TRACING EMOTIONS IN RUSSIAN VOWELS

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Abstract

This paper examines acoustic clues of six emotional states (neutral, surprise, happiness, anger, sadness, and fear) in the production of Russian vowels. The findings for unstressed, stressed and pitch accented vowels are presented and discussed. The research data come from RUSLANA (Russian Language Affective) database of standard Russian.

1. Introduction

Expression of emotions in speech currently attracts scholars from a wide range of disciplines, such as literary criticism, neuroscience, anthropology, pragmatics, communication sciences, psychology, physiology, linguistics, applied linguistics, education, engineering, computer science, psychotherapy, and psychiatry (Wierzbicka, 1999; Johnstone & Scherer, 2000), Pavlenko, 2005; Imai, 2007). Humans can express and identify emotions with a variety of communication forms including vocal (linguistic, verbal art) and non-vocal (facial expressions, posture, clothing, hairstyle, non-verbal art, gesticulation, behavioral patterns) (Anolli & Ciceri, 2001). Linguistically, emotions are rendered via phonetic (acoustic), graphic, phonological, morphological, syntactic, sociolinguistic, textual and pragmatic devices as well as their combinations (Bazzanella, 2004), i.e. all the structural levels and most functional forms of language are serving to express emotions. It is often extremely hard to disentangle some of the emotional cues or estimate their exact contribution to perceived emotion (Dietrich et al, 2006).

The task of analyzing linguistic portrayal of emotions is made even more challenging due to disagreements among scholars about definitions and classifications of emotions (Nordstrand et al. 2004). Dimensional approaches view emotions as a continuum or gradual transition and often map emotions in two- or three-dimensional space continua (Osgood, 1957, Davitz, 1964, Plutchik, 1980, Nordstrom et al, 2004). However, for simplicity reasons, most phonetic studies (e.g., Nordstrom et al, 2004; Waaramaa et al, 2006) follow the discrete or category approach, which identifies a few basic emotions that are considered distinct from each other (Ekman, 1979, Iida, 2002). In this study, we also follow discrete approach. From the commonly identified list of basic emotions, we have selected five emotive-affective states (fear, joy, sadness, surprise, anger) which are examined against the 'neutral' or unemotive ones.

This paper focuses on the acoustic clues of emotions. The total list of features singled out by researchers as acoustic correlates of emotive states can vary from around 30 (McGilloway et al., 2000) to over 100 (Fernandez, 2004). In phonetic studies of emotive and affective speech, most attention has been

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given so far to prosodic correlates of emotion, primarily to pitch parameters, such as the types, magnitudes, duration and steepness of pitch movements, and the declination within phrases (Banse & Scherer, 1996; Paeschke & Sendlmeier, 2000). Some characteristics of temporal and rhythmical organization of speech have been also shown to be relevant for emotive information (Arnfield, Roach, Setter, Greasley & Horton, 1995). Other suprasegmental parameters which have been shown to contribute to the expression of emotions in speech include voice quality, pauses and boundaries (Cowie et al., 2001; Min Lee & Narayanan, 2005).

It has been observed that some segmental features, such as segmental durations, spectral characteristics of segments and formant frequencies are also salient for the expression of emotion (Min Lee & Narayanan, 2005, Kienast & Sendlmeier, 2000, Cowie et al, 2001; Tickle, 2001; Fernandez, 2004).

As far as the effect of emotions on vowel quality is concerned, while some studies conclude that vowel quality significantly changes under emotion (Fernandez, 2004), some other studies have shown that emotions do impact vowel quality, but this effect is minimal (Szameitat et al., 2009). Some explanations on the changes of vowel characteristics under affect are found in the speech production studies which show the articulatory changes in emotional states, such as the changes in the lip opening, rising, protrusion and rounding (Magno Caldognetto et al. 2004), and in the tongue movements (Fonàgy, 1976). Another observed change in emotive vowels is the increase of F3 and F4 values under some negative emotions, which is explained by more tense and shortened vocal tract (Waaramaa, Alku & Laukkanen, 2006). Some recent experiments suggest that the observed impact of some emotions on articulation (such as the vertical and lateral labial distance) may differ by the type of vowel (Nordstrom et al, 2004). All above research studies have been performed on languages other than Russian.

