POSITION-DEPENDENT VOWEL REDUCTION IN RUSSIAN

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ABSTRACT

The present paper deals with the problem of quality and quantity change (reduction) of unstressed vowels in Russian depending on their position relative to the stressed syllable and to the word boundaries. Quality change is measured by calculating the probability of vowel omission or replacement by another vowel phoneme. The study is based on a large corpus of read speech (over 30 hours). The results show that (1) there are two clear degrees of vowel reduction; (2) pre-stressed and post-stressed parts of the word are not symmetrical in terms of vowel reduction; (3) in pre-stressed syllables vowel quality change is correlated with quantity change.

Keywords: Russian vowels, vowel reduction, positional variants of vowels

1. INTRODUCTION

Lexical stress in Russian is variable and its main correlate is quantity [5]. Reduction of unstressed vowels—a universal phenomenon [6] especially noticeable in Russian—depends on two positional factors: position relative to word boundary (absolute-initial or absolute-final vs. non-absolute-initial or non-absolute-final) and position relative to the stressed syllable (pre-stressed vs. post-stressed, 1-st pre-stressed vs. 2-nd and further pre-stressed). Thus, there are two degrees of reduction: (1) 1st pre-stressed or absolute-initial; (2) 2-nd and further pre-stressed, but not absolute-initial, and post-stressed [1][2]. It is also common to distinguish an additional, stronger degree of reduction for the vowel /ɑ/ [5]. However, there is no agreement among authors on the degree of reduction for word-final vowels in open syllables: the 2-nd degree according to R. I. Avanesov [1], and the 1-st degree according to L. V. Bondarko et al. [5]. M. I. Matusevich [8] claims that such vowels may have the 1-st degree of reduction in elaborate speech but their duration may also reduce to zero in fast colloquial speech.

For long words—containing more than one post-stressed syllable or more than two pre-stressed syllables—it is still to be discovered whether the vowels of the same degree of reduction have the same quality, since there is no research published on the subject.

The present study investigates the influence of position of vowels within the word on the probability of vowel omission or replacement based on a large speech corpus. Both omissions and replacements are the result of major change in quality. This allows us to suppose that the nature of the relation between vowel position within the word and the number of omissions or replacements for this type of position is similar to that of vowel reduction. Thus, the total number of omissions or replacements for vowels in the 1-st pre-stressed syllable might be lower than for vowels in the 2-nd pre-stressed syllable; absolute-initial position might also lead to a decrease of this value.

It is widely accepted [4] that vowel quality change in Russian is a result of decreased vowel duration: the shorter the vowel, the less time the articulatory system has to perform the articulatory program—thus, the more reduced the vowel. We assume that the number of replacements or omissions is dependent on vowel duration as well.

Therefore, the present study is aimed at answering three major questions.

1. How many degrees of vowel reduction are there in Russian?
2. Are pre-stressed and post-stressed parts of the word symmetrical in terms of vowel reduction?
3. How do positional factors influence the correlation between quality change and quantity change of vowels?

2. MATERIAL

The corpus used in this study is CORPRES (Corpus of Professionally Read Speech) developed at the Department of Phonetics, St. Petersburg State University [9]. It contains recordings of various texts read by 8 professional speakers; the total duration is over 30 hours; it contains over 1.1 mln sounds. Along with the word level and the level of prosodic annotation, the corpus contains two phonetic tiers:

- the tier of manual transcription made by experts based on auditory analysis and spectral data;

- the tier of automatic transcription based on grapheme-to-phoneme rules including those describing the processes observed in connected speech (such as assimilation at word boundaries, lack of stress on clitics etc.).

The system used in CORPRES for segmental annotation contains 6 vowels: /i/, /e/, /ɑ/, /o/, /u/, /ɨ/. The system is described in detail in [9].

3. METHOD

A comparison of acoustic transcription with the rule-based transcription shows that even in professionally-read speech it is not uncommon to observe vowel and consonant omissions or replacements: e.g. /ɑpstɑˈjɑtʲlʲstvɨ/ (circumstances) instead of /ɑpstɑˈjɑtʲilʲstvɑ/—an omission of /i/ between /tʲ/ and /lʲ/ and a replacement of absolute-final /ɑ/ by /ɨ/.

