CONTRASTIVE STUDY OF THE MRI REPRESENTATION OF RUSSIAN VOWEL ARTICULATION (AGAINST FRENCH, GERMAN AND KOREAN ANALOGUES)

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Abstract: The MRI investigation of Russian vowels articulation inventory was realized upon original technology elaborated by the authors for real-time visualization of the speech articulation dynamics. One series of experiments dealt with articulation of the Russian sustained vowels. The data was collected in the course of several experimental sessions with the time gap of one months and one year. In all sessions the highest degree of MRI matching within various productions of a particular vowel by the same speaker was observed. Distinct inter-speaker differences were also analyzed and an appropriate interpretation suggested. The research focused on detailed visualization of lips and tongue evolutions, diversification of resonances in oral cavities, configuration of soft palate and larynx throughout the speech production process. Thereupon the Russian vowels articulation inventory was defined and confronted with corresponding data of the French, German and Korean. The factual identity of the Russian vowels articulation thus could be explicitly stated and appropriate instructions for the language teaching and learning elaborated.

1. Introduction

Speech articulation is a multidisciplinary area *per se*. Speech production is directed by social and individual psychological patterns and regulations, basic physiological and neuropsychological mechanisms of mental processes and motor activity, anatomical constraints of human articulatory apparatus. Therefore interdisciplinary investigation of basic language phenomena – speech production and particularly, speech articulation, – was strongly recommended by prominent Russian linguists from the very beginning of the experimental linguistics and phonetics in Russia (I. Baudouin de Courtenay, V. Bogoroditsky, L. Ščerba), and its results highly appreciated.

Russian tradition of exploration of complex medical instrumental facilities (X-ray cine- and photo filming) in linguistic research dates from mid-1970s. A comprehensive collection of Russian and Ukrainien visual data of selected speech articulation processes was hence accumulated by L. Skalozub and her disciples [1, 2]. Since the X-ray investigation is a very harmful and extremely dangerous to the human health empirical method, many questions of that research work remained unanswered, therefore numerous significant aspects of the Russian speech articulation are still unexplored until nowadays. However, a constant search for new less risky experimental instruments never stopped in Russian linguistics as well. In this context wide range of facilities provided by MRI was considered as very promising, though unlike to the latest Western trends in experimental phonetics, the MRI investigation of speech production in Russia is definitely at its outset. There are not so many authentic reproductions of Russian articulatory patterns traced upon on-line MR-imaging techniques, either for the vocal or consonant system of the Russian language. This situation is even more regrettable as there is a considerable amount of positive knowledge on articulation basis of other world languages (French, English, German, Japanese, Korean, Swedish, etc.) available in the literature.

Therefore our MRI investigation of main Russian vowel phonemes based upon admitted procedures and techniques [3] (though expanded with several new original methods of the authors [4]) would be an innovative one.

2. Materials and methods

Articulation patterns of main Russian vowel phonemes were investigated after having been traced upon articulation data collected from two reference subjects (male and female native speakers of Russian with standard pronunciation, free of any articulatory disease) using Magnetic Resonance Imaging (MRI). MRI experiments were realized in Educational-Research Center of

Magnetic Tomography and Spectroscopy of the Moscow State Lomonosov University on a 1.5 T MR system (Tomikon S50 «Bruker»). The receiver coil was a quadrature neck coil (Fig. 1).

Both speaking subjects were lying in supine position, any special mechanism of the head fixation not provided. They were required to produce a sustained phonation of Russian vowel phonemes: [a], [o], [u], [i], [e] several times during acquisitions of MR images. The experimenter instructed the subject to initiate the speech process by counting every second, a couple seconds before the MRI acquisition starts.

The mentioned above physical conditions of the MRI experiments (supine position, noisy environment, sustained pronunciation, etc.) raised a problem of the data validity according to the language investigation. An evaluation of effects of the supine position (a.k.a. “gravitational effect”) in MR investigation of speech articulation was the main purpose of recently conducted research work [5], [6]. In both papers was concluded that the body position (supine or facing downwards) produces a certain affect on the position and shape of the tongue body, mostly perceptible on MR-images of articulation process of the phoneme [a]. According to the authors, this impact was not perceptible to the ear or observable in a sonagramme, and therefore could be interpreted as a kind of compensation strategies of the speaker, who tends to maintain acoustic consistency of his/her speech through adjustment of common articulation patterns to various spacial situations of speech production.

The speech signal was simultaneously recorded through a microphone LifeVideo™, fixed on a receiver’s coil close to the speaker’s mouth (see Fig. 1). Parallel recording of the starting points of MRI sequences was also prearranged. Both recordings were presented as a two-channel oscillogram, which enables more precise timing of MR image to the particular phase of phonation in the future phoneme articulation identification. Apart from the MRI sessions, control audio and video recordings of the same speech data from the same reference subject were made in a professional record’s studio environment.