This paper contributes to the field by investigating emotion-related parameters in the acoustic characteristics of Russian vowels. The materials for the study were retrieved from RUSLANA, a Russian affective speech database which represents the phonemes, major syntactical and intonation contour types in Russian (Makarova & Petrushin, 2002). Emotions were simulated by the speakers, a procedure so commonly employed in other phonetic experiments and emotive databases (e.g., Nordstrom et al, 2004; Toivanen et al, 2006) that it has been called "the preferred way of obtaining emotional voice samples" (Scherer, 2003: 232). The database and the extracted features are described in the following section.

2. Materials and Methods

2.1 The Database

RUSLANA (Russian language affective) database includes the recordings of speakers of standard (St Petersburg) Russian portraying the following six emotional states: neutral, anger, fear, happiness, sadness, and surprise. It also represents the major syntactical types in Russian (statements, 'yes-no', alternative and wh-questions, echo-questions, exclamations). The database includes utterances from 61 subjects (12 male and 49 female). Each subject

recorded 10 sentences of different syntactical types and intonational patterns portraying the above mentioned six emotional states. In our research we used 600 utterances from 10 subjects (5 male and 5 female), which count 60 utterances per subject or 100 utterances per emotional state. The subjects were selected based on their high ranks in ability to express emotions.

2.2 Features Extraction

The list of extracted acoustic features included:
Phoneme duration (Dur);
Percentage of voicing;
Average energy (E);
Average fundamental frequency value (F0);
Average F0 derivative (F0deriv);
Average formant values (F1, F2, F3);
Average formant bandwidths (BW1, BW2, BW3).

Additionally the values of average power spectrum on logarithmic scale were estimated for the following 16 sub-bands: 0 – 500 Hz, 501 – 1000 Hz, 1001 – 1500 Hz, 1501 – 2000 Hz, 2001 – 2500 Hz, 2501 – 3000 Hz, 3001 – 3500 Hz, 3501 – 4000 Hz, 4001 – 5000 Hz, 5001 – 6000 Hz, 6001 – 7000 Hz, 7001 – 8000 Hz, 8001 – 10000 Hz, 10001 – 12000 Hz, 12001 – 14000 Hz, 14001 – 16000 Hz. These spectral features are denoted by letters "Fq" followed by the upper bound of frequency range, for example, the sub-band 2501 – 3000 Hz is denoted as Fq3000.

Altogether, the features for about 17,100 occurrences of phonemes have been extracted. The phoneme level labeling for vowels allows distinguishing between unstressed, stressed, and pitch accented sounds.

The extracted features were subjected to Univariate ANOVA analysis with subsequent Post-Hoc analysis to determine whether every feature significantly varies with the factor of emotion type, and if so, which of he pairs of emotional states show significant differences in the average feature values.

3. Results

3.1. Vowel groups (accented, stressed and unstressed vowels)

This section describes the features, which were found to be significantly different across the six emotive-affective states for vowel quality. We consider the three classes of vowels: unstressed, stressed and accented.

1. Maximum number of segmental features responsible for the expression of affect is found in accented vowels, fewer features can be traced in stressed and the least – in unstressed vowels. This shows that prosody is closely linked with vowel quality. Unstressed vowels have shorter duration and less distinct formant characteristics, which makes them worse suited carrying much information about affect.
2. Features of maximum salience for all the vowels pooled together are vowel duration (Dur), average energy (E), F0, and all the power spectrum features.
3. Parameters of medium salience are first and second formants (F1, F2).

4. Parameters of low salience are: F3, F0 derivative, and formant bandwidths (BW1, BW2, BW3).
5. Emotional states are associated with the following specific vowel characteristics.

Neutral: low duration, energy, F0 and all the power spectrum features (Fq-features), medium formant (F1, F2, F3) and BW2 values, positive F0 derivative, and high BW1, BW3 values.

Sadness: high duration, low energy, low values of F0 and all the Fq-features, low positive values of F0 derivative, medium values of F1 and BW1, low F2, high F2, BW2, F3, medium BW3 values.

Fear: medium vowel duration, energy and all Fq-features from 500 Hz to 8000 Hz, and high values of Fq-features from 10000 Hz to 16000 Hz.

Anger: medium vowel duration, high energy, high values of Fq-features, medium F0 values, low negative F0 derivative, high F1, F2, low BW1, high BW2, medium F3, and low BW3 value.

Surprise: high vowel duration, medium energy, medium Fq-feature and F0 values, and high positive values of F0 derivative.

