VARIATION IN VOWEL QUALITY AS A FEATURE OF ESTONIAN QUANTITY

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Euroopa Liit
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Eesti tuleviku heaks

Introduction

In Estonian, disyllabic feet can be in short (Q1), long (Q2), or overlong (Q3) quantity degree. The feet are left headed. Phonologically **it is a combination of a stressed vowel and/or following consonant that carries the quantity** (see Table 1). **The duration of the second syllable compensates for the variation of the first syllable,** being long in Q1, short in Q2 and extra-short in Q3. **The quantity can be described as the ratio of syllable rhyme duration**, e.g. [1], [6], [7], [8], [9], [10], [12], or by comparing the V1 duration with the weighted sum of segment durations within a foot, e.g. [14].

Table 1. Possible combinations of sound segments that demonstrate the quantity opposition.

Q1	Q2	Q3
[vilu·] 'chilly'	[vi:lu] 'slice, sg. gen.'	[vi::lu] 'slice, sg. part.'
[kalʲi·] 'kvass'	[kalʲ:li] 'hug, sg. nom.'	[kalʲ:li] 'precious, sg. gen.'
[sate·] 'fall-out'	[sa:tte] 'get, pl. 2nd pers.'	[sa:t:te] 'broadcast, sg. gen.'

The pitch is relatively flat in the first syllable and falls at the syllable boundary in Q1 and Q2, whereas in Q3 pitch falls at the beginning of the first syllable [1], [8], [9], [10]. Perception studies [11] show that conflicting temporal and pitch cues can confound the discrimination of Q2 and Q3, whereas temporal cues are sufficient for successful discrimination if the pitch cue is not present. These results suggest that instead of a fixed set of features that describe the quantity degrees, there is a more complex interaction between different features that are weighed by the listener.
In Estonian there are **nine vowels /i, y, u, e, ø, ɤ, o, æ, ɑ/** that can occur in the first syllable, but only four of them /i, u, e, ɑ/ can occur also in non-initial syllables, e.g. [2], [15]. Vowel length has a relatively small effect on vowel quality. **In the stressed syllable, vowels in Q3 feet are the most peripheral (while longest in duration) while vowels in Q1 feet are the most centralized.** This variation does not exceed 1 Bark difference and therefore is not perceivable [5]. **In an unstressed syllable quantity degrees affect the vowel quality in the opposite direction** and the variation crosses the perceptual boundaries [5].

Materials and methods

The data were extracted from the University of Tartu phonetic corpus of Estonian spontaneous speech. 11 hours and 44 minutes of speech from 14 speakers (6 female, 8 male; age ranging from 21 to 50 years with an average of 33.8 years) was used.
The data were analyzed with Praat [4]. Words with two open syllables in Q1, Q2 and Q3 were found and segment durations as well as F1, F2, F3, and F4 values at the mid-point of V1 and V2 were extracted with a Praat script. Formant values found by the script were manually checked.
The vowels /y, ø, ɤ/ and the unstressed vowel /u/ were left out of the analysis because there were less than five observations of each vowel in the first syllable of Q2 and Q3 words. In total 726 words were analyzed: 392 words in Q1, 200 words in Q2, and 134 words in Q3. The number of tokens for each vowel is presented in Table 2.

Table 2. Number of observations of vowels in the first and the second syllable.

		V1						V2			
Sex	**Foot**	**i**	**u**	**e**	**o**	**æ**	**ɑ**	**i**	**u**	**e**	**ɑ**
	Q1	32	16	33	17	27	29	10	45	16	83
F	Q2	11	5	32	9	8	9	14	3	44	13
	Q3	7	11	14	9	5	12	17	1	12	28
	Q1	56	23	43	24	44	48	35	55	27	121
M	Q2	27	10	29	25	14	21	25	2	82	17
	Q3	11	9	14	13	6	23	24	0	12	40

Results and Discussion

Figure 1: The segment durations were compared between the quantity degrees.
- Initial consonant (C1) is about 20 ms shorter in Q1 than in Q2 and Q3.
- Stressed vowel (V1) is about twice as long in Q2 than it is in Q1, but only about 20% longer in Q3 than in Q2.
- Intervocalic consonant (C2) is about 10 ms shorter in Q1 and Q2 than in Q3.
- Unstressed vowel (V2) is about 5 ms longer in Q1 than in Q2 and about 15 ms longer in Q2 than in Q3.

