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ACOUSTIC-PHONETIC ANALYSIS OF CHILDREN'S /r/

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Introduction

In recent years it has become a practice in speech therapy in Slovenia to examine all children at the age of five. There are two reasons for choosing this age. First, at the age of five all speech sounds should have been fully acquired. Second, any eventual speech disorders can be corrected before a child enters elementary school (at the age of six).

One of the most common speech disorders among preschool children is rhotacism. According to the survey of Globačnik (1999) rhotacism is found in 15 % of all Slovenian preschool children. The term rhotacism in speech therapy means a failure to realize /r/ in the standard way.

The standard Slovenian r-sound is an apico-alveolar tap. It consists of a vocoid (schwa) and a tap. In speech it has two different realizations: as a consonantal and as a vowel-like /r/. Consonantal /r/ is realized before or between vowels (*riba*, *omara*) and at the end of a word following a vowel (*sir*). Vowel-like type of /r/ is realized at the beginning of a word when it precedes a consonant (*rdeč*) or between two consonants (*vrt*) (Omerza, 1970 and Globačnik, 1999). According to frequency, consonantal /r/ is on the 8th and vowel-like /r/ on the 25th place among 27 Slovenian sounds (Globačnik, 1999).

Rhotacism, as well as misarticulation of any sound, can be seen as omission, substitution, or distortion. The first two are mostly found in the speech of young children and are rarely present in the speech of adults, while distortion is seen in adults. Distortion does not affect the understanding of speech as severely as omission or substitution, so the 'environment' tolerates it more and the speaker does not feel the need for correction.

Omission means the non-realization of /r/, but the place for it is kept as a pause or as prolonged neighboring sounds. In the case of substitution /r/ is substituted by a sound that belongs to the sounds in the speaker's language. Distortion in a way means a 'wrong' articulation of a particular sound and the used sound is not part of the speaker's language. A speaker with distortion of /r/ articulates an r-sound that is not standard for his or her language.

In speech therapy different types of distortion of /r/ are classified according to the place of articulation into two categories: front and back distortions (Vuletić, 1987).
Front distortions are articulated in the front of the oral cavity in the labial and alveolar area. There are two types of front distortions in Slovenian: bilabial and lateral rhotacism. In bilabial rhotacism /r/ is produced by vibrating both lips. Such a sound is very unpleasant for the speaker and the listeners and it is usually quickly corrected. Lateral /r/ is a result of unsymmetrical tongue activity. Half of the apeks is vibrating and the other half is just pressed against the alveolar ridge. This type of /r/ is not very noticeable but it is difficult to correct that is why it is often found in the speech of adults.
Back distortions are articulated at the back of the oral cavity. There are three types of back distortions in Slovenian: dorsal, uvular and laryngeal rhotacism. Dorsal rhotacism represents the /r/ produced with the back of the velum vibrating against the tongue. In uvular rhotacism /r/ is articulated in the same area, the difference is that the uvula vibrates against the back of the tongue. The /r/ in laryngeal rhotacism is produced between the back of the pharinx and the root of the tongue. The vibrations are slower than in the other types.

Besides all these types of rhotacism there is a large variety of other r-sounds that can usually be described but cannot be classified in any category (Vuletić, 1987).

As it is evident from the above description distortions are diagnosed only according to the place of articulation. And in doing that speech therapists can rely only on their own perception and experiences. In my opinion they could benefit from using a software tool for speech analysis. It would provide them with objective data of different characteristics (e.g. duration, formant values), which could help in setting better diagnosis and in planning the therapy. But in order to achieve that, the main characteristics of standard Slovenian speech sounds should be investigated and compared with the characteristics of nonstandard sounds.