Happiness: low vowel duration, high energy, high Fq-feature values under 12000 Hz, medium Fq values at 14000 Hz and 16000 Hz, high F0, low negative F0 derivative, high F1, F2, F3, low BW1 and BW2, and medium BW3.

6. Post-hoc pair-wide comparisons of the parameter differences across emotional states have shown that parametric distances are unequal. The pairs of emotional states with maximum parametric differences and minimum of overlapping parameters are the following: anger-neutral, happiness-neutral, anger-sadness, sadness-happiness, and anger-surprise. Emotional states with the minimal parametric differences are sadness-neutral and anger-happiness.

3.2. Individual vowels

This section considers the parameters of different vowels.

3.2.1 Vowel Durations

Duration of neutral vowels is represented below in Table 1.

Table 1. Duration of neutral vowels, ms

Durations	I	**a**	**e**	**i**	**u**	**o**
unstressed	61	**65.6**	83	49	**63.2**	**80**
stressed	109	**82.9**	75	61.4	**66.6**	**77**
accented	113	107	**92**	69.3	**88.5**	**89**

All the accented vowels are longer than the unstressed vowels. Stressed vowels /ɪ, a, i, u/ also show a significant increase in duration as compared to unstressed vowels. Vowels /e/ and /o/ do not have a significant increase in duration between the unstressed and stressed variants, probably because they normally undergo reduction in rapid speech turning into /i/ and / /-like vowels respectively. The cases when they retain their quality in unstressed position might be considered to be a case of weakened prominence and they therefore do not reduce in length. In the unstressed position, the relative vowel lengths can be represented as i<ɪ<u<a<o<e, which reflects the general universal trend for close vowels to have shorter durations than open vowels as well as the above described reduction of <o> and <e> vowels. In the stressed and accented positions, /i/ is still the shortest vowel, however, the longest vowel is /ɪ/. The change in pattern probably reflects the intrinsic vowel quality in Russian. It is often suggested by teachers of Russian as a foreign language that /ɪ/ has higher muscular tension, which may require additional length. This assumption, however, needs to be supported by further experimental evidence.

Variation of vowel durations under emotive states is represented in Table 2 below. As can be seen from Table 2, statistically significant differences between vowel durations across emotional states were obtained in these data only for unstressed and stressed /a, i/, accented /e/, stressed and accented /o/. In general, neutral state tends to have shorter vowel duration than emotional states. No other common patterns were observed across the individual vowels. Further research is necessary to find out whether these results are explained by the differences in vowel samples (numbers of different vowels per the three accentual categories), or whether there could be individual use of vowel length across the emotional states. For example, while the increased duration of stressed /a/ and /i/ may serve to signal happiness or anger, the increased duration of stressed /o/ may be used to signal surprise and sadness.

Table 2. Vowel duration across emotional states

	ɪ			i			e		
	unstr	str	acc	unstr	str	acc	unstr	str	acc
N	154	30	8	963	288	50	339	289	68
Sig	X	X	X	0.000	0.014	X	X	X	0.016
an	59.5	79.1	65.3	**60.7**	**71.5**	84.2	99.8	88.3	**117.9**
sa	59.1	87.4	96.9	**57.0**	**70.9**	108	88.2	86.5	**136.8**
afr	55.9	87.1	116,9	**57.3**	**67.2**	95.4	90.5	83.5	**134.4**
ha	50.1	79.9	74.8	**54.0**	**73.2**	96.7	92.0	86.5	**104.2**
neu	60.8	109	112.9	**48.9**	**61.4**	69.3	83.2	75.3	**92.3**
sur	49.4	87.6	67.51	**53.8**	**66.4**	125	86.5	80.8	**119.2**

		a			**u**			o	
	unstr	str	acc	**unstr**	**str**	acc	unstr	str	**acc**
N	1844	337	80	**335**	**85**	27	256	364	**92**
Sig	0.000	0.001	X	**X**	**X**	X	X	0.03	**0.010**
an	75.8	99.68	131.1	**85.2**	**92.9**	82.1	100.2	92	**120.5**
sa	71.8	95.51	139.9	**70.3**	**83.7**	91.9	100.4	92	**151.8**
afr	74.1	98.36	121.1	**72.8**	**81.5**	106	100.2	91	**117.4**
ha	70.5	105.1	121.3	**71.3**	**86.6**	81.9	93.72	92	**113.3**
neu	65.6	82.94	107.5	**63.2**	**66.6**	88.5	79.82	77	**89.13**
sur	70.7	98.6	131.2	**67.9**	**82.3**	83.8	89.95	88	**115.3**

3.2.2. Energy

Energy of neutral vowels is represented below in Table 3. We did not observe expected differences in energy in regards of the accentual and articulatory types of vowels. The emotive type serves as a more salient factor for vowel energy than either its accentual or articulatory (open/close) type.

