94	117	49.82	235.07	116	42.78	291.94	108	55.06	103.17	120	18.46	143.67	118	25.92	76.49	80	16.76	83.75	120	14.98	156.97	118	28.32
Short	2299			/			1819			1268			/			1042			/			857		
	271.78	48	76.89				257.95	59	65.82	117.94	50	32.69				60.67	60	15.35				93.56	20	41.00
F3																								
Acute	2947			2839			2680			2650			2431			2689			2678			2533		
	355.81	120	63.66	274.39	78	60.89	305.04	68	72.50	197.99	107	37.52	206.01	50	57.10	217.01	58	55.85	303.61	89	63.08	238.34	89	49.52
Circumflex	2916			2848			2640			2668			2554			2723			2706			2519		
	340.42	117	61.68	261.70	116	47.62	329.12	108	62.07	194.19	120	34.75	195.58	118	35.29	241.68	79	53.29	243.38	118	43.91	253.81	119	45.60
Short	2858			/			2607			2581			/			2627			/			2506		
	335.77	47	95.99				225.99	60	57.18	283.17	49	79.29				190.75	59	48.67				211.68	20	92.77
F4																								
Acute	3836			3828			3884			3825			3719			3733			3591			3661		

Table 1. *Average values of formant frequencies (in Hz) of tonal speakers, according to phoneme, formant, and prosodic combination. Below the mean values, standard deviation, sample size, and confidence interval (± of mean value, α = .05) are listed.*

SD is similar in both varieties of SS, on average. Coefficient of SD is 11.22 % for the non-tonal and 10.55 % for the tonal variety, although the individual SDs for several phonemes and prosodic combinations vary. This is further discussed in section 4.

On the other hand, comparison of prosodic combinations within their phonemic domain reveals fundamental differences between the two varieties of SS. Acute, circumflex and for most phonemes also short vowels are clearly much more dispersed in the tonal SS. This is clearly visible from Fig. 1, where the more dispersed accent types of the tonal SS are depicted with empty symbols (as opposed to the full symbols of the non-tonal variety). To evaluate the statistical significance of the differences among prosodic combinations a single-factor ANOVA was performed for each of the combinations. In F1, there are no statistically significant ($p < .05$) differences between the accent types, for all phonemes in the non-tonal variety of SS. In the tonal SS however, accent types are statistically distinct for /e/ and /o/. For /a/ the difference between long and short is highly significant (but no difference between acute and circumflex). The distinctions in /ɛ/ and /ɛ/ are marginal, as there is statistical significance only between

	/i/			/e/			/ɛ/			/a/			/ə/			/ɔ/			/o/			/u/		
F1																								
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Short	283			/			591			661			/			623			/			327		
	37.85	50	10.49				66.97	60	16.95	97.13	50	26.92				45.10	60	11.41				47.80	20	20.95
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	248.19	114	45.56	244.61	75	55.36	311.36	68	74.00	110.42	110	20.63	118.48	50	32.84	83.10	58	21.39	92.00	90	19.01	141.08	90	29.15
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Circumflex	2916			2848			2640			2668			2554			2723			2706			2519		
	340.42	117	61.68	261.70	116	47.62	329.12	108	62.07	194.19	120	34.75	195.58	118	35.29	241.68	79	53.29	243.38	118	43.91	253.81	119	45.60
Short	2858			/			2607			2581			/			2627			/			2506		
	335.77	47	95.99				225.99	60	57.18	283.17	49	79.29				190.75	59	48.67				211.68	20	92.77
F4																								
Acute	3836			3828			3884			3825			3719			3733			3591			3661		
	380.30	111	70.75	363.90	78	80.76	450.37	66	108.65	371.66	108	70.09	348.04	50	96.47	309.98	58	79.78	379.54	88	79.30	407.23	88	85.08
Circumflex	3846			3846			3878			3853			3703			3772			3617			3629		
	424.67	114	77.96	412.27	115	75.35	437.27	106	83.24	351.46	119	63.15	329.46	118	59.44	278.42	79	61.40	363.69	119	65.34	429.93	117	77.90
Short	3796			/			3799			3763			/			3692			/			3573		
	397.22	49	111.22				411.82	60	104.20	353.38	47	101.03				298.32	60	75.48				468.60	20	205.37

Table 2. *Average values of formant frequencies (in Hz) of non-tonal speakers, according to phoneme, formant and prosodic combination. Below the mean values, standard deviation, sample size and confidence interval (± of mean value, α = .05) are listed.*

most distinct prosodic combinations, i.e., acute and short (but not between acute and circumflex, and circumflex and short).