The total data set was collected in two separate experimental sessions with the time gap of one month and one year, but using the same reference subjects and with the same language stimuli for all acquisitions.

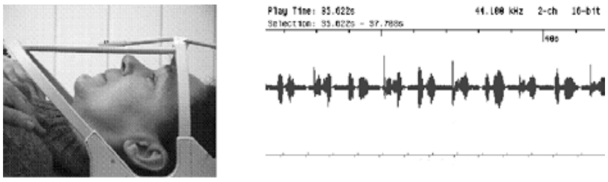

Figure 1. Position of a reference subject in MRI experiment. To the right: two-channel oscillogram displaying phonation (upper line) and starting points of MRI sequences (bottom line).

The MR-images were reconstructed and displayed in real time. Repetitions of vowel phonemes have been recorded for a male and a female speaker at respectively 2,0 and 2,7 images per second. A reference subject has been reproducing each vowel phoneme up to 33 times in every experimental session, the aggregate total of relevant MR-images being 768 items from the speaker.

All types of the data obtained in each experimental session are disposed on Figure 2.

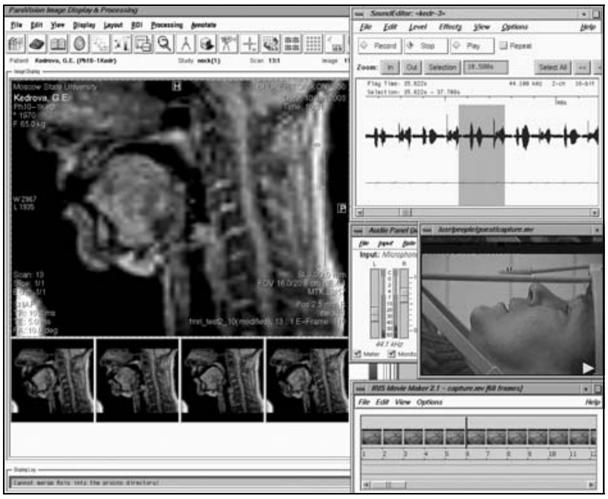

Figure 2. Experimental data of MRI acquisitions’ interface, post-MRI session control audio and video recordings incorporated.

2.1. MRI data

In our experiments on MRI research of articulatory models of Russian vowel phonemes, MR scanning was executed on sagittal slice with the slice thickness of 9 mm and to a field of view 200x120 mm. Well known pulse sequence "gradient echo" was used with the following parameters: TR=12 ms, TE=5.5 ms, FA=10 degrees. Under these conditions it was possible to obtain MR images with 2-2,7 frames in a second and with 3 mm in-plane resolution.

Numerous available through the literature MRI studies of sustained vowels in various languages provided us with articulatory contours of French and German vocal phonemes [i: e: a: o: u:], Korean vowels [i: a: u:] outlined through experimental sessions with similar conditions [7, 8, 9, 10, 11].

2.2. Russian vowel phonemes' articulation contours.

The whole data set of MR images collected in both experimental MRI acquisitions was identified and ascribed to each phase of a phoneme realization. In all experimental sessions we've observed the highest degree of image matching within each speaker's various performances of a particular vowel that was repeated several times in different vocal contexts. Thus, we consider our results as a proof of the linguistic concept of phoneme defined as a "psychomotor complex formed in the early childhood via association of contiguity" [12]. However, evidence from the first and the second MRI acquisition séances provided us with slightly different MRI data - see Fig. 3.

We refer this misconsiliences between two experimental sessions of the shape and position of tongue body in the male-speaker's pronunciation to previously mentioned "gravitational effect", more significant with the different (slightly upset) position of his head. This effect was definitely less obvious in the female-speaker's articulations while the head position was more homogeneous.

