ARTICULATORY PATTERNS OF RUSSIAN DIPHTHONGIZED VOWELS: PILOT MRI INVESTIGATION

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ABSTRACT

Paper presents main results of a targeted MRI-investigation of articulatory patterns of the Russian diphthongised (gliding) vowel phonemes, vowel /ɨ/ first and foremost. The investigation's relevance is assured by serious general discordance of opinions discussing articulatory patterns of diphthongised Russian vowel /ɨ/. Our research revealed critical differences in the vowel's articulatory dynamic patterns caused by specific role of core articulators in formation of heterogeneity of a speech sound. The first articulatory pattern supports gliding articulation of the vowel /ɨ/ through gradual displacement of tongue root and tongue blade/tongue dorsum towards anterior area of the buccal cavity, the other articulatory pattern is spatially and temporary realized through complex interaction of both tongue transformations and a special mandible articulatory gesture. Such exceptional jaw activity being unknown in common descriptions of the Russian articulatory base would make Russian vowel /ɨ/ a singular item within phonetic system of the Russian language.

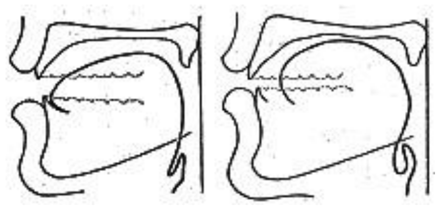
Keywords: Russian phonetics, vowels, diphthong, MRI.

1. INTRODUCTION

It is well known that the Russian phonological system has no diphthongs as linguistic phonetic units, however most researchers acknowledge gliding articulatory gestures during pronunciation of some Russian vowels, first and foremost close central unrounded vowel /ɨ/ and rounded back vowel /o/ [1]. Whereas, articulatory pattern of the Russian vowel /o/ has been described in detail in multiple experimental and theoretical research as that of a diphthongised phoneme with the key role of the tongue and main articulator, the articulation pattern of the vowel /ɨ/ is still rather ambiguous. Various descriptions of the Russian vowel's /ɨ/ production constantly instigate phoneticians to discordance of opinions upon its main articulatory pattern(s).

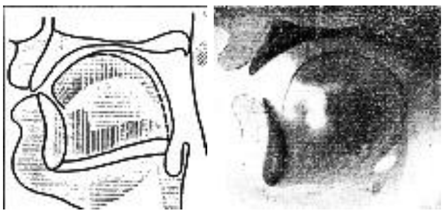
In the common literature there are at least two generally accepted opinions on articulatory dynamic mechanism of the vowel's /ɨ/ production. Author of the most cited source on phonetic standards of the Russian language R. Avanesov describes articulatory postures of the vowel /ɨ/ through correspondence with articulation of the Russian close front phoneme /i/: "in both cases tongue dorsum is raised high towards palate, but for /i/ an overall tongue movement is realized with its medial part, whereas for /ɨ/ it's the tongue back that is more active. Tongue tip during pronunciation of /i/ is close to lower teeth, whereas for /ɨ/ the whole tongue body is retracted backwards and the tongue tip is slightly raised. Switching from pronunciation of /i/ to pronunciation of /ɨ/ one could easily feel displacement of the focus of articulation backward into interior part of her/his oral cavity" [2]. Similar description of the gliding articulation of /ɨ/ is presented in the textbook of the Russian Phonetics written by L. Bondarko. Alongside with the cited descriptions there is another most authoritative statement on the /ɨ/'s articulations exposed in the manual of Russian Phonetics written by M. Matusevič upon university lectures of L. Ščerba [3]. Matusevič describes two context dependent modes of articulation of the vowel /ɨ/: that of non-diphthongized close middle vowel as in /sɨn/ (son), /bɨk/ (bull), /mɨ/ (we), and that of a gliding (diphthongized) one as in /bɨt'/ (to be), /mɨt'/ (to wash) – see figure 1.

Figure 1: Articulatory contours of the two variants of the Russian vowel /ɨ/'s articulation.