In F2, statistical significance is attested for both accent types of /o/ in the tonal SS. Acute and circumflex difference is significant also in [ɛ], [a], [u], circumflex vs. short in [a], and acute vs. short in [ɛ] and [ɛ]. In [a], significance is only marginal. In sum, the accent types of [a] and of both tense mid vowels [e], [o] differ significantly, while in [ɛ] and [ɛ] this effect is only marginally significant. There is no statistical significance only among the accent types of the high vowel [i] and central vowel [ə]. Detailed results of the analysis for both F1 and F2 are presented in Table 3.

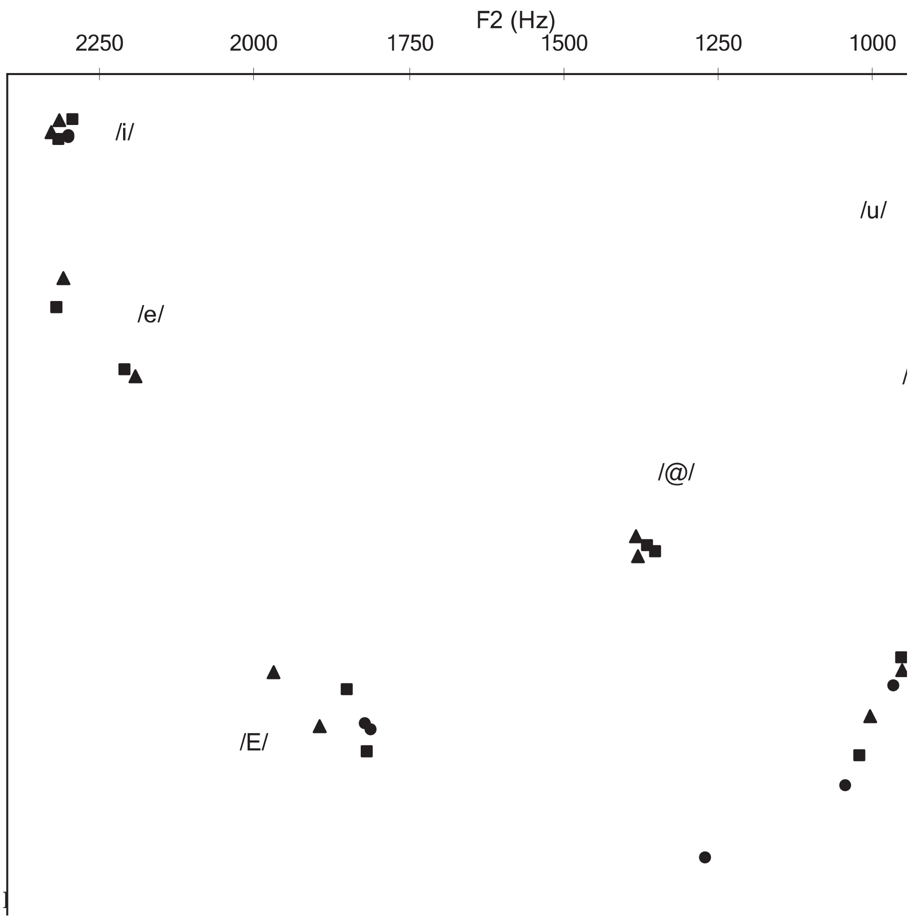

Table 3. *F1xF2 vowel space of tonal and non-tonal varieties of SS.*

This is not the case in non-tonal SS, where no variability is attested in F1. In F2 however, a marginal statistical significance is found in [ɛ], [a] and [u] (see Table 4 for further results). This fact is explained in Section 4.

4 Discussion and conclusion

Previous section revealed several differences between the groups of tonal and non-tonal speakers, either related to purely acoustic phonetic factors of tone itself or not. As regards the latter, one could say that in the tonal variety, low-mid and high-mid vowels are less central. [e] and [o] are therefore more tense perceptually, or higher articulatorily in the tonal SS than in the non-tonal, while [ɛ] is lower. The only exception is [ɛ], which exhibits no such tendency. Generally, in Slovenian spoken in central

