MODEL EXPERIMENTS ON VOWEL REDUCTION IN BULGARIAN

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ABSTRACT

This paper reports the results of model experiments designed to test hypotheses concerning the articulatory correlates of vowel reduction in Bulgarian. It is concluded that reduction can be explained in terms of neutralization of mandibular depression, of lingual and labial compensation for mandibular variation, and of labial activity.

INTRODUCTION

Vowel reduction in Bulgarian is characterized, in traditional terms, by raising and not by centralization. There is a reducing set /e,o,a/, whose reflexes merge with those of a non-reducing set /i,u,ă/ in unstressed syllables in informal speech (/e/⟶[i], /o/⟶[u], /a/⟶[ă]). The character "ă" denotes an [ɐ] or [ɜ]-like timbre.

The actual occurrence of vowel reduction in everyday Bulgarian speech is subject to normative, social and dialect constraints (1). Unstressed /a/ is reduced in all dialects. Complete reduction of both /e/ and /o/ is limited to eastern dialects, but they are reduced to a varying extent elsewhere, depending on the formality of the situation. The reduction of /o/ is common in the Sophia dialect, but /e/ is frequently not reduced.

Figure 1 shows the F1 and F2 frequencies of the vowels in fully stressed syllables, recorded by an informant from the Sophia region. The examples of /u/ with the highest F2 frequencies are preceded by dental consonants. The position of /ă/ is central and midway between /e/ and /o/ (F1 about 350-450 Hz and F2 about 1300-1600 Hz), agreeing with the traditional analysis of the Bulgarian vowel system with /ă/ as an "indeterminate" mid central vowel.

However, the well known correlation between traditional tongue feature usage and formant frequencies does not express a causal relationship, since all parts of the vocal tract contribute to each resonance. One cannot deduce articulation by translating F1 into "height" and F2 into "backness". Further, it was formerly believed that a central tongue position narrowed the mouth channel at some point between the hard and soft palates, but this is not substantiated by midsagittal x-ray profiles (2,3). Instead, the vocal tract is narrowed at one of four locations: along the hard palate for [i-ɛ] and [y-œ]-like vowels, along the soft palate for

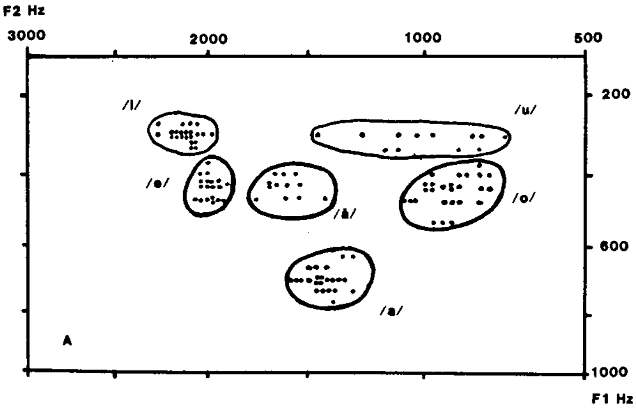

Figure 1
The frequencies of F1 and F2 for stressed vowels in isolated words and in focused words in sentences. The large variation in F2 for /u/ is related to consonant environment (high F2 with preceding dentals).

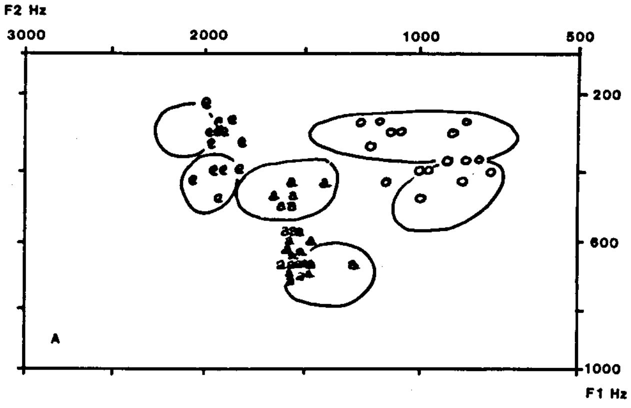

Figure 2
The frequencies of F1 and F2 for unstressed /e,a,o/ in isolated words, compared with the stressed vowel areas (Fig. 1). The variation of F2 for /o/ is related to consonant environment.