In order to calculate the number of vowel omissions or replacements in different positions relative to the stressed syllables, the corpus data were analyzed automatically. (Based on the ideas of [3], we assume that all the syllables in Russian are open excluding those ending in /j/.) For each accentual phrase in the corpus the two types of transcription were aligned using a modified version of Levenstein algorithm [7]. Then for each vowel the following parameters were calculated:

- position of the vowel within the word:
    - for pre-stressed vowels: 1 for the 1-st syllable, 2 for th 2-nd syllable etc.
    - for post-stressed vowels: 1 for the 1-st post-stressed syllable, 2 for th 2-nd post-stressed syllable etc.;
- for unstressed vowels: the length of the pre-stressed or post-stressed part of the word where the vowel occurs;
- 1 or 0 depending on whether the transcriptions for the vowel differ or not;
- duration of the vowel normalized by the mean and standard deviation for the particular speaker and type of vowel.

Then the percentage of omissions and replacements was calculated for each position. Similar calculations were performed for the duration values.

The values for unstressed vowels were grouped according to the length of the pre-stressed or post-stressed part of the word where it occurs. (Compound words containing more than one stressed syllable were excluded from the analysis.) Thus, for instance, words with stress on the 3-rd syllable were in the same pre-stressed group regardless of the number of post-stressed syllables in the word, and vice versa.

Then for each group N vowel positions were analyzed, where N is the length of the pre-stressed or post-stressed part of the word. Since vowels occurring at word boundaries are less reduced in Russian, vowels in initial and final syllables were subdivided into two groups: absolute initial (final) vowels and vowels preceded (followed) by one or more consonants, respectively.

Due to the fact that the absolute duration of vowels differs for different types of vowels—e.g., /ɑ/ is longer than /i/—a reliable comparison of these vowels requires a calculation of duration values normalized by the mean and standard deviation. The formula used here is as follows:

$$\tilde{d}(i) = \frac{d(i) - \mu_p}{\sigma_p}$$

where $\tilde{d}(i)$ is the normalized duration of phone i, $d(i)$ is its absolute duration, μ_p and σ_p are the mean and standard deviation of the duration of the corresponding phoneme p for the given speaker.

Positive normalized duration values show that the duration of vowel is higher than the mean for this phoneme. Thus, in CORPRES the mean duration of /ɑ/ ranges between 75 and 90 ms for different speakers, while the mean duration of /i/—between 55 and 70 ms. Similarly, negative normalized duration values show that the duration of vowel is lower than the mean for this phoneme. The value itself is measured in standard deviations; for the vowel /ɑ/ it ranges from 15 to 35 ms depending on the speaker, for the vowel /i/—from 20 to 23 ms.

For the calculation of these vowel duration values only those part of the vowel was taken where formant structure could be observed. Voiceless parts of vowels and parts with tone but no formant structure were therefore excluded from the analysis.

4. RESULTS

4.1. Stressed vowels

As a starting point, the values for the stressed vowels were calculated. Not surprisingly, the amount of stressed vowel omissions or replacements is below 3 %, the majority of the cases being the result of stress shift due to non-standard or occasional pronunciation variants not included into the automatic transcriber's vocabulary.

The normalized values of stressed vowel duration range between 0.3 for short words and up to 0.7 for long words (3 and more syllables). However, the relation between word duration and vowel duration is beyond the present study; the values are given

here only for comparison with the values for the un-
stressed vowels.

4.2. Pre-stressed vowels

The total number of words analyzed is as follows:
65,574 words with 1 pre-stressed syllable, 29,593
words with 2 pre-stressed syllables, 6454 words
with 3 pre-stressed syllables, 787 words with 4 pre-
stressed syllables, and 114 words with 5 pre-stressed
syllables.

Figure 1 shows the percentage of vowel omissions
or replacements plotted against the position of vowel
in the word (where N denotes the N-th syllable) for 5
types of pre-stressed groups based on their length (in
syllables). For initial syllables two values are given:
for vowels preceded by a consonant (dashed lines;
for 1-syllable pre-stressed groups—unfilled circle)
and for absolute-initial vowels (solid lines; for 1-
syllable pre-stressed groups—filled circle). Figure 2
shows the corresponding duration values.