Phoneme	F1					F2			
	Accent types	df	F	p (α=.05)		Accent types	df	F	p (α=.05)
/i/	Acute vs. circumflex	1, 238	.005	.942		Acute vs. circumflex	1, 229	.497	.481
	Acute vs. short	1, 168	2.30	.131		Acute vs. short	1, 160	.156	.694
	Circumflex vs. short	1, 168	2.68	.103		Circumflex vs. short	1, 163	.022	.882
/e/	Acute vs. circumflex	1, 198	8.43	.004		Acute vs. circumflex	1, 189	.055	.814
/ɛ/	Acute vs. circumflex	1, 174	.852	.357		Acute vs. circumflex	1, 174	6.67	.011
	Acute vs. short	1, 126	5.64	.019		Acute vs. short	1, 125	8.65	.004
	Circumflex vs. short	1, 166	2.48	.177		Circumflex vs. short	1, 165	.461	.498
/a/	Acute vs. circumflex	1, 228	.400	.528		Acute vs. circumflex	1, 228	4.21	.041
	Acute vs. short	1, 158	23.71	<.00001		Acute vs. short	1, 158	.118	.731
	Circumflex vs. short	1, 168	21.01	<.00001		Circumflex vs. short	1, 168	3.84	.052
/ə/	Acute vs. circumflex	1, 166	1.41	.237		Acute vs. circumflex	1, 166	2.04	.155
/ɔ/	Acute vs. circumflex	1, 136	4.04	.047		Acute vs. circumflex	1, 136	1.40	.239
	Acute vs. short	1, 116	12.16	.0007		Acute vs. short	1, 116	8.41	.004
	Circumflex vs. short	1, 138	3.01	.085		Circumflex vs. short	1, 138	3.54	.062
/o/	Acute vs. circumflex	1, 208	9.29	.003		Acute vs. circumflex	1, 208	7.86	.006
/u/	Acute vs. circumflex	1, 207	.000	.992		Acute vs. circumflex	1, 206	9.07	.003
	Acute vs. short	1, 108	2.87	.093		Acute vs. short	1, 108	.791	.376
	Circumflex vs. short	1, 137	4.55	.035		Circumflex vs. short	1, 136	.876	.351

Table 4. *Single-factor ANOVA results for separate phonemes and prosodic combinations of the tonal SS. The default Alpha factor is used (.05). Statistically significant values are underlined; marginally significant p-values (0.035–0.055) are marked with a dashed line.*

dialects, including Ljubljana, the feature [+ ATR] has greater effect on vowel quality, decreasing F1 of high-mid vowels. This is complemented by the increased F1 of low-mid, but the effect is rather limited. The above-mentioned phonetic property is consistent with experimental data from non-central Slovenian in Ozbič 1998ab for SS as spoken in Trst (Trieste) and in Jurgec 2005a, for speech of Ovčja vas (Valbruna).

One should also take into account the gender of both groups of speakers: 3 females and 2 males are tonal (the situation is reversed for the non-tonal speakers). Average F0 of females is higher than that of males, and there is a positive correlation between average F0 and formant frequencies. Therefore, the increased F2 of tonal speakers in /ɛ/, /e/, and /i/ can be attributed to this, but no such effect should be present in F1.

Moreover, certain phonological variables influence formant frequencies of the tonal variety. Quantity contrast in SS stressed vowels is at least questionable (Srebot Rejec 1988, Petek et al. 1996), if not already completely neutralized, at least for speakers of Ljubljana, as well as for most speakers in southwest and northeast Slovenia. On the other hand, these oppositions are still present on dialectal level and

Phoneme	F1					F2			
	Accent types	df	F	p (α=.05)		Accent types	df	F	p (α=.05)
/i/	Acute vs. circumflex	1, 238	1.81	.179		Acute vs. circumflex	1, 237	.279	.598
	Acute vs. short	1, 168	.371	.543		Acute vs. short	1, 168	.695	.406
	Circumflex vs. short	1, 168	.211	.647		Circumflex vs. short	1, 167	.220	.640
/e/	Acute vs. circumflex	1, 195	.141	.708		Acute vs. circumflex	1, 194	.189	.665
/ɛ/	Acute vs. circumflex	1, 174	.483	.488		Acute vs. circumflex	1, 173	6.59	.011
	Acute vs. short	1, 116	.012	.914		Acute vs. short	1, 116	6.11	.015
	Circumflex vs. short	1, 154	.275	.600		Circumflex vs. short	1, 153	.043	.836
/a/	Acute vs. circumflex	1, 228	.009	.924		Acute vs. circumflex	1, 228	7.45	.007
	Acute vs. short	1, 158	.321	.572		Acute vs. short	1, 158	.018	.893
	Circumflex vs. short	1, 168	.308	.580		Circumflex vs. short	1, 168	4.77	.030
/ə/	Acute vs. circumflex	1, 159	.309	.579		Acute vs. circumflex	1, 159	.372	.543
/ɔ/	Acute vs. circumflex	1, 113	.340	.561		Acute vs. circumflex	1, 113	.0006	.980
	Acute vs. short	1, 91	.559	.456		Acute vs. short	1, 91	.671	.415
	Circumflex vs. short	1, 108	1.72	.192		Circumflex vs. short	1, 108	.670	.415
/o/	Acute vs. circumflex	1, 206	.216	.643		Acute vs. circumflex	1, 206	1.07	.303
/u/	Acute vs. circumflex	1, 208	1.06	.304		Acute vs. circumflex	1, 207	7.60	.006
	Acute vs. short	1, 108	3.46	.066		Acute vs. short	1, 107	.0005	.994
	Circumflex vs. short	1, 138	1.78	.184		Circumflex vs. short	1, 136	2.20	.140