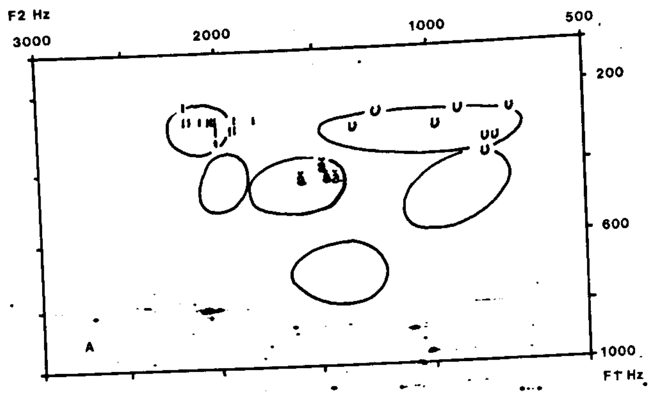

Figure 3
The frequencies of F1 and F2 for unstressed /i,u,ă/ in isolated words, compared with the stressed vowel areas (Fig. 1). The variation of F2 for /u/ is related to consonant environment.

[u-ʊ] and [ɯ]-like vowels, in the upper pharynx for [o-ɔ] and [ɤ]-like vowels, and in the lower pharynx for [æ-ɑ]-like vowels.

Examination of x-ray profiles by Tilkov (4,5) indicates that the tongue articulation for /ă/ and /a/ is similar, with a pharyngeal narrowing. The main difference is that the jaw opening is less open for /ă/, as in the similar difference between [ɛ] and [i] and between [o] and [u]. The spectral effects of these manoeuvres will be tested in the model experiments.

Figure 2 shows how reduction of /e,o,a/ shifted F1 and F2 well beyond the contrastive spectra of the accented vowels, in many cases causing coalescence with /i,u,ă/ respectively. The reduction recorded in Fig. 2 reflects the extent to which this informant has respected the norm and avoided reduction. This was most obvious in the recordings of the word lists. When the words were placed in sentences, there was more reduction, but /e/ typically remained most resistant. Figure 3 shows that the spectra of weak /i,u,ă/ are similar to those of the respective stressed forms.

Possible phonetic explanations for this pattern of reduction include (i) relaxed articulatory control, neutralizing articulatory components of the nonreduced vowel and leading to a continuous transition between unreduced and fully reduced forms. Alternatively, (ii) switching between integral articulations by substituting different manoeuvres, would lead to discrete jumps between reduced and nonreduced forms. Explanation (ii) is, by its nature, categorical. Phonological accounts are also, for convenience, categorical. The spectral regressions between nonreduced and fully reduced /e,o,a/ in Fig. 2 support explanation (i).

MODEL EXPERIMENTS

The spectral consequences of selected articulatory manoeuvres are studied by manipulating the contours

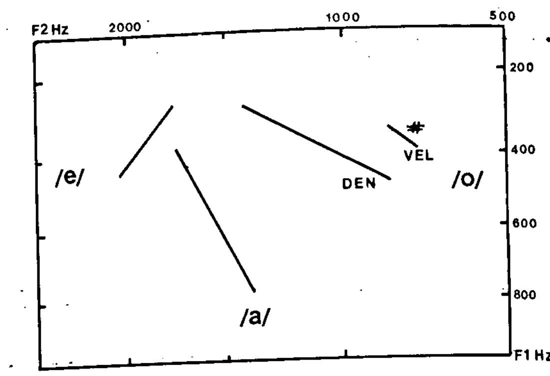

Figure 4
Regressions of F1 and F2 for all stressed and unstressed /e,o,a/. The /o/ renderings are divided into subclasses according to consonant environment: word initial /o/ (*), preceding velars (VEL), preceding dentals (DEN).

of vocal tract profiles and then computing the resonance frequencies for each new configuration. The rationale for selecting manoeuvres to experiment with is outlined in detail at each example. The general principle is to deduce appropriate manoeuvres in each case from knowledge of speech physiology and the structure of each vowel configuration.

The spectrographic data in Figs. 2, 3 were obtained from 56 words recorded in isolation and in sentences, both in focal and nonfocal positions (6). The recordings were analysed using an LPC method. The trends of the gradual spectral transitions from the nonreduced renderings to the fully reduced renderings are captured by linear regressions in Fig. 4. The aim of the model experiments is to reproduce the regressions by subtracting selected manoeuvres from complete [ɛ], [a] and [o]-like profiles.