Method

Two groups of children participated in this study, a group with standard /r/ and a group with distortion. All children were examined by speech therapists and the selection was based on the

Table 1. Data of the speakers. (1 = speaker, 2 = gender (f: female, m: male), 3 = date of birth (dd.mm.yyyy), 4 = age (y;m), 5 = level of education (pre: preschool; 1st, 2nd: year of elementary school) , 6 = type of rhotacism, 7 = other speech disorders, 8 = date of recording (dd.mm.yyyy))

1	2	3	4	5	6	7	8
A	f	15.11. 1998	5;00	pre	distortion: uvular /r/		03.12. 2003
B	f	12.09. 1998	5;03	pre	distortion: uvular /r/	distortion: interdental /c/, /s/, /z/	08.12. 2003
C	m	24.09. 1996	7;02	2nd	distortion: uvular /r/	distortion: palatal /c/, /s/, /z/, /č/, /š/, /ž/; developmental dysphasia	08.12. 2003
D	m	13.08. 1997	6;03	1st	distortion: dorsal and/or uvular /r/		08.12. 2003
E	f	07.09. 1999	4;03	pre	distortion: uvular /r/		11.12. 2003
F	f	07.09. 1999	4;03	pre			11.12. 2003
G	f	17.04. 1996	7;07	2nd	distortion: lateral and/or unilateral /r/		11.12. 2003
H	m	13.11. 1997	6;01	pre	distortion: lateral /r/	distortion: lateral /c/, /s/, /z/, /č/, /š/, /ž/	12.12. 2003
M	f	16.12. 1998	5;00	pre			16.12. 2003
R	m	11.02. 1998	5;10	pre			16.12. 2003
S	m	19.02. 1998	5;09	pre			16.12. 2003
T	f	18.02. 1998	5;09	pre			16.12. 2003
AC	m	05.01. 1998	5;11	pre			16.12. 2003
AH	m	30.01. 1998	5,10	pre			16.12. 2003
AP	f	01.09. 1998	5;03	pre			16.12. 2003
AS	m	17.01. 1997	6;11	1st	distortion: uvular /r/		18.12. 2003

Table 2. Frequency of first syllable /r/ for each group of speakers.

	standard /r/ (8 speakers)	uvular /r/ (5 speakers)	dorsal-uvular /r/ (1 speaker)	lateral /r/ (2 speakers)	Σ
/r/	138	89	11	25	263

diagnosis. The speakers with distortion were all at the beginning of speech therapy and none of them were using standard /r/ in spontaneous speech.

Both groups consisted of eight children, four girls and four boys. Mean age of the speakers with standard /r/ is five years and six months (SD is six months) and of the speakers with distortion six years and four months (SD is one year and one month). I think that the age difference does not influence the /r/ realizations. All speakers with distortion were past the age of acquisition of standard /r/. Table 1 shows detailed data of the speakers.

The speakers with distortion were divided into three groups according to the diagnosis. The first group includes five speakers with uvular rhotacism, the second group one speaker with dorsal/uvular rhotacism and the third group two speakers with lateral rhotacism. I did not find any information confirming that the presence of other speech disorders influences production of /r/.

Recordings were made in rooms for speech therapy at the Institute for deaf and hard of hearing Ljubljana and in the conference room of kindergarten Mladi rod, Vetrnica, Ljubljana.
Sony DCR-PC 11E camcorder and free standing microphone AKG C451B were used for recording.
Each speaker was recorded individually. They were all told the same short story which they later retold. While retelling most children helped themselves by using picture cards. Some of the children needed help in the form of additional questions. The aim of this procedure was to get children relaxed and to record as spontaneous a speech as possible but still get the same 'target' words.

All further work on the recorded speech was done using the computer program Praat (Paul Boersma and David Weenink, Institute of Phonetic Sciences, University of Amsterdam).
First different speakers were labeled, which enabled the extraction of children's speech. Following these utterances were labeled and orthographically transcribed. Then only those words containing /r/ were extracted and the phonetic transcription was made. Later on all the analyses were done using only these isolated words.

In the speech of 16 speakers 453 realizations of /r/ were found. Only the first syllable /r/'s were selected in the later analysis. Table 2 shows their frequency for each group of speakers. These 263 /r/'s were additionally divided according to consonantal and vowel-like type,

Table 3. Frequency of /r/ according to type, syllable position and stress.