Table 5. *Single-factor ANOVA results for separate phonemes and prosodic combinations of the non-tonal SS. The default Alpha factor is used (.05). Statistically significant values are underlined; marginally significant p-values (0.035–0.055) are marked with a dashed line.*

in the sub-standard speech as qualitative changes, i.e., phonological reduction processes. Thus when speaking SS, speakers tend to avoid these processes, and since they are unable to produce any quantity contrasts, diachronically short vowels merge with unreduced long vowels (Rigler 1968). Present data confirm only marginally significant contrast between short and long vowels, limited to the tonal SS, namely to the phonemes /ɛ/ and /ɛ/, in F1 and F2 (see Table 3–4). The only exception is /a/, where phonologically short [a] is considerably centralized. The average F1 of short [a] is 67 Hz lower than the average F1 in long [a]. This is highly significant ($p < 0.0001$), although the coefficient of SD is moderately increased (14.7 % in F1). This unique phenomenon, not attested in other phonemes, can be corroborated by the data in Petek et al. 1996, where /a/ was the only phoneme that exhibited (some) durational differences. This inconsistency has not been explored yet and has had no influence on normative practice so far.

As regards the influence of phonological tone on formant frequencies, the results prove a positive correspondence. To confirm the research hypothesis, one should first prove that there are differences in formant frequencies of the tonal SS and that they are statistically significant. Furthermore, that no such differences exist in the non-tonal SS, and that this situation cannot be explained otherwise, for example as a consequence of other phonetic features.

Suprasegmental (phonological) variables are statistically significant in majority of phonemes in the tonal SS (Fig. 1). Upon further inspection (ANOVA, cf. Table 3–4), only /i/ and /ə/ exhibit no significant differences between the accent types. /ə/ is a phonetically neutral vowel and attested differences should not be contraindicative to the research hypothesis. On the other hand, the same situation in /i/ cannot be explained in terms of general phonetics. However, other data from Slovenian and its formant frequencies (Jurgec 2005bc), posit an interesting property of Slovenian /i/, being the least subjected to influences of stress and word-position. In contrast, another high vowel, /u/, is subjected to much greater degree of variance, while the influence of tone is only marginal.

In the non-tonal SS, individual accent types of each phoneme are clearly less dispersed. This is evident from Fig. 1 (e.g., phonemes /e/, /o/, /ɛ/, and /a/), and corroborated by statistical analyses in Tables 3–4. In F1, no prosodic differences are statistically significant. In F2 however, there are a few exceptions: acute [ɛ] is distinctive of circumflex and short, as it is circumflex [a]. There is also statistical significance in acute or circumflex [u].

Dispersion in [ɛ] could be attributed to the problematic distribution of both front mid vowels, which are morphonologically connected, and the distribution in SS differs greatly from the contemporary dialectal and sub-standard realization. When unstressed, both phonemes are neutralized and merged into a single archiphoneme (Lehiste 1961, Srebot Rejec 1988, 1998), which is realized as [e] in the pre-stressed and as [ɛ] in the post-stressed position (see Jurgec 2006 for further data and discussion). This is corroborated by the increased coefficient of SD, which is exhibited in both front mid vowels of the non-tonal SS; in F1 of [ɛ] the coeff. is 20.1 %, almost twice the average, in [e] it is 15.3 % (F2 of both vowels is too close to influence SD). Although erroneous cases of pronunciation were discharged (see the drop in sample size of both phonemes in Table 2), a partial overlap in formant frequencies is a possible and also probable explanation. The increase is also noticeable in back mid vowels (yet lower than in front vowels) and in [ɛ] of the tonal SS (but not in front vowels and [e]) and exhibits a general phonological tendency of contemporary Slovenian. To sum up, the data of the non-tonal [ɛ] should be regarded highly inconclusive.