Table 3. Energy of neutral vowels

Energy	I	**a**	**e**	**i**	**u**	**o**
unstressed	0.0242	0.0304	0.0259	0.0226	0.0204	0.0401
stressed	0.0189	0.0344	0.032	0.0214	0.0178	0.0296
accented	0.0439	0.0264	0.0263	0.0219	0.0139	0.0214

b) Variation of vowel energy across emotive states

Energy of the three vowel groups (stressed, unstressed, accented) across emotive states is represented in Figures 1-3 below. We observed significant differences in energy across emotional states for all the individual five vowels and for the three vowel groups (stressed, unstressed, accented). 'Happy' and 'angry' states are associated with highest energies, 'neutral' and 'sad' with the lowest energies, 'surprised and 'afraid' with medium energies.

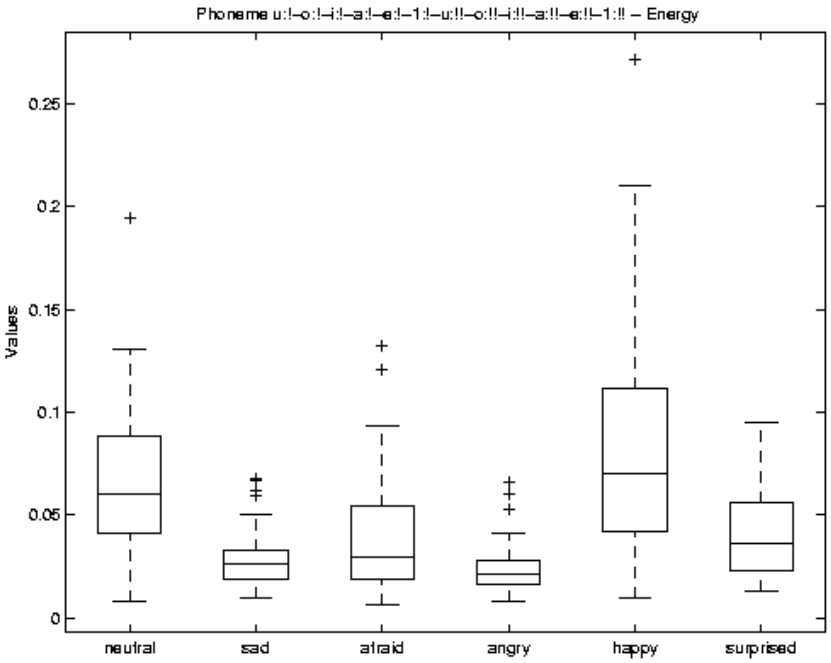


Figure 1. Energy of accented vowels group

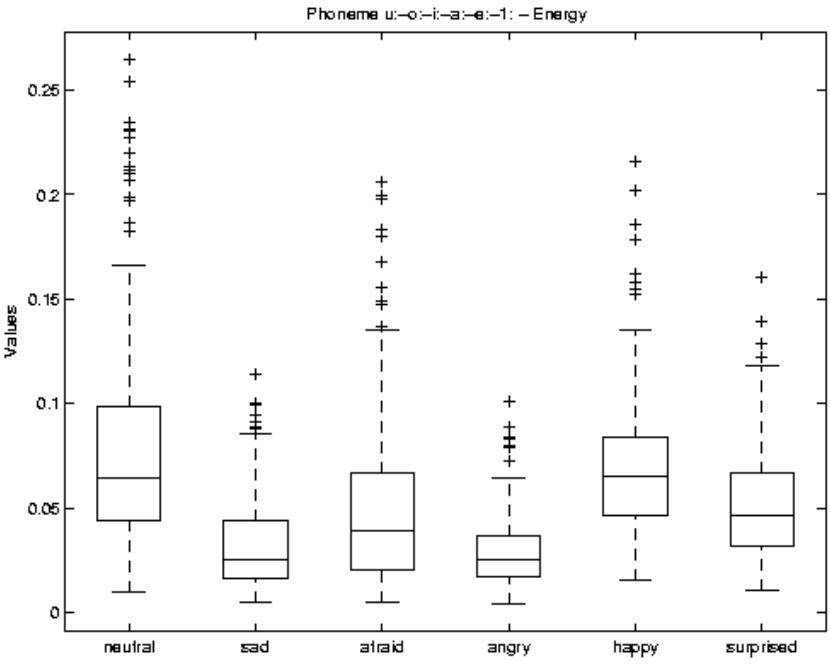


Figure 2. Energy of stressed vowels group

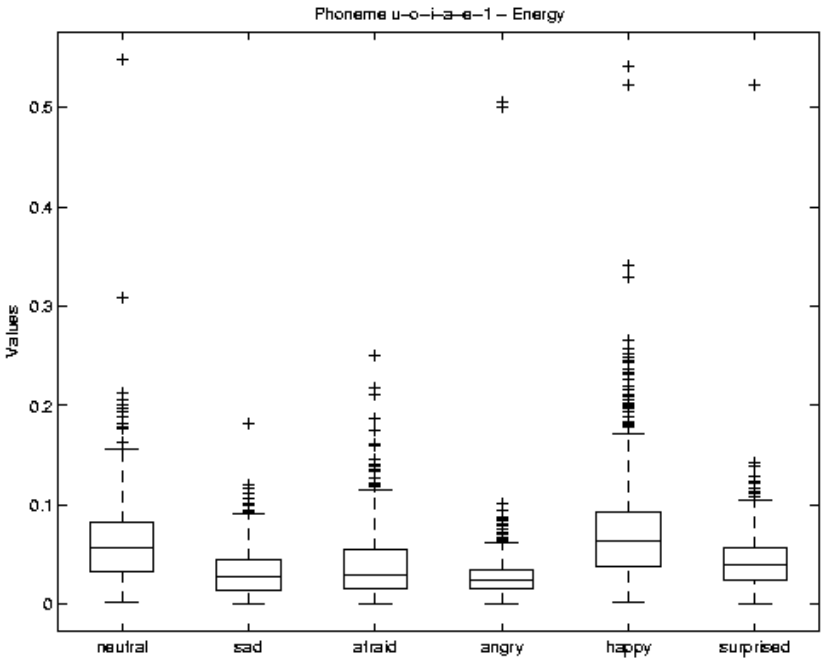


Figure 3. Energy of unstressed vowels group

3.2.3. F0

F0 in neutral vowels is represented below in Table 4.

Table 4. F0 in neutral vowels, Hz

F0	I	**a**	**e**	**i**	**u**	**o**
unstressed	198	188	209	186	190	260
stressed	170	138	156	159	125	142
accented	262	228	233	277	218	243

For all the stressed vowels F0 values are lower than for unstressed vowels. This could be explained by pitch lowering in the stressed vowels, since pitch participates in Russian in the realization of stress and falling pitch in stressed syllables with high pre-accented syllables are common. The highest pitch values (with the exception of stressed /o/ which is higher in pitch than stressed /o/, but has about the same pitch as the unstressed variant) are found in the accented vowels, which reflects the commonality of rising and rise-falling pre-nuclear and nuclear tones in Russian (Makarova, 2000).

Unstressed vowels do not show differences in pitch depending on the features front/back, open/close. Frequency values in the stressed and accented variants are reflecting their quality: high back /u/ has lower F0 values, mid-open and open /e,o,a/ have medium F0 values, and high front and central /i, ɪ/ have the highest F0 values.

Variation of F0 across the emotive states is represented below in Table 5.