/r/	initial		in consonantal cluster		Σ
	unstressed	stressed	unstressed	stressed	
consonantal	18	119	12	48	197
vowel-like	25	0	9	32	66
Σ	43	119	21	80	
	162		101		263

syllable position (initial or part of consonantal cluster) and syllable stress. The frequency for each of these subdivisions is shown in table 3.

For all segmented sounds duration and F1, F2 and F3 frequencies were measured. Formant frequencies were measured at the beginning and at the end point of the sound and at one quarter, a half and three quarters of its duration. Based on the perception the manner of articulation was established for the selected /r/'s.

Results and discussion

Manner of articulation

As shown in table 4 all r-sounds produced by the speakers with standard /r/ are alveolar and 71 % of them are taps. It might be expected that the percentage of apico-alveolar /r/'s should be even higher as this is the standard Slovenian /r/ and all the speakers were selected by speech therapists as having standard pronunciation. But based on the findings of other authors (Lindau, 1985 and Sebregts, 2004) such result was expected. Variability in manner (and also in place) of articulation of /r/ is fairly common among speakers of the same language.

The speakers with nonstandard /r/ produced /r/ at two places of articulation, at the one established in the diagnosis and in alveolar area. Uvular and dorsal-uvular /r/'s are mostly approximants and lateral /r/'s are trills. All alveolar /r/'s are taps which shows that the speakers with diagnosis as having nonstandard /r/ produce a standard one as well. This is in accordance with previous studies (Vladisavljević, 1981 and Šimáčková, 2003). Both authors also say that r-sounds that follow stops are more often produced in a standard way (referring to alveolar trills which are closely related to taps). This was not confirmed in the present study though (table 5). The percentage of standard /r/'s is slightly higher for positions #r and #Cr (C= /č/). The reasons for such result could be the difference in number of /r/'s in different syllable positions and big inter- and intra-speaker differences.

Table 4. Place and manner of articulation of /r/ for each group of speakers.

		standard /r/ (8 speakers)		uvular /r/ (5 speakers)		dorsal-uvular /r/ (1 speaker)		lateral /r/ (2 speakers)		Σ
place	Manner	f	%	f	%	f	%	f	%	f
alveolar	Tap	98	71,0	13	14,6	1	9,1	8	32,0	120
	Trill	13	9,4	0	0	0	0	0	0	13
	approximant	24	17,4	0	0	0	0	0	0	25
	Fricative	3	2,2	0	0	0	0	0	0	3
as in diagnosis	Tap	/	/	12	13,5	2	18,2	4	16,0	18
	Trill	/	/	12	13,5	2	18,2	8	32,0	22
	approximant	/	/	52	58,4	6	54,5	5	20,0	62
	Fricative	/	/	0	0	0	0	0	0	0
Σ		138	100	89	100	11	100	25	100	263

Table 5. Standard and nonstandard /r/'s according to syllable position for each group of speakers.

syllable position		uvular /r/ (5 speakers)	dorsal-uvular /r/ (1 speaker)	lateral /r/ (2 speakers)	Σ	
					f	%
#rV	nonstandard /r/	43	5	9	57	85
	standard /r/	5	0	5	10	15
#CrV	nonstandard /r/ (C=/t/, /d/, /p/)	18	1	5	24	83
	standard /r/ (C=/t/, /d/, /p/)	4	1	0	5	17
#r	nonstandard /r/	6	1	1	8	67
	standard /r/	3	0	1	4	33
#Cr	nonstandard /r/ (C=/t/, /d/, /k/, /p/)	7	1	0	8	89
	standard /r/ (C=/t/, /d/, /k/, /p/)	0	0	1	1	11
#Cr	nonstandard /r/ (C=/č/)	2	2	2	6	75
	standard /r/ (C=/č/)	1	0	1	2	25
Σ		89	11	25	125	

Duration

The results in tables 6, 7 and 8 show mean values and standard deviation in milliseconds (ms) and in the percentage of the duration of syllable. By presenting duration in the later form the influence of individual speech rate is excluded.