The increased coefficient of SD is observed in [u] as well, both tonal and non-tonal (on average, well above 15 % in F2). The fact that circumflex [u] is statistically distinct from the acute and short is also surprising. In most vowels, circumflex is more similar to short than the acute, which is in accordance with the traditional theory that considers phonologically short vowels circumflex in tone. As the significance is similar in both varieties of SS, one can say that the analysis is dubious: [u] must also be influenced by other variables. For example, the difference between word-final and initial vs. medial position of the two high vowels, documented in certain sources (e.g., Toporišič 2000: 50). The present analysis, based on linguistic material of the existing and generally known words in Slovene, cannot answer this problem satisfactorily. This will be done in the future work.

The phoneme /a/ has a moderately increased coefficient of SD as well, under acute tone more than under circumflex and as short. One reason for this could be a considerable backness of the low vowel in Styrian and Pannonian dialects, where three of our speakers originate.[6] If this is true, only the acute is being influenced and is statistically significantly differs from circumflex and short [a]. This cannot be caused by the phonetic factors per se, but by dialectal phonetic influences and should therefore be disregarded.

All things considered, vowel formant frequencies of the tonal SS are affected by phonological tone. The differences may not be large (as opposed to influence of consonantal environment, stress, and certain extralinguistic factors), but they are still significant, and, as a rule, not present in the non-tonal speech. Whether this is directly related to the distinctions in fundamental frequency or intensity attested in Slovene acute vs. circumflex tone, remains unknown. However, F0 and formant frequencies show a positive correlation (via stress, gender or speaking style), and the correspondence grows exponentially, higher formants exhibiting much larger increase than the lower ones if F0 rises. Intensity (via duration, stress or speaking style) also corresponds to formant frequencies, i.e., vowels with greater intensity have higher formant frequencies (either via duration, stress, or speaking style), all other things being equal. – The design of the present experiment itself renders it impossible to account for all acoustic and articulatory factors and to determine their extent. It proves, however, that such differences occur.

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Povzetek

Članek predstavlja formantne frekvence samoglasnikov tonemske in netonemske različice standardne slovenščine (SS).

Upoštevajoč fonološko distribucijo in nadsegmentne lastnosti je bil sestavljen obsežen korpus eno-, dvo- in trizložnic. 241 besed je v naključnem vrstnem redu izolirano bralo deset govorcev, enakomerno porazdeljenih po spolu, izvoru in tonemskosti. Pet jih je bilo tonemskih (3 ženske in 2 moška govorca), pet netonemskih. Snemanje je bilo digitalno, pri standardnih pogojih, tj. frekvenci vzorčenja 44,1 kHz in 16-bitni kvantizaciji. F1–F4 skupno 5.960 samoglasnikov so bili izmerjeni z LPC-analizo v programu Praat, pri standardnih nastavitvah. Izmerjene vrednosti so bile razvrščene v skupine in izračunana povprečja. Sledila je statistična analiza, vključno z analizo variance (ANOVA). Za podrobnejše podatke gl. Jurgec 2005b.

Povprečne vrednosti (skupaj s standardnim odklonom, številom meritev in intervalom zaupanja) obeh različic SS so v prikazih 1 in 2 (Table 1 in 2). V prikazu 3 (Figure 3) je akustični diagram F2/F1 za tonemske (prazni simboli) in netonemske (polni simboli) govorce. V prikazih 4 in 5 (Table 3 in 4) pa so rezultati analize variance (najprej za tonemske, potem za netonemske govorce).

Rezultate lahko razdelimo v dve skupini, ki so bodisi (nad)narečni v fonetičnem in fonološkem smislu ali strogo akustični. V prvi skupini so tako razlike v F1 [+ ATR] srednjih samoglasnikov [e] in [o], ki je v tonemski slovenščini nižji, kratki [a] je pri tonemskih govorcih občutno centraliziran, česar ni pri drugih samoglasnikih tonemskih ali netonemskih govorcev.

Razlike med akutiranimi, cirkumflektiranimi in kratkimi samoglasniki posameznega fonema so pričakovano večje v tonemski SS in povečini tudi statistično značilne v F1 in/ali F2. Ni pa take razlike pri [ə] in [i]. Pri [u] so očitno pomembnejše druge segmentne spremenljivke, saj se F1 in F2 obeh skupin tu bistveno ne razlikujejo. Sicer so v netonemski SS statistično značilne razlike redke; tako lahko F2 pri [a] pojasnimo z narečnimi vplivi, pri [ɛ] pa je problematična distribucija.

Razpršenost skupin akutiranih, cirkumflektiranih in kratkih samoglasnikov ter njihovih formantnih frekvenc v tonemski SS lahko razložimo (tudi) kot posledico osnovne frekvence in jakosti na eni ter jakosti in fonetične redukcije oz. učinka podhranjenosti (undershoot) na drugi.