Analysis of published radiographic data for some 15 languages (7) indicates that, for nonhigh vowels, the mandible is usually depressed beyond about 8 mm, typically to about 10 mm. Larger openings, to say 15 mm, would occur for example in public speaking. Smaller openings would occur in mumbling. Usually the tongue compensates for mandibular variation by maintaining a suitable degree of narrowing of the palatal passage, of the velar passage or of the pharynx, as the case may be.

Pharyngeal /a/

The first experiment examines the effect of varying the jaw opening from 14 to 6 mm with full lingual compensation in order to maintain the optimum degree of pharyngeal narrowing. This modification is illustrated at A in Fig. 5.

The next experiment assumed that lingual compensation is turned off during reduction (the tongue would not be drawn back into the pharynx at closer jaw positions). Another likely characteristic of reduced /a/ is that the typical pharyngeal activity is weakened. Both of these features will result in a wider pharynx and narrower palatal passage. This

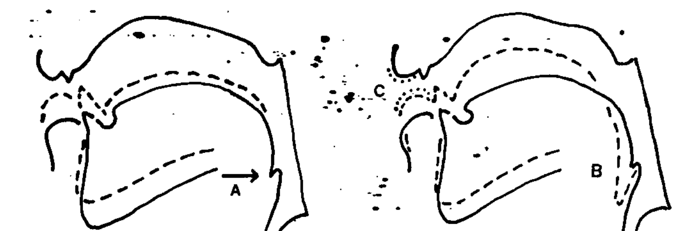

Figure 5
Modelled jaw opening variation 14-6 mm in an /a/-like configuration: with full lingual compensation (A), no lingual compensation (B), and weakened lip spreading (C).

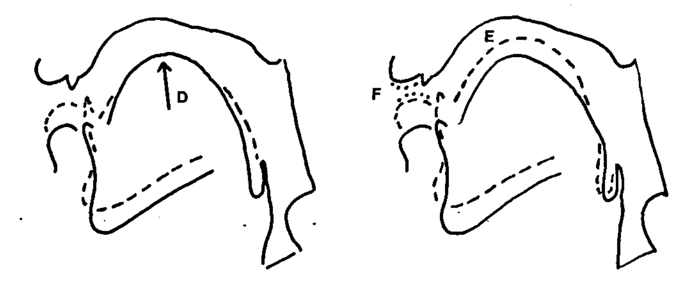

Figure 6
Modelled jaw opening variation 14-6 mm in an /e/-like configuration: with full lingual compensation (D), no lingual compensation (E), and weakened lip spreading (F).

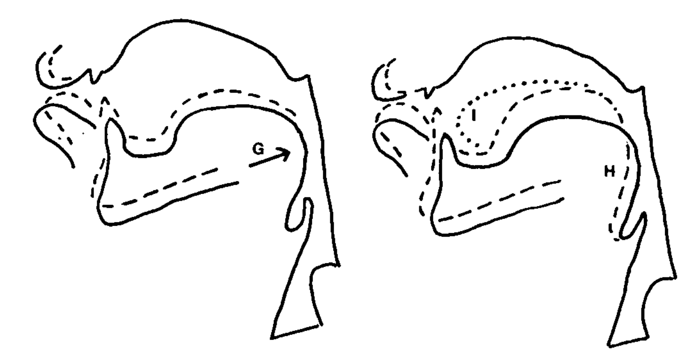

Figure 7
Modelled jaw opening variation 14-6 mm in an /o/-like configuration: with full lingual (G) and labial compensation, no lingual compensation (H), and elevated tongue blade (I).

combined modification is illustrated at B in Fig. 5.

A further possible reduction effect is neutralization of lip spreading (C in Fig. 5).

Palatal /e/

The same variation of jaw opening between 14 and 6 mm with perfect lingual compensation for /e/ is illustrated at D in Fig. 6. This maintains an ideal degree of palatal constriction. E in Fig. 6 illustrates the same mandibular reduction, but without lingual compensation (the narrower palatal passage due to the higher mandible position is not corrected by lowering the the tongue). Again, a further possible feature of vowel reduction is neutralization of lip spreading (F in Fig. 6).