Table 5. F0 across emotive states, Hz

F0	ɪ			**e**			**i**		
	unstr	**str**	**acc**	**unstr**	**str**	**acc**	**unstr**	**str**	**acc**
N	154	30	8	339	289	68	963	288	50
Sig	0.002	X	X	0.018	0	X	0	0	X
an	**228.9**	254.9	315.8	**229.8**	**198.6**	290.1	**236.3**	**199.2**	301.4
sa	**202**	192.6	278.7	**224.4**	**159.3**	252.5	**193.2**	**166.9**	248.3
afr	**245.6**	258.9	315.8	**230**	**220.1**	309.3	**227**	**211.9**	230.5
ha	**275.6**	243.8	354.5	**263.5**	**217.3**	281.7	**251.6**	**238.6**	315.6
neu	**198.4**	170.2	262.3	**209.1**	**156.2**	233.1	**185.9**	**159**	276.7
sur	**231.5**	207.7	291.5	**255.4**	**192.2**	289.6	**233.6**	**206.6**	253.2
F0		a			**u**			**o**	
	unstr	str	acc	**unstr**	**str**	acc	**unstr**	**str**	acc
N	**1844**	337	80	**335**	**85**	27	**256**	**364**	92
Sig	**0.000**	0.000	X	**0.02**	**X**	X	**0.05**	**0.000**	X
an	**209.7**	193	274.8	**224.0**	**188.1**	279.4	**271.5**	**191.4**	297.9
sa	**191.8**	149	254.9	**192.0**	**135.3**	258.6	**258.9**	**160.7**	270.3