Multiplicity of the descriptions of vowel's /ɨ/ articulation constantly provokes further experimental instrumental investigation of articulatory dynamics of the Russian phoneme in question as instrumental research methods considered most informative and independent. One of the recently elaborated instrumental methods of articulatory dynamics of the Russian articulatory patterns' investigation uses X-Ray technique. The method has been successfully realized in Kiev by L. Skalozub [4] and assured wide-ranging research work of the Hungarian scholar K. Bolla [5]. Bolla published a compendium with ample description of every Russian phoneme's articulatory contour accompanied with acoustic analysis of the corresponding sound. Contrary to K. Bolla's description acknowledging diphthong-like articulation of the Russian /ɨ/, experimental data exposed in the book of L. Skalozub was much more uniform and fitted in well with the Matusevič / Ščerba's description of first variant of articulation of vowel /ɨ/ as a stable (non-diphthongised) central close vowel (both descriptions are presented on figure 2).

Figure 2: Articulatory contours of the vowel /ɨ/: left image upon K. Bolla's data (diphthongised vowel); right image upon X-ray data of L. Skalozub (non-diphthongised vowel).

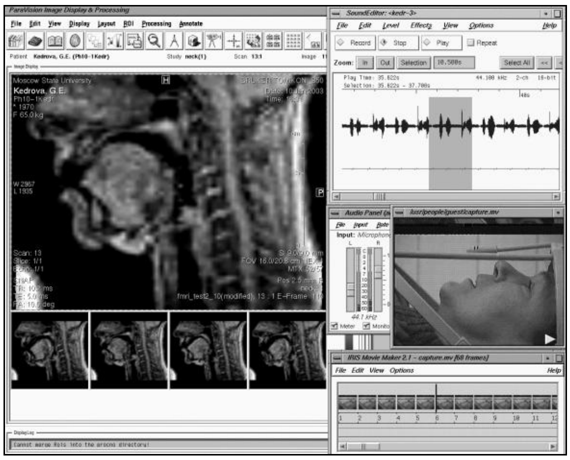


Thus, one could state that the nature of acticulatory heterogeneity of the Russian unrounded close central vowel /ɨ/ still is rather vague and yet needs more precise and comprehensive description based upon approved and more objective evidence. Nowadays MRI is acknowledged to be valuable and powerful tool both for studying static articulatory postures and dynamic articulatory processes in human speech activity [6]. Most often noted advantages of the MRI comprise: perfect signal-to-noise ratio of the images, on-line fixation of the articulatory processes, reach data for computerized 2D and 3D modeling of articulations, high contrast MRI imaging of the soft tissue's transformations, etc. [7]. All this advantages look highly promising for investigation of vowels' speech articulations, therefore we've also used in our investigation of articulations of the Russian /ɨ/ advanced magnetic resonance imaging (MRI) techniques. Brief description of MRI capacities and experimental methodology used in the current research, as well as main results of the experimental study follows.

2. MATERIALS AND METHODS

The MRI facilities for our experimental research were provided by the Research Center for MRI and MRS of Moscow State Lomonosov University in cooperation with MRI laboratory of NRC Kurchatov Institute. MRI experiments were realized on a 0.5 T MR system (Tomikon S50 "Bruker"). MR scanning was executed on sagittal plane with the slice thickness of 9 mm and to a field of view 200*120 mm. The pulse sequence 'gradient echo' was used with the following parameters: TR=12 ms, TE=5.5 ms, FA=10 degrees. Under these conditions it has become possible to obtain MR images with 2.7 frames in a second and with 3 mm in-plane resolution. MR signal was received by quadrature neck coil. The speaking subject was required to repeat experimental stimuli (sustained pronunciation of Russian cardinal vowels) at his/her own pace as many times as possible during acquisitions of MR images. The investigation of articulatory patterns of the Russian vowel /ɨ/ was based upon phonation of 3 speaking subjects: two of them were monolingual native Russian male speakers (speaker 1 and speaker 2), both born in Moscow with the parents also born and living in Moscow region all their lives. The third experimental subject (speaker 3) was a native monolingual female speaker of Russian born in Tashkent (Uzbekistan), though living in Moscow for more than 40 years. While it has been difficult to extract relevant acoustic characteristics of the speech phonation recorded in noisy MRI environment, we've also done post-hoc recordings of the same experimental stimuli in the professional recording studio as well. Types of the experimental data are presented on figure 3.

Figure 3: Experimental data of MRI acquisitions' interface, post-MRI session control audio and video recordings incorporated.