Pharyngovelar /o/

The profile modifications for raising the mandible from 14 mm to 6 mm with perfect labial and lingual compensation in /o/ (to maintain an ideal lip opening and degree of pharyngeal narrowing) are illustrated at G in Fig. 7. Mandibular reduction without lingual or labial compensation, with reduced pharyngeal activity and weakened lip rounding is shown at H in Fig. 7.

Figure 4 shows that reduced /o/ preceded by dental consonants in the informant's speech had a higher F2, which is probably due to the tongue blade remaining elevated in /o/. This modification is illustrated at I in Fig. 7.

RESULTS

The results of the model experiments are recorded in Fig. 8.

Full compensation

With full lingual compensation for mandibular variation 14-6 mm (and labial compensation in /o/), the vowel spectra remained in the respective contrastive areas of the nonreduced vowels (A, D, G; compare /a,e,o/ in Fig. 1). This illustrates the extent to which compensated mandibular variation contributes to the normal spectral variation of stressed vowels in speech.

No lingual compensation

The simulated reduction of /a/ (B in Fig. 8) compares well with the /a/ regression in Fig. 4. The wider pharynx, narrower palatal passage and narrower mouth opening resulting from an uncompensated smaller jaw opening shifted F1 and F2 in the direction of the observed regression.

The simulated reduction of /e/ (E in Fig. 8) shifted the spectrum towards an [i]-like vowel, but with a high F2 rather than with the lower F2 exhibited by the informant (Figs. 2, 4).

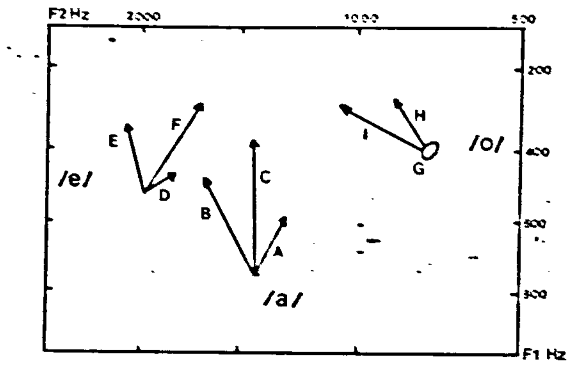

Figure 8
The results of the modelled articulatory modifications (Figs. 5–7), for comparison with the regressions observed in the informant's speech (Fig. 4).

The simulated reduction of /o/ (H in Fig. 8) compares well with the regression for /o/ preceded by velar consonants (Fig. 4).

Weakened lip spreading

Two experiments also assumed weakened lip spreading for the spread-lip vowels /e,a/. The results are recorded at F and C respectively in Fig. 8. Compared with E and B, F2 is lower. Both B and C shift the /a/ spectra towards the /ă/ area. For /e/, the weakened lip spreading (F) matches the /e/ regression observed in the informant's speech (Figs. 2,4).

Elevated tongue blade

The final experiment added an elevated tongue blade to the simulated reductions of /o/. The result, illustrated at I in Fig. 8, is a higher F2 compared with H. This compares well with the regression for /o/ preceded by dental consonants (Fig. 4).

DISCUSSION AND CONCLUSIONS

The articulatory behaviour modelled in the experiments successfully reproduced the spectral reduction recorded from the informant. The results demonstrate that the reduction of Bulgarian /e,o,a/ can be explained in terms of neutralization of mandibular depression, of lip spreading or rounding, and of lingual and labial compensation for mandibular variation. This assumes that reduction is a process of subtraction, and not one of substituting a new set of manoeuvres for the reduced vowel. The gradual spectral transition from nonreduced to fully reduced depends on which components happen to be turned down and how far. If there is a hierarchy for neutralization, we suggest the following order: mandibular depression, compensation, lip activity.

The formant frequencies yielded in the experiments do not reproduce those of the informant exactly. To do that, it would be necessary to model the informant's own vocal tract. The results have general interest precisely because the observed spectral tendencies were reproduced by manipulating a set of profiles that were chosen at random.

We propose that the feature that distinguishes the reducing set /e,o,a/ from the nonreducing set /i,ɥ,ă/ is the degree of jaw opening, and that the other phonetic correlates of reduction are subsumed. The reducing set are [open] and the nonreducing set [nonopen]. Vowel reduction in Bulgarian will then be captured by the following rule:

$$[+\text{open}] \longrightarrow [-\text{open}] \Big/ \frac{\quad\quad}{[-\text{stress}]}$$

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