afr	**218.3**	201.8	296.3	**215.1**	**197.6**	278.6	**267.5**	**205.8**	314.2
ha	**233.3**	206.5	275.3	**234.8**	**192.8**	297.7	**315.3**	**217.6**	319.7
neu	**188.4**	138.1	228.4	**190.2**	**125.7**	218.8	**259.7**	**141.8**	242.6
sur	**212.9**	181.2	282.5	**205.6**	**172.4**	301.7	**263**	**182.4**	278.8

Statistically significant differences were observed across F0 values of all the vowels (unstressed and stressed variants), but not for any of the accented variants. The pitch values of the accented vowels are strongly determined by the phrasal prosody, and within the small sample of accented vowels, no significant dependency on the accentual type could be found. ‘Happy’ state is associated

with high F0 values for all the vowels. ‘Neutral’ and ‘sad’ have the lowest F0 values. ‘Angry’, ‘surprised’, ‘afraid’ are characterized by medium F0 values

3.2. 4. Formants

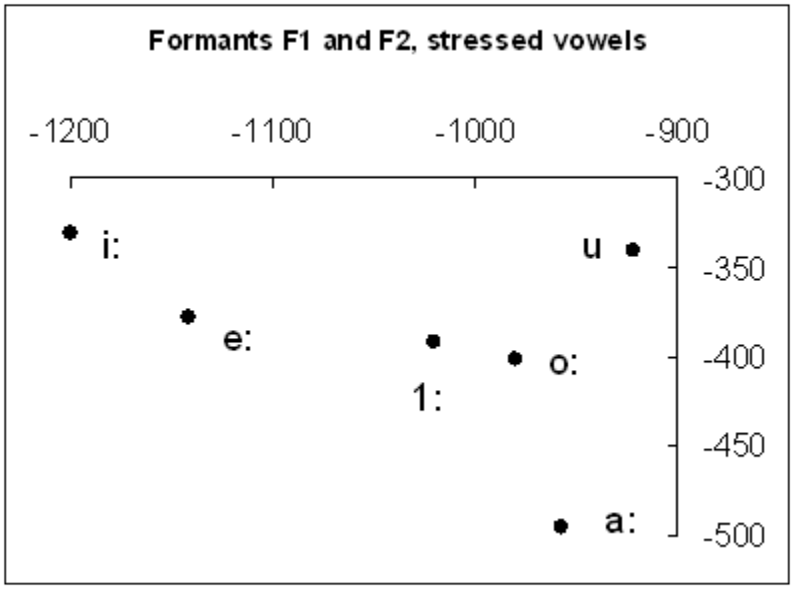
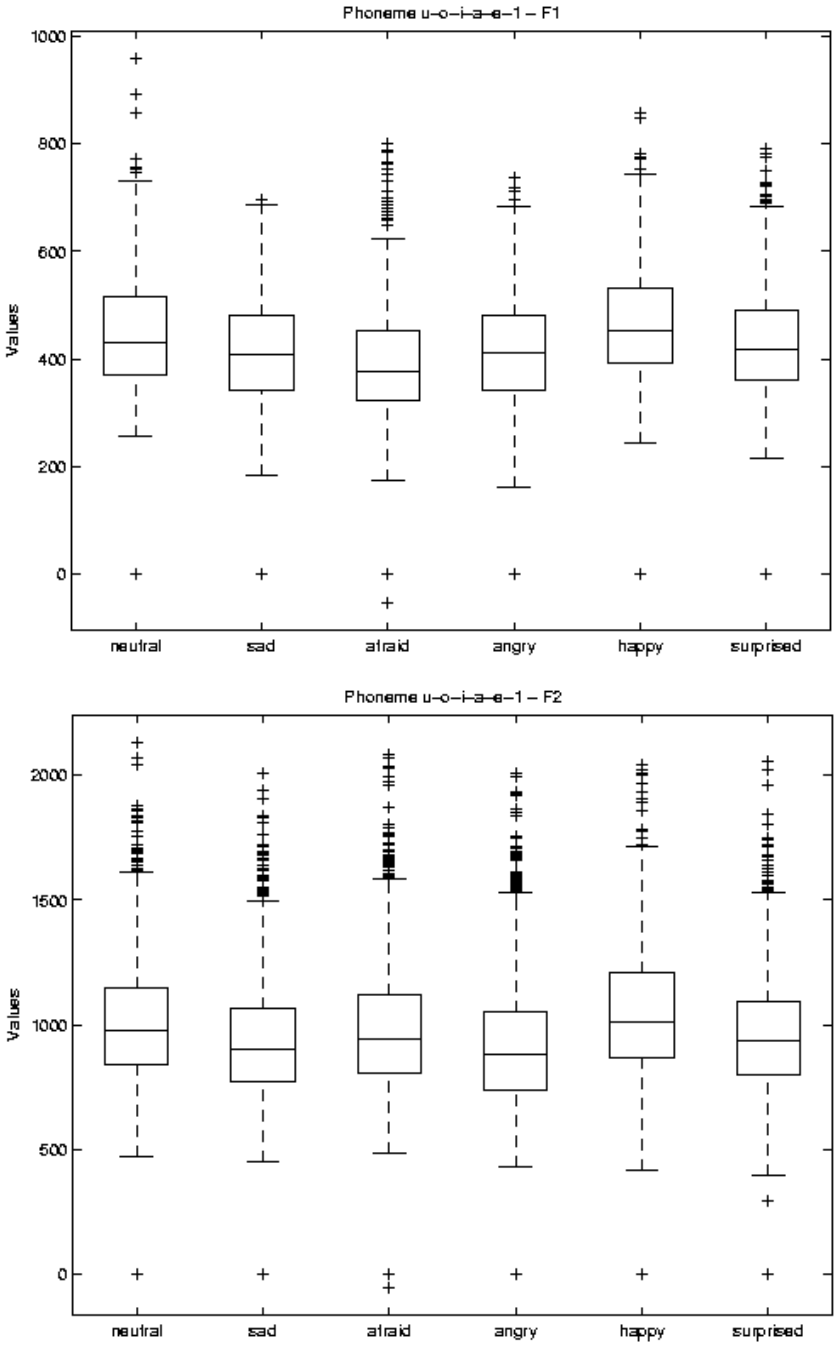


