

Lyakso E.E., Grigoriev A.S., Kurazhova A.V., Bednaya E.D., Gaikova Ya., Checliarova Ya.
ACOUSTICS OF CHILD'S SPEECH: DYNAMICS OF VOWEL SPECTRAL CHARACTERISTICS

Saint Petersburg State University, Biology and Soil Sciences Faculty
199034, Saint Petersburg, Universitetskaya emb.7 -9
Phone: (812)3213361
Fax: (812)3232454
e-mail: lyakso@gmail.com

Acoustical features of vowel-like sounds in vocalizations and vowels in syllabic and in words of 100 children at the age from 3 months till 7 years are analyzed. The material has made 85000 of vowel-like sounds and vowels. Changes of values and variability of duration, pitch and formant frequencies subject to children age are revealed. Obtained on a material of Russian data confirm available data in different languages, that reduction of duration of stationary parts and frequency characteristics of vowels is with the years one of the basic trends of development of the acoustic aspect of speech at normally developing children.

A series of our researches is devoted studying of formation of acoustic aspect of speech in ontogenesis. The purpose of the present work consisted in studying of dynamics of acoustic characteristics of vowel-like sounds from vocalizations and vowels from words of children of first seven years of a life.

It is shown that at the first year of infant's life the vowel-like sounds (described using the perceptive analysis and transcribed in symbols of International Phonetic Alphabet (IPA) and SAMPA), characterized by high values of pitch (F0) and first two formant frequencies (F1 and F2). Pitch meanings in infant's vocalizations correspond to F1 meanings in [o], [u], [i] of adult speech. Tendency to decrease of pitch occurs since the second half of the first year of life, mainly for vowel-like sounds produced in a quiet condition. Meanings of F1 and F2 in vowel-like sounds of infants at the first month of life occupy high-frequency area on the two-formant coordinate plot. The areas occupied by the sound pairs [o], [u] and [e], [ɨ] are almost joint together; those occupied by the vowel-like [i], [a] overlap in F1 values and partly overlap in F2 values [1]. Since six month of age differences are revealed ($p < 0,01$) in the meanings of the second formants of sounds [a] and [e], by the ninth month of age – in the meanings of the first formants ($p < 0,05$) of [o] and [u] vowel-like sounds [2].

Analyzing words of children during the second year of life, criteria of accuracy recognition was the meaning defined by child's mother. Simple words were recognized easily at the age of 1 year and 3 months and at 1 year and 6 months. Words containing three different syllables or two following one each other consonants were worse for recognizing. Vowel [a] prevailed over other recognized vowels in children words, like at the first year of life. There was no clear dynamics observed in improvement of recognition with the increase of children age, but there was a tendency to improvement in recognition of vowels [e] and [o] by the second half of the second year of life. Vowels [a], [e], [ɨ], [o] occupy corresponding areas on the two-formant plot. F1 meanings for vowel [i] are moved to the area of vowel [e]. It is due by the fact that the values of F0 remain still high. It should be highlighted the coincidence of the formants' values of vowels [o] and [u] on the two-formant plot and their location close to the area of vowel [o]. There were no significant differences revealed between vowels' formant frequencies that can be due to their individual pronunciation peculiarity in words.

Similar tendency remains relative to the first two formants in children vowels of the third year of life. By the end of the third year of life children clearly pronounce words consisting of 3 and 4 syllables, combining it to phrases of 3-5 words. During the third year of life the vowel stress is formed. Duration of all stressed vowels is to be longer than in unstressed ones. Peculiarity of vowels in words of three-years-old children tends to decrease in dispersion of the meanings, mainly for the second formant. It may evidence of the pronunciation model for stressed and unstressed vowel development forming by children. Remained high F0 values make it impossible to describe the vowels [i], [u], [ɨ] in terms of the first two formants absolute values, but these vowels are identified clearly in the words (independently of their stressed or unstressed position) [1]. The palatalized versus non-palatalized consonants opposition development begins, which is found in the characteristics of vowels following them. For words of three years old children, there is a tendency to emergence of significant differences ($0,05 < p < 0,1$) between relative F2 values in non-nasalized coronal consonant context for palatalized and non-palatalized consonants. There are also significant differences between these meanings in velar consonants and nasalized coronal consonant context ($p < 0,05$) [3]. There is a tendency to appearance of differences between absolute F2 values at the transition part from consonant, assessed as non-palatalized by auditors, to vowel [a], and transition from palatalized consonant to vowel [i], that is an evidence of non-palatalized consonants articulation model's development. Comparing F2 meanings on transition and stationary parts in non-nasalized coronal consonant context, revealed the significant differences between vowel [a] after non-palatalized consonant (by