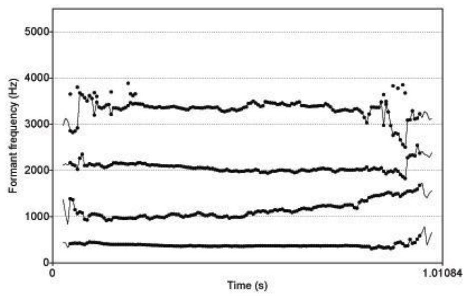
Additional MRI investigation of the same experimental stimuli (Russian vowels) produced by speaker 2 was also realized in the MRI laboratory of NRC Kurchatov Institute on 3 T MR scanner (Magnetom Verio 3T "Siemens") with following parameters: MR scanning was executed on sagittal plane with the slice thickness of 10 mm and to a field of view 130*130 mm. The pulse sequence ‘gradient echo’ was used with the following parameters: TR=3.5 ms, TE=1.48 ms, FA=10 degrees. Under these conditions it has become possible to obtain 4-5 MR images per second. The on-line dynamic MRI technique, previously elaborated and adopted in [8] relies on gated scanning of numerous repetitions of the same speech sequence to reconstruct the real articulatory movement progressing in time (a.k.a. stroboscopy-like method). On the average, each vowel phoneme was produced from 30 to 43 times in every experimental session, the aggregate total of relevant MR-images being up to 680 items for each speaker. The total amount of MR images exposing vowel’s /ɨ/ articulation was up to 98 items for speaker 1; up to 40 items for speaker 2; and up to 67 items for speaker 3 It is worthy of special mention that there have been several sessions of MR image acquisition, i.e. three separate experimental sessions with the time gap of one month and one year. This technology proved a considerable MR image matching within each speaker’s various performances of a particular phoneme irrespective of time gap between experimental sessions, same as in [9].

3. RESULTS

The total data set of MR images collected in all experimental MRI sessions has been identified and ascribed to each vocal phoneme’s realization and if possible, to various phases of a vowel’s production (onset, steady phase and offset of phonation). Similar to [10] there has been also observed in our experimental data highest degree of image matching within speaker’s various performances of a particular phoneme throughout all experimental sessions. In order to make more evident comparative appraisal of the vowel /ɨ/’s articulations, we ascribed to each typical sagittal cut slice an appropriate contour of the vocal tract’s active and passive relevant organs’ configurations. The contours were manually traced upon corresponding MR images using plane Photoshop drawing capacities. On the next stage we’ve done a superposition of the traced contours for every vowel in pronunciation of every speaker, the overlapping being aligned upon several fixed anatomical landmarks (normally upon the individual geometry of the speaker’s maxilla as well as configuration of his/her vertebral column).

For more detailed information on eventual peculiarities of speakers’ individual pronunciation mode we considered useful to analyse an appropriate sonogram of speakers’ post-hoc studio recordings. The spectrum analysis of /ɨ/ phonation sample in pronunciation of speaker 1 is presented on figure 4. The sonogram was produced by standard spectral analysis procedures provided in Praat program kit. It’s worth mentioning that the formants’ trajectories presented on the sonogram coincide with commonly reported in the literature formant configurations typical to the Russian vowel /ɨ/.

Figure 4: Formant trajectories of the vowel /ɨ/ (speaker 1).



Representative and typical MR images of sagittal articulatory contours for vowel’s /ɨ/ productions in pronunciation of three experimental subjects are exposed on figure 5. Integrated juxtapositions of manually discerned profiled articulatory sample contours of the vowel in pronunciation of three experimental subjects are presented on figure 6.

Figure 5: Sample MR-images of two phases of articulation of the vowel /ɨ/ (upper row: speaker 1; middle row: speaker 2; lower row: speaker 3).

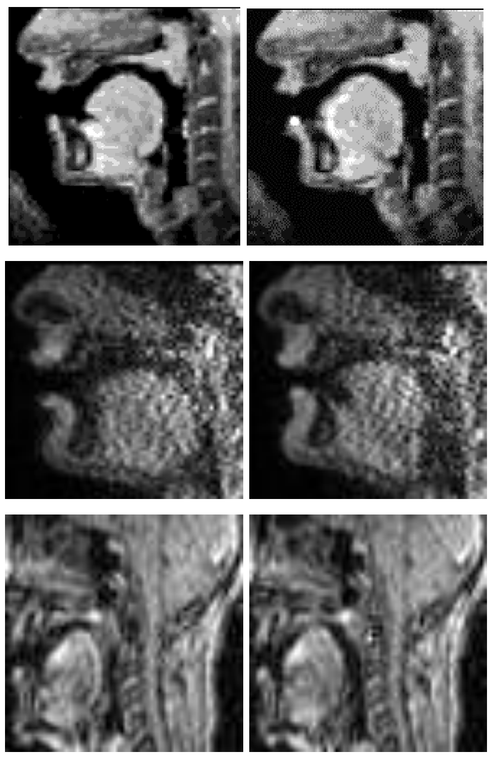
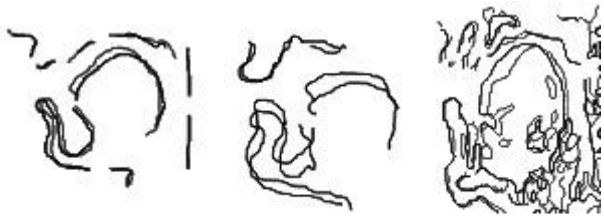