Figure 4. F1 and F2 values for neutral vowels.

F1 and F2 values for neutral (unemotional) vowels are represented above in Figure 4. The distribution of formant 1 and 2 values coincide with the articulatory descriptions of Russian vowels with the exception of the vowel /ɪ/ which appears to be half-close rather than close. This suggests that both articulatory and acoustic characteristics of /ɪ/ need further investigations. It should be mentioned that the obtained formant values in this experiment represented in Figure 1 are more ‘central’ than the usually reported formant values, since in this experiment, the values were pooled together for 5 male and 5 female subjects, and the features including formants were extracted from the whole durations of the vowels (including formant transitions).

F1 and F2 values get significantly affected by emotional states, whereby the effect of F1 appears to be stronger than for F2. ‘Angry’, ‘happy’ have higher values of F1 and F2, ‘sad, neutral, afraid’ – lower ones. In terms of articulation it means that vowels become more open and move slightly to the front with the emotions of ‘happy’ and ‘angry’, and close (plus may move slightly backwards) when people are afraid or sad. Since this applies to all the three groups of vowels, the tendency is illustrate below with the example of unstressed vowels in Figures 5 and 6.



Figures 5-6. F1 (top) and F2 (bottom) for unstressed vowels.

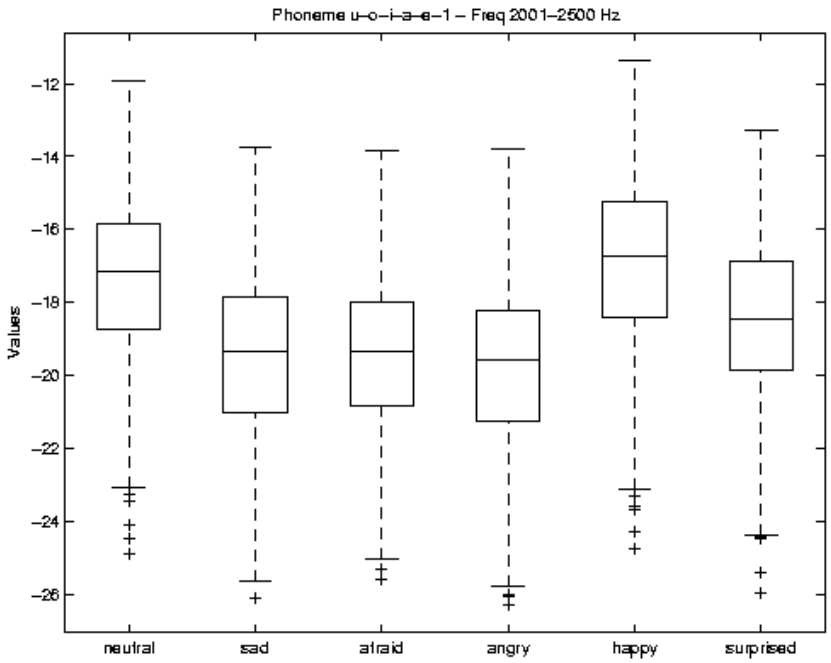
F3 values were of little significance for the emotive types of vowels.

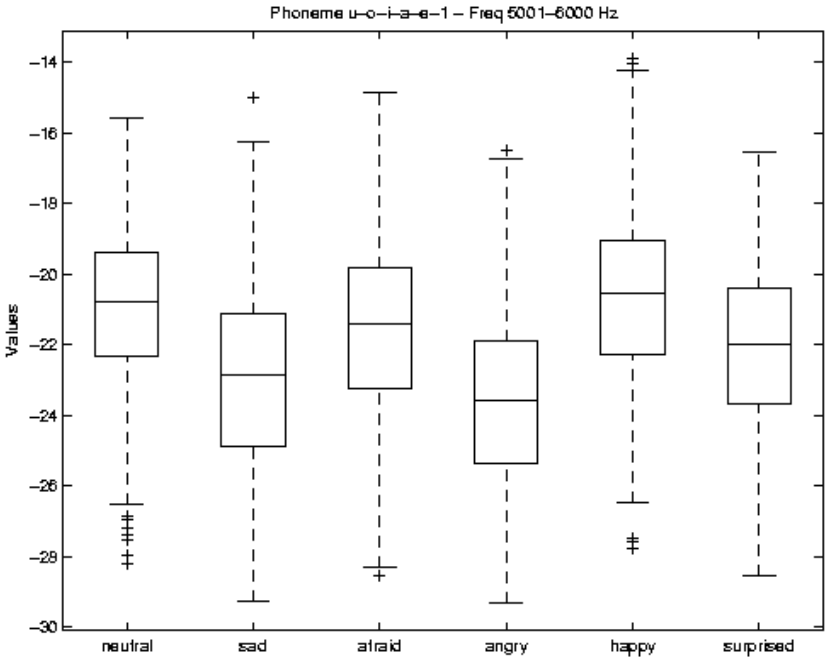
3.2.4. Some other parameters

Formant bandwidths and F0 derivative values were of little or no significance for the emotion expression. Power spectrum bands for all the three vowel accentual groups presented a uniform tendency: lower spectrum ranges (between 0 to 4000 Hz) showed higher energy values for 'neutral' and 'happy' emotive types, medium values for 'surprised' and low values for 'sad', 'afraid', 'angry'. For higher frequency bands, the pattern changed, whereby 'afraid' emotive type also yielded higher values similar to 'neutral' and 'happy' ('sad' and 'angry' remaining at low energy). This finding is illustrated below with the example of unstressed vowels in Figures 7-8.

4. Conclusion

The results reported above show that vowel quality does contribute to the expression of emotive characteristics in Russian. Parameters of maximum salience are vowel duration (Dur), average energy (E), F0, and all the power spectrum features. The formant values obtained for stressed Russian vowels confirm the articulatory descriptions of Russian vowels, however, the formant characteristics of /I/ suggest that it may be a half-close vowel. The results are limited by the number of subjects and segments employed and further investigations of segmental characteristics of Russian speech on a wider material better controlled by subject gender are necessary.





Figures 7-8. Power spectra 2000-2500 Hz (previous page) and 5000-6000 Hz (above) ranges**.**

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