auditors' estimation) and vowel [i]. (Differences in words of children at the first half of the third year of life - $0,02 < p < 0,03$; in words of ones at the second half of the third year - $0,04 < p < 0,05$). There are no similar differences between vowel [a] after palatalized consonant and vowel [u], between vowels [a] after consonants, estimated by auditors differently [3].

At 4 years of age in all children the duration of stressed vowel and its stationary part, as well as difference between them, is higher for the stressed vowels than for the unstressed ones. At 5 years of age the difference between the stressed vowel duration and its stationary parts duration is still higher than that for the unstressed vowels in all children. By 4 years age, word stress is formed, stressed vowel marks on the base of duration and pitch. Vowel distinction by pitch in some of the children is more expressed at 4 years than at 5 years old. This fact let us assume that in speech of these children there are some features which help to form stress in Russian language. Higher values of pitch in stressed vowels, as compared to that in unstressed ones, influence on arrangement of unstressed vowels on two-formant plot. Context has the big influence on spectral features of unstressed vowels that correlate with its reduction by duration. By the age of five years, the arrangements of F1 and F2 on two-formant plot are stayed non-informative [4].

Pitch values in stressed vowel of 6-7 years old children do not significantly differ, but it tends to decrease by the 7 years. Stressed vowels' duration is significantly higher than in unstressed ones in words of 6 and 7 years old children. By 7 years stressed vowels in words are marked out by the duration which is relevant for Russian language. Effects of coarticulation with the regard to the context or without one expressed at 6 and 7 years of age [5].

Thus in every above mentioned study vowel features were compared within the analyzed age periods. So the present study is aimed to reveal the dynamics of vowel spectral features. Hence, in the present study the aim was to reveal the dynamics of vowels' spectral characteristics.

Infant's vocalizations at the first year of life, syllabic constructions and words of the children at the second year of life and words at the 3-7 years of life were analysed. Recording of vocalizations and speech material has been held since 2000 to 2012 year. Recording equipment has been changed during this period: 2000 – 2001 гг. – audio recorder - «Pioneer» CT-W704RS, microphone-MD-59; 2002-2005 years – “Marantz PMD222”, since 2007 year - digital recorder “Marantz PMD660” with external microphone “SENNHEIZER e835S”.

Analyzing material is longitudinal records of 5 children from 3 to 84 months; for each children – 10 vocalizations at the age of 3 and 12 months, 10 words and speech-like constructions at 24 months, 10 phrases with words of 1-3 syllables; 100 words at the age of 48-84 months. Records of infants vocalizations at the first year (for each child)- 50 vocalizations at 3,6,9,12 months; 40 words for ten 2, 3 and 4 –years-olds; 100 words for 15 five years old children, 10 children at the age of 6 and 7 years. Total amount of analyzed vowel-like sounds and vowels were 85000 sounds, adult speech material was 50 sounds.

Perceptive analysis of sounds and words of children was held by Russian adult's native speakers. At the age of 3 to 12 months – 137 auditors, 24 months – 103 auditors, 36 months – 137 auditors, 48-60 months 165 auditors, 72-84 months 100 auditors. Vowel (in vocalizations and words) were analysed if 75% of auditors recognized them.