/r/ presents from 36 % to almost 45 % of the syllable (table 6). This shows that /r/ could have an important influence on the understanding of syllables and words. It would be interesting to investigate the understanding of words produced with different kinds of /r/'s.

It was expected that there would not be any differences in the duration of standard and nonstandard /r/'s. Even when /r/ is completely omitted (as a result of its development or pathology), the place for it is kept in the form of a short pause. But the study showed a statistically significant difference in the case of the group with uvular /r/.

Because there are two types of /r/ in Slovenian (consonantal and vowel-like) the differences between them were measured too. As it is evident from table 7 vowel-like /r/ occupies a bigger portion of syllable in all three groups of speakers with nonstandard /r/, which is not the case with the group with standard production. The difference between the groups is again statistically significant only for the group with uvular /r/.
However these results should be taken with great caution because of the possible mistakes in speech segmentation. Slovenian /r/ consists of vocoid and tap and vowel-like /r/ always follows schwa. While segmenting, it was often impossible to determine where the schwa ends and /r/ begins.

In the present study the interest was also paid to the duration of /r/ in stressed and unstressed syllables. Three quarters of selected /r/'s were positioned in stressed syllables. For all groups of speakers r-sounds in unstressed syllables occupy a bigger portion than in stressed ones (table 8). It was expected to be the other way around. Because of its vocoid part Slovenian /r/ is somehow similar to vowels and Slovenian vowels are generally longer when stressed (Petek et al., 1996). But on the other hand that also means that stressed vowels occupy a bigger portion of syllable and that other sounds are shorter.
The difference between the /r/'s in stressed and unstressed syllables is statistically significant only for groups with uvular and lateral /r/.

Table 6. Mean duration of /r/ for each group of speakers and statistical significance of differences between the group with standard /r/ and the groups with nonstandard /r/.

	duration of /r/ (ms)		/r/ in syllable (%)		t	df	stat. sig. (2-tailed)
	M	SD	M	SD			
standard /r/ (n=138) (8 speakers)	93	56	37,1	13,9			
uvular /r/ (n=89) (5 speakers)	132	57	44,7	16,0	3,779	225	0,000
dorsal–uvular /r/ (n=11) (1 speaker)	92	40	36,0	13,1	0,226	147	0,790
lateral /r/ (n=25) (2 speakers)	122	59	42,5	18,7	1,668	161	0.097

It was expected that the differences in all comparisons would be either statistically significant for all groups of speakers or for none. But it is not so. I think that the main reason for this is the difference in the number of /r/ realizations for different groups, types and syllable positions.

Formant structure

Based on acoustic theory it was predicted that /r/'s produced by speakers with standard and lateral /r/ would have higher F2 and lower F3 values. Standard and lateral /r/ are both produced with tongue apeks vibrating in alveolar area. Uvular and uvular-velar /r/ are produced in uvular area, tongue is moved backwards and its back part is lifted, so these sounds should have lower F2 and higher F3 values.

Figure 1 and 2 show formant values of consonantal and vowel-like /r/ in two syllable positions for each group of speakers. The most striking difference between the groups is the course of formants. It is generally more constant for the groups with standard and uvular /r/ than for the other two. The lines of consonantal and vowel-like /r/ are more parallel for these two groups as well.

In the group with standard /r/ mean F1 values of consonantal and vowel-like /r/ are roughly the same, but F2 and F3 values are slightly higher for consonantal /r/'s. All three formant values are approximately 200 Hz higher for both types of /r/ in consonantal clusters in comparison with the initial /r/'s.