Figure 6: The integrated superposition of articulatory contours of articulation of the vowel /ɨ/ (from left to right): speaker 1, speaker 2, and speaker 3.



4. DISCUSSION

Theoretical and practical validity of the results presented in previous section is supported by comprehensive and authentic MRI data extraction procedures. Although MRI data collected in the current research generally supports previously published statements of non-stable, diphthongised articulatory patterns of Russian vowel's /ɨ/ production, we would like to draw attention to key differences between experimental subjects' speech production strategies regularly observed throughout overall experimental MR images' data set. Thus, the MRI data revealed two distinctly different dynamic patterns of the vowel's /ɨ/ articulatory heterogeneity. The first one was regularly reproduced in speech production of the speaker 3. Articulatory patterns of this subject fully conforms to traditional descriptions of the vowel's /ɨ/ articulation as it has been previously described in manuals of Russian Phonetics. This articulatory pattern is implemented by drifting displacement of the tongue dorsum and tongue blade from central position towards anterior part of the buccal cavity, gradually enlarging thus resonant airspace in the pharyngeal area. Other two experimental subjects, however, manifested very particular articulatory manner, different from the first type though similar to both of them. One could state that articulatory heterogeneity of the phoneme /ɨ/ in pronunciation of speakers 1 and 2 is spatially and temporary determined by complex interaction of several articulators. The interaction involves both tongue transformations (first and foremost of tongue body and tongue blade's displacement) and apparent peculiar activity of the speakers' mandible. Special palatal constriction characteristic of the phoneme's /ɨ/ quality (reflected in the complicated configurations of formats in acoustic signal) is therefore adjusted through specific lower jaw's displacement. Generally, any kind of jaws' activity has been rarely (if ever) taken into consideration in conventional descriptions of significant items composing inventory of Russian articulations, nor was it ever mentioned among basic parameters of the Russian articulatory base. It's even more regrettable while some previously conducted research of the articulatory base of various languages already proved substantial dynamic syncretism of lower jaw and tongue body movements (jaw-tongue coupling) [11], [12]. We also esteem as highly important constant and stable correlation between phonemes' durations and certain extent of aticulatory jaw's activity postulated in the published papers. This statement correlates well with commonly accepted data on inherent phoneme's quantity of the Russian vocalic samples widely presented in modern phonetic literature. It was also stated in the research work [13] that the Russian phoneme /ɨ/ has rather exceptional temporal pattern: one of the characteristic temporal parameter of the vowel is its time span stability. We also suggest that the two general types of articulatory behaviours revealed in current study could presumably correlate with two main types of articulatory patterns of palatalised and non-palatalised consonants in Russian discussed in [10]. We propose to consider all this observations as relevant ones for possible linguistic interpretation of peculiar phonological status of the vowel /ɨ/ which is rather ambiguous in Russian. Some phonetic theories decline phonological status of the vowel and admit its inclusion into phonetic inventory only as an allophone of the Russian phoneme [i]. We suggest that this exceptional position of the phoneme /ɨ/ within the Russian phonetic system might be associated with peculiarities of its articulatory realizations.

5. CONCLUSIONS

It has become obvious that any kind of purposeful mandibular activity rather rarely occurs in Russian speech production, though it might play an important role in the complex machinery of speech articulations. It also worth mention that experimental data on this purpose is extremely few and unrepresentative. Mandibular articulatory gesture has been earlier supposed to constitute a special component of the Russian articulatory base in production of a very restricted set of consonantal phonemes only. We are planning therefore further MRI-based research of jaws' articulations in production of other vocalic and consonant phonemes as primary targets for more detailed and systematic description of the Russian base of articulation. We also state that methodological and technological approach presented in current MRI investigation of speech production processes has proven its validity and could be recommended for implementation.

6. REFERENCES

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