Figure 2: The ratio of syllable rhymes. **The S1/S2 ratio is 0.7 in Q1, 1.7 in Q2, and 2.5 in Q3** (ANOVA $F(2) = 455.29$, $p < 0.001$). Despite the relatively high deviations these results are similar to those found in earlier studies, e.g. [1], [9].

Figure 3: the vowels are plotted in the space of F1 and F2´. The standard deviation is plotted with an ellipse as follows: vowels from Q1 feet are plotted in dot-dashed black lines, vowels from Q2 feet in slashed blue lines, and vowels from Q3 feet in solid red lines. F2´ was calculated using the formula from [3]. The formant values were converted to Bark using the formula from [13].

- **Stressed vowels are closer to the center in Q1 and more peripheral in Q2 and Q3.**
- There is not much difference in V1 quality between Q2 and Q3.
- **The difference between Q1 vs. Q2 and Q3 exceeds 1 Bark level.**
- **Unstressed vowels show more variation in general, but this variation is less related with the quantity**.
- **The place of articulation of an unstressed /e/ is that of the low front vowel /æ/ in feet of all quantity degrees.**
- Differences of the mean values of unstressed /i/ and /ɑ/ formants do not exceed 1 Bark between quantity degrees.

In order to compare vowel quality in relation to the quantity of the word, formant values were normalized by calculating the ratio of single vowel formant values and the mean values of that vowel. As vowel reduction is directed toward the center of the vowel space, ratios were calculated for the following relationships: $F1_i/F1_{mean}$ for low vowels, $F1_{mean}/F1_i$ for the high vowels, $F2_i/F2_{mean}$ for front vowels, $F2_{mean}/F2_i$ ratio for back vowels. Therefore, the ratio is more than 1 for more peripheral formant values and less than 1 for more centralized formant values.

- **Formant ratios of V1 both for F1 and F2 are 0.9 in Q1 foot and 1.0 in Q2 and Q3 feet**. The difference of Q1 vs. Q2 and Q3 is significant for F1 ratio at $F(2) = 24.440$, $p < 0.001$ and for F2 ratio at $F(2) = 122.24$, $p < 0.001$.
- **The mean F1 ratio of V2 is 1.0 in all cases** (1.020 in Q1, 1.008 in Q2, and0.983 in Q3), but possibly due to the higher F1 value of /e/ in Q3 feet of female speakers, an ANOVA finds a significant difference between quantity degrees ($F(2) = 3.326$, $p < 0.01$).
- **The mean F2 ratio of V2 is also 1.0 in all cases** and there is no variation between the quantity degrees ($F(2) = 1.453$, $p = 0.235$).

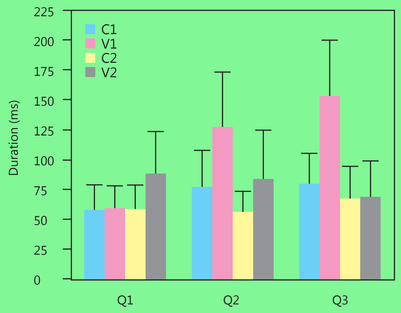

Figure 1: Mean segment duration and standard deviation.

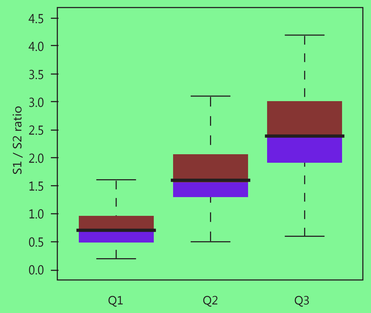

Figure 2: The ratio of syllable rhymes.