Table 7. Mean duration of consonantal (con.) and vowel-like (vow.) /r/ and statistical significance between the two types for each group of speakers.

		duration of /r/ (ms)		/r/ in syllable (%)		t	df	stat. sig. (2-tailed)
		M	SD	M	SD			
standard /r/ (8 speakers)	con. /r/ (n=101)	98	60	37,7	14,1	0,826	136	0,410
	vow. /r/ (n=37)	81	45	35,5	13,4			
uvular /r/ (5 speakers)	con. /r/ (n=70)	130	52	42,1	13,6	3,182	87	0,002
	vow. /r/ (n=19)	137	73	54,6	20,3			
dorsal-uvular /r/ (1 speaker)	con. /r/ (n=7)	79	34	33,4	15,9	0,845	9	0,420
	vow. /r/ (n=4)	116	44	40,5	4,6			
lateral /r/ (2 speakers)	con. /r/ (n=19)	123	65	39,9	17,4	1,232	23	0,230
	vow. /r/ (n=6)	118	37	50,6	22,2			

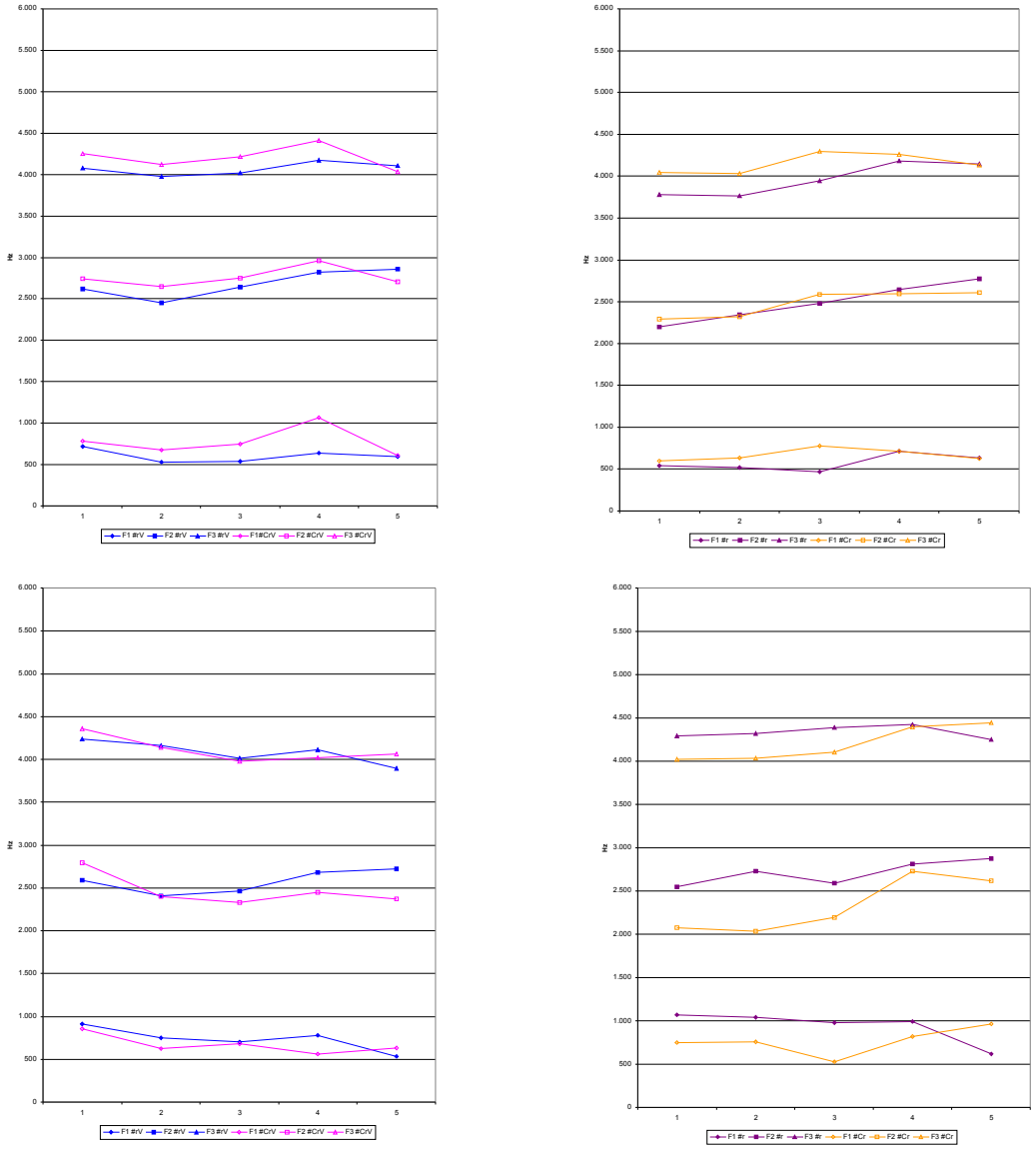

Figure 1. Formant values measured at five points. Left column shows values for consonantal /r/ and right column for vowel-like /r/. Upper row shows values for standard /r/ and lower row for uvular /r/.