Figure 1: Percentage of vowel omissions and re-
placements in pre-stressed syllables.
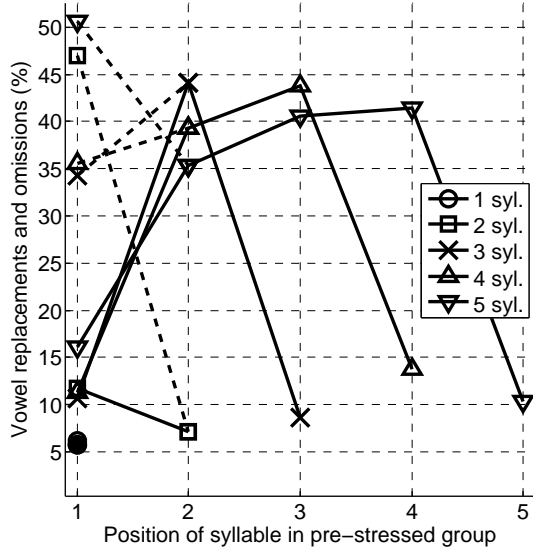
If rotated and flipped, these two pictures will look
rather similar. This provides evidence for a cor-
relation between the amount of vowel omissions
or replacements and vowel duration in pre-stressed
groups: the higher the vowel duration, the lower the
amount of vowel omissions or replacements.

Our data confirms the idea that there are at
least two degrees of vowel reduction in pre-stressed
groups. The first (lower) degree is observed in
two positions: the 1-st pre-stressed syllable and
absolute-initial position; within this group there is
a tendency for higher reduction of absolute-initial
vowels. The amount of omissions or replacements
for this degree of reduction is below 20 %, the

Figure 2: Normalized vowel duration in pre-
stressed syllables.
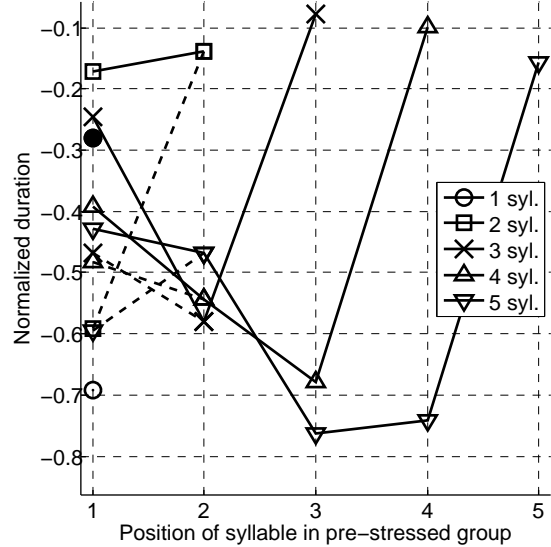
duration values—above –0.3. The latter is dis-
putable since absolute-initial vowels of long words
are shorter. However this might be explained by the
fact that in these cases words often start with clitics.

The second (higher) degree is observed for all
other syllables. The amount of omission and re-
placements for the second degree of reduction is
above 30 %, the duration values—below –0.4. It
is worth noting that for these syllables vowel dura-
tion slowly decreases towards the beginning of the
word, while the amount of vowel omissions or re-
placements increases.

Initial vowels preceded by a consonant have the 2-
nd degree of reduction as opposed to absolute-initial
vowels since their duration is considerably lower.

4.3. Post-stressed vowels

The total number of words analyzed is as follows:
698,965 words with 1 post-stressed syllable, 25,694
words with 2 post-stressed syllables, 3843 words
with 3 post-stressed syllables, and 461 word with
4 post-stressed syllables.

Figure 3 shows the percentage of vowel omis-
sions or replacements plotted against the position of
vowel in the post-stressed group (where N denotes
the N-th post-stressed syllable) for 4 types of post-
stressed groups based on their length (in syllables).
For final syllables two values are given: for vow-
els in closed syllables (dashed lines; for 1-syllable
post-stressed groups—unfilled circle) and for vow-
els in open syllables (solid lines; for 1-syllable post-
stressed groups—filled circle). Figure 4 shows the
corresponding duration values.