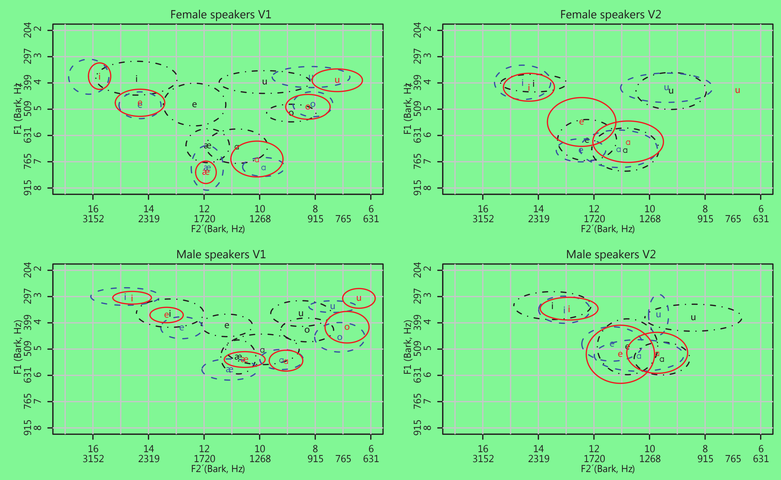

Figure 3: the vowels are plotted in the space of F1 and F2´. The standard deviation is plotted with an ellipse as follows: vowels from Q1 feet are plotted in dot-dashed black lines, vowels from Q2 feet in slashed blue lines, and vowels from Q3 feet in solid red lines.

Table 3. Multinomial logistic regression analysis of the quantity of the foot (Q3 as the reference level). **In the comparison of Q1 vs. Q3 all segment durations are significant**, but the most significant results are the effects of V1 and V2 duration. **The formant ratios of V1 are significant**. Surprisingly, the F1 formant ratio of V2 has a significant impact, even thought the differences of the mean values are minimal. The impact of V2 F2 ratio is not significant. **In the comparison of Q2 vs. Q3, the duration of C1 is not significant and the effects of V1 and V2 are much weaker**. Also, the F1 ratio of V1 is significant, even though the mean difference of the ratio between Q2 and Q3 is relatively small. The F2 ratio of V1 and the formant ratios of V2 are not significant.

	b	S.E.	z-value	Pr(>|z|)	exp(b)
Q1 vs. Q3					
Intercept	20.214	3.786	5.339	<0.001	
C1 duration	-0.027	0.009	-3.053	<0.005	0.973
V1 duration	-0.156	0.015	-10.161	<0.001	0.856
C2 duration	0.042	0.014	2.986	<0.005	1.043
V2 duration	0.076	0.009	8.627	<0.001	1.079
V1 F1 ratio	-7.306	2.168	-3.370	<0.001	0.001
V1 F2 ratio	-7.370	2.709	-2.720	<0.01	0.001
V2 F1 ratio	4.628	1.760	2.629	<0.01	102.324
V2 F2 ratio	-1.427	2.310	-0.618	0.268	0.240
Q2 vs. Q3					
Intercept	5.388	2.310	2.333	<0.01	
C1 duration	-0.004	0.005	-0.974	0.165	0.996
V1 duration	-0.023	0.004	-5.699	<0.001	0.977
C2 duration	-0.030	0.007	-4.357	<0.001	0.971
V2 duration	0.035	0.005	6.447	<0.001	1.035
V1 F1 ratio	-2.474	1.227	-2.017	<0.05	0.084
V1 F2 ratio	-0.351	1.531	-0.229	0.409	0.704
V2 F1 ratio	1.329	1.054	1.261	0.104	3.776
V2 F2 ratio	-0.666	1.330	-0.501	0.308	0.514

Table 4. The probability of the quantity predicted by the model using the mean values. **The model seems to handle the opposition of Q1 vs. Q2 and Q3 very well, but the opposition of Q2 and Q3 is not so clear.** A lot of variability in segment duration could be reduced by taking the phrasal position and accentuation conditions into account. The model could be improved also by considering a characteristic of the pitch contour as a variable.

	p_{Q1}	p_{Q2}	p_{Q3}
Q1 mean values	0.992	0.008	0.000
Q2 mean values	0.002	0.760	0.238
Q3 mean values	0.000	0.401	0.599

Conclusions

- The duration of vowels is more important for Estonian quantity opposition than the duration of syllable initial consonants. Rather than the V1 duration by itself, it is **the ratio of the segment durations within the foot that describes the quantity degrees contrastively**.
- The variation in vowel quality is related to the quantity. **Vowels in stressed syllables of Q1 feet are closer to the center and in stressed syllables of Q2 and Q3 feet they are more peripheral.** The difference in V1 quality between Q1 vs. Q2 and Q3 should be perceivable as it exceeds 1 Bark difference.
- Vowels in unstressed syllables vary significantly, but the most of the variation is not connected with the quantity of the foot. **While the space of V2 in general is more centralized, the vowel /e/ has moved to the low front corner of the space, and is realized as /æ/**.

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