The formant structure of /r/'s produced by the speakers with uvular /r/ is the most similar to the /r/'s produced by the speakers with standard /r/. The main difference is that formant values are lower for /r/'s in consonantal clusters than for initial /r/'s.

Vowel-like /r/'s generally have lower F2 values when produced by the speakers with uvular and dorsal-uvular /r/. The same is not evident for consonantal /r/.

I do not believe that any final conclusions about standard and nonstandard Slovenian /r/'s could be made. The results are influenced by too many factors: different number of /r/ realizations, variability of manner and place of articulation for speakers of the same group, different neighboring sounds, mistakes in speech segmentation. However, they do give an insight into the formant structure of Slovenian /r/ and could be helpful in future research.

Conclusion

The aim of the study was to describe main acoustic- phonetic characteristics of children's /r/ and to establish which of them distinguish the standard pronunciation of /r/ from a nonstandard one. Based on the research following findings can be given:

1. standard Slovenian /r/ is an apico-alveolar tap,
2. speakers with standard production of /r/ produce /r/ in different manners as well,
3. variability of the manner of articulation is greater for speakers with nonstandard /r/'s,
4. speakers with nonstandard /r/'s produce a standard one as well,
5. realization of standard /r/ does not depend on /r/'s syllable position,
6. /r/ presents a fairly big part of a syllable,
7. the difference in duration of /r/ is statistically significant only between groups with standard and uvular /r/,

Table 8. Mean duration of /r/ in unstressed (0) and stressed (1) syllable and statistical significance between them for each group of speakers.

		duration of /r/ (ms)		/r/ in syllable (%)		t	df	stat. sig. (2-tailed)
		M	SD	M	SD			
standard /r/ (8 speakers)	0 (n=35)	75	46	37,8	12,6	0,343	136	0,732
	1 (n=103)	99	59	36,9	14,4			
uvular /r/ (5 speakers)	0 (n=20)	138	61	57,4	17,7	4,457	87	0,000
	1 (n=69)	130	56	41,0	13,5			
dorsal-uvular /r/ (1 speaker)	0 (n=2)	65	8	46,2	0,7	1,249	9	0,243
	1 (n=9)	99	42	33,7	13,5			
Lateral /r/ (2 speakers)	0 (n=7)	133	52	58,1	16,8	3,013	23	0,006
	1 (n=18)	118	62	36,4	16,0			