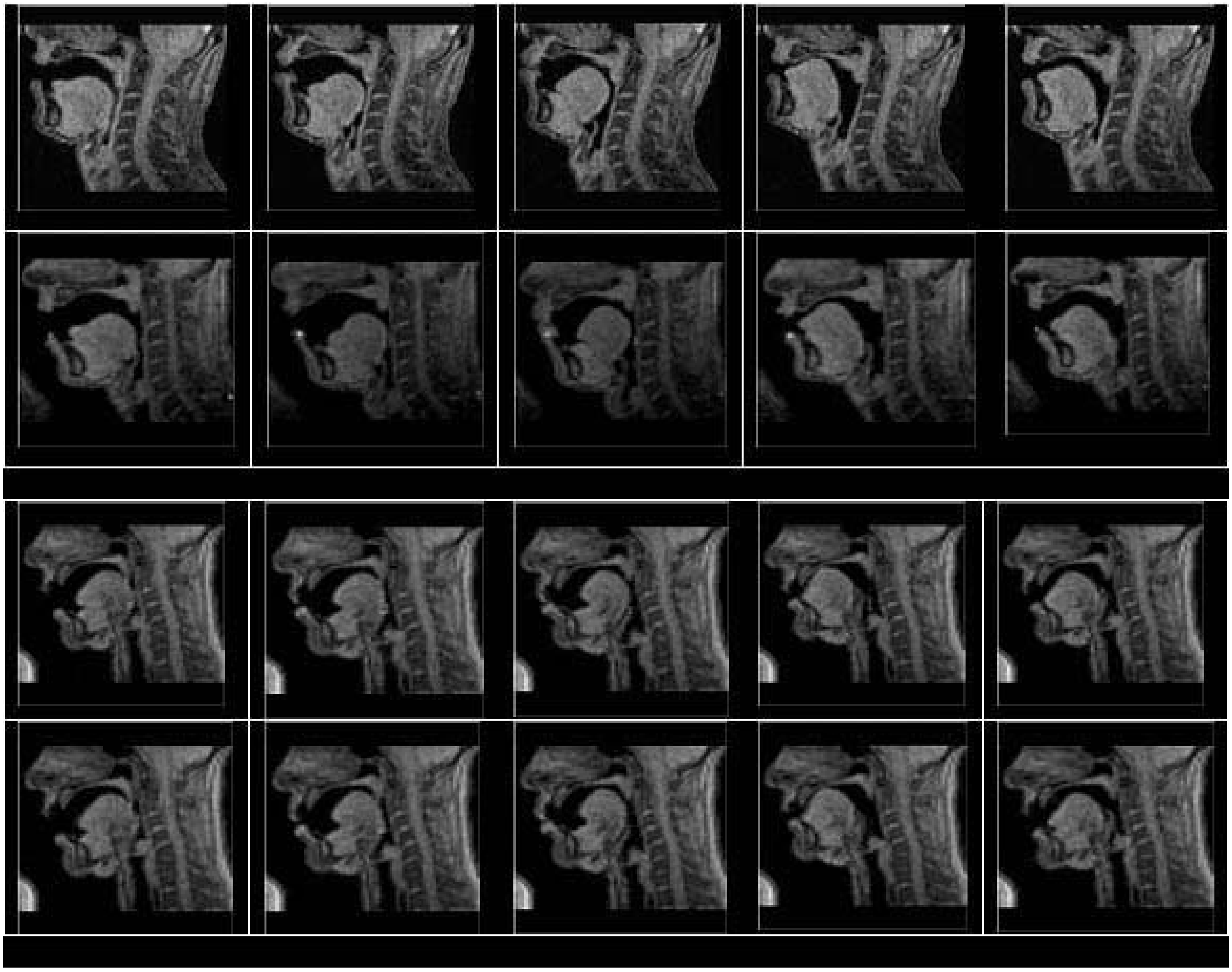

Figure 3. Experimental data of MRI acquisitions, performed with the time gap of one year (upper two rows - male speaker, first (1) and second (2) experimental sessions; lower two rows – female speaker, first (3) and second (4) experimental sessions). Vowel phoneme sequence is (from left to right): [a: o: u: i: e:]

More distinct inter-speaker differences also attached our attention and were thus analyzed in detail. Primarily, we would like to notice major discrepancies in the shape of back/front cavity volumes for the articulation of the vowel [a] between the two subjects. A perceptive analysis of the appropriate recordings detected distinct faucal timbre of the phonation of [a] and apparently of [o] in female-speaker's pronunciation of experimental stimuli. We are inclined to charge the observed phenomena (first and foremost, noticeable significant decrease in passage in the pharynx) on the forgoing description of the gravitational effect. We suggest that in this case it should be interpreted as an action of the supine position, uncommon to the speaker. Thus, she has testified her inability to compensate with changed articulational patterns an impact of irregular spatial situation and of unusual environment.

3. Conslusion

In our investigation a set of representative articulation contours for the Russian standard pronunciation was extracted upon a certain algorithm from the MR images taken during sustained phonation of five Russian vowels [a: o: u: i: e:]. We've supposed that the observed inter-speaker and inter-session dissimilarity derives from certain external situational factors (such as gravitational effect or individual speaker's compensational strategies). Therefore, our research enabled elaboration of the verified articulation inventory for basic Russian vowel phonemes.

A comparative study of corresponding data referring to other languages (German, French and Korean) showed more open character of front and mid-vowels in Russian (more substantial against German vocal system and much less evident for the French articulation patterns); marked shift backwards into pre-faringeal zone, of general configurations of Korean articulation base for the vocals (noticeable even on the contour of front vowel [i], while most evident contrast was observed for the Russian [a]); greater labialization and more close articulation of the German back vowel [u] against its Russian counterpart; more shifted backwards articulation of the Russian vowel [u] in comparison to the French analogue; apparent center-oriented position of the Russian mixed vowels [e] and [o] compared to other languages. Thus, we are convinced that the comparative detailed study of articulation mechanisms in different languages might form a solid basis for effective methods in foreign language teaching and learning.

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