For post-stressed syllables both the amount of

Figure 3: Percentage of vowel omissions and replacements in post-stressed syllables.
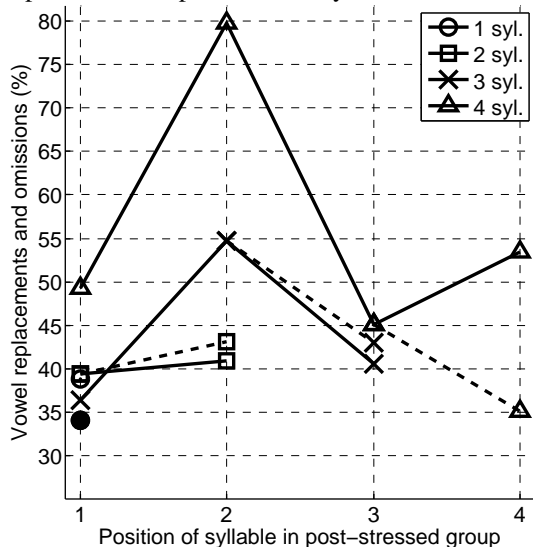
omissions or replacements and duration lie within the range typical for the 2-nd degree of reduction for pre-stressed syllables. An exception is the duration of final open vowels, where the values are between –0.3 and –0.4. This does not allow us to classify them as having either the 1-st or the 2-nd degree of reduction.

Vowel duration grows gradually towards the end of the word. In spite of decrease in articulation speed the precision does not improve in the same way. In long post-stressed groups the percentage of vowel omissions or replacements is higher for the 2-nd post-stressed syllable than for the 1-st post-stressed. Thus, for post-stressed vowels no conformity is observed between vowel duration and the amount of vowel omissions or replacements.

5. CONCLUSIONS

According to our data, for *pre-stressed vowels* there are two clear degrees of vowel reduction:

- 1-st degree: for vowels in the 1-st pre-stressed syllable and absolute-initial position;
- 2-nd degree (stronger): for vowels in other pre-stressed syllables.

Most *post-stressed vowels* are reduced in the same way as pre-stressed vowels of the 2-nd degree. However, our data seem to provide evidence for an additional, stronger degree of post-stressed vowel reduction, which is observed for vowels in long words in the 2-nd post-stressed syllable. Thus:

- 3-rd degree (equal to the 2-nd degree): for vowels in most post-stressed syllables;
- 4-th degree (stronger): for vowels in 2-nd post-stressed syllables of long words.

The existence of the additional 4-th degree of vowel reduction supports the ideas suggested earlier by L. V. Bondarko et al. [5] for post-stressed /ɑ/.

Our results enable us to treat the vowels in final open syllables as having the 3-rd degree of reduction. Therefore, these results seem to support the ideas suggested by R. I. Avanesov [1], confronting those of L. V. Bondarko et al. [5].

Figure 4: Normalized vowel duration in post-stressed syllables.
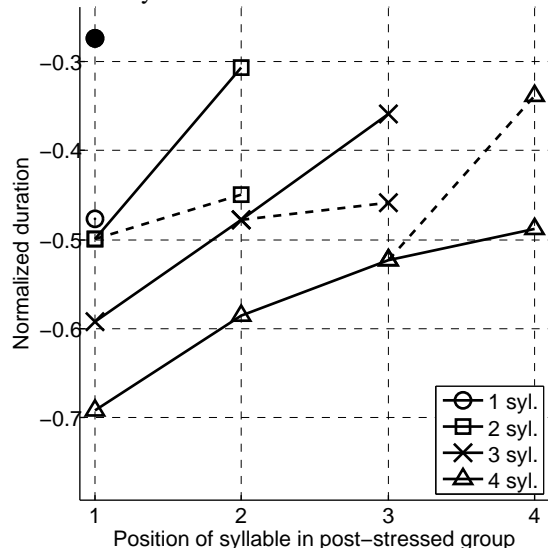
Pre-stressed and post-stressed parts of the word are not symmetrical with respect to the stressed syllable. The main reason for this is the fact that the first pre-stressed syllable is very different from other pre-stressed syllables in terms of vowel quality and quantity change. But if we exclude this syllable from the analysis, we will see a symmetry in vowel duration: it gradually increases from the stressed syllable to the word boundaries. However this does not help with the amount of vowel omissions or replacements since the 1-st post-stressed syllable has low values, which shows smaller quality change.

In general, the hypothesis that quality change and quantity change of vowels are correlated is not supported by our data. The correlation is observed only for the pre-stressed part of the word: the longer the vowel the lower the amount of omissions or replacements. The absence of similar correlation for post-stressed vowels may be explained by poor lexical content of word endings carrying purely grammatical meaning and therefore often not pronounced properly.

6. ACKNOWLEDGEMENTS

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