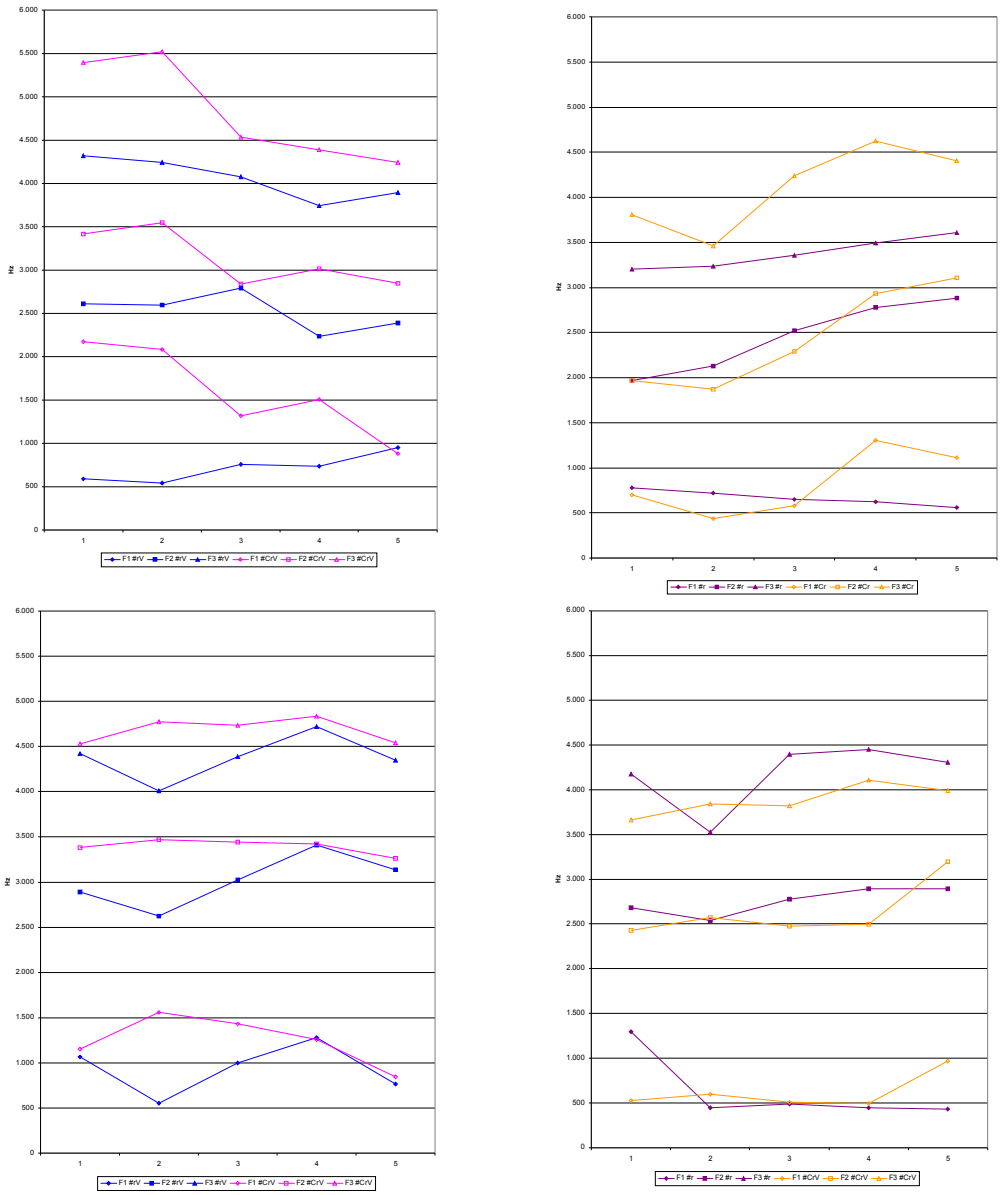

Figure 2. Formant values measured at five points. Left column shows values for consonantal /r/ and right column for vowel-like /r/. Upper line shows values for dorsal-uvular /r/ and lower line for lateral /r/.

8. the difference in duration of consonantal and vowel-like /r/ is statistically significant only in group with uvular /r/,
9. the difference in duration of /r/ in stressed and unstressed syllable is statistically significant only in groups with uvular and lateral /r/,
10. formant values of standard consonantal /r/ are lower than formant values of standard vowel-like /r/,
11. standard /r/'s in consonantal clusters have higher formant values than initial /r/'s.

In my opinion these findings cannot be generalized to all r-sounds of preschool children. The main deficiencies are not well structured /r/'s (manner and place of articulation, syllable position, surrounding sounds) and low number of realizations.
But despite all that these results do uncover the complexity of Slovenian /r/ produced by children and hopefully they will evoke more interest in speech analysis.

Analyzing a bigger number of speech sounds would enable describing main characteristics of all standard Slovenian speech sounds. Such findings would be very useful for speech therapy and could be used in a diagnostic process and in therapy of different speech and language impairments, not just articulation disorders.
With the help of acoustic analysis speech therapists could get objective information about certain person's speech sound characteristics. These could later be compared with the characteristics of standard sounds, which would help establishing a therapy process.

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