Vowel and its stationary part duration, pitch (F0) and the first two formants values (F1, F2) were measured on the stationary part of vowel using sound editor «Cool Edit». The same parameters were compared using the Mann-Whitney criterion in /a/, /i/ and /u/ after the following consonants: /k/ and /d/ for /a/, /b/ and /g/ for /u/ and /t'/ for /i/.

Statistical analysis was conducted using nonparametric criterion Mann-Witney.

Duration of vowel-like sounds tend to decrease by 12 months, vowel duration in words of 2-4 years olds has maximal values and significantly decrease by 5 years of age, reaching minimal values by 7 years (Fig.1 A). By three years of age stressed and unstressed vowels differ by duration. Beginning from this age and up to 7 years stressed vowel and its stationary part duration statistically significant longer than that in unstressed one (Fig. 1 B). Exception is the vowels in 5 years old children, in wich stationary part duration is shorter than that in unstressed one.

Pitch values is tend to decrease with the age of children, and significantly decrease by 7 years (Fig. 2).

Comparing pitch values in stressed and unstressed vowel without regarding to context and quality of vowel it is shown that the differences are more significant at 3, 4 and 6 years than at 5 years. Meanings of stressed and unstressed vowel do not significantly differ in words of 7 year old children.

Pairwise comparasion of vowel by meanings of two first formant shown that the first differences can be seen in development of vowel system already at the first year of life, however inclusion of vowels in words leads to its inaccurate articulation. Vowels of seven years old children differ from ones in adult speech by frequency meanings. The least differences between pairs of vowels [a/u], [a/o], [u/e], [o/e] and the greatest one between [i/e] and [u/o] pars are found (table 1).

36 mos.	F1	-	-		-	++	-	-	-	-	-
	F2	++	+++		-	+	-	-	-	-	-
48 mos.	F1	++	-		-	-	-	-	-	-	-
	F2	+++	+++		-	+	-	-	-	-	-
60 mos.	F1	+++	+	-	-	+	+++	+++	-	-	-
	F2	+++	+++	+	-	+	++	+++	-	+	++
72 mos.	F1	+	+	-	-	-	-	-	-	-	-
	F2	+++	+++	+++	-	-	+	+++	-	-	+++
84 mos.	F1	-	-	-	-	+++	+++	+	-	+	-
	F2	++	++	+++	-	+	+++	+++	-	++	+++
Adult	F1	+++	+++	+++	+++	+++	++	+++	+++	+++	-
	F2	+++	+++	+++	-	+++	++	+++	+++	+++	+++

Comments: - - not significant differences; + - significant differences ($0,05 > p > 0,01$); ++ - very significant differences ($0,01 > p > 0,001$); +++ - extremely significant differences ($p < 0,001$); p – nonparametric criterion Mann-Witney.

Thus, in a course of present study it is shown that by the seven years feature of vowel duration is forming, which is relevant for Russian language, but articulation model isn't formed.

In connection with this it is perspective to continue to study dynamics of spectral features of vowels and comparison ones in stressed and unstressed vowels with regarding to context or without it.

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REFERENCES

1. E.E.Lyakso, O.V.Chelibanova, A.D.Gromova, I.V.Novikova, V.I.Galunov. Noise immunity development in the early ontogenesis // Proceedings of the XIII Session of the Russian Acoustical Society. M.: GEOS, 2003. V.3. P. 518-523.
2. V. I. Galounov, E. E. Lyakso. Formation the acoustic image of signal in the early ontogenesis // Proceedings of the XI Session of the Russian Acoustical Society M.: GEOS., 2001. V.3. P.399-402.
3. E.E.Lyakso, A.D.Gromova, O.V.Frolova., O.A. Romanova. Acoustical aspect of speech development of children at the third year of life // Physiological journal. 2004. V.90., №1 P.83-96.
4. Lyakso E., Gromova A. The acoustic characteristics of Russian vowels in children of 4 and 5 years of age // Psychology of Language and Communication, 2005. Vol. 9 № 2. P. 5 - 14.
5. Lyakso E., Frolova O., Grigoriev A. Acoustic Characteristics of Vowels in 6 and 7 Years Old Russian Children// Interspeech, 2000. P. 349-357.