VOWEL REDUCTION IN BULGARIAN

Thore Pettersson and Sidney Wood

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1. INTRODUCTION

In this report we present phonological vowel reduction in Bulgarian and review the phonetic data given in the literature, as an introduction to a cinefluorographic and spectrographic study to be published in future reports. While this investigation deals specifically with Bulgarian, it is also of interest for the problem of vowel reduction in general, the phonetic character of schwa-like vowels, and consequently for theories of speech production and motor control and for phonology.

We shall have occasion to refer to both formal and informal speech, dialect and standard forms, since phonological reduction in Bulgarian is subject to both stylistic (formality and situation) and dialect constraints. Contemporary Standard Bulgarian (CSB) is defined by Scatton (1975) as "the contemporary literary norm of the Bulgarian capital, Sofia, as reflected in their formal speech and in normative grammars".

We distinguish between phonological reduction (regular vowel to vowel alternations depending on whether the syllable is lexically stressed or not) and phonetic reduction (a tendency for a vowel quality to become indistinct as it weakens and shifts towards schwa). In many languages these two processes may coincide, the phonological reduction also being towards schwa. In Bulgarian they do not coincide.

A classical account of the Bulgarian vowel system is that given by Trubetskoy (1939). In many languages, says Trubetskoy, the indeterminate vowel only appears in partial systems in those phonic positions where several oppositions based on degree of

aperture and oppositions of timbre are neutralized. But Bulgarian is an example of a language where

> an indeterminate vowel in a triangular system can become a specific vowel by entering into a relation of bilateral opposition with a. The Bulgarian indeterminate vowel has approximately the same degree of aperture as o and e, but it is neither rounded nor palatal. It would hardly be possible to assume a pure opposition of timbre between Bulgarian ə and o or between Bulgarian ə and e. But the proportions o:a=u:ə, e:a=i:ə and the proportions u:o=i:e=ə:a deduced therefrom may well be established. The conditions in unstressed syllables (at least in a part of the local types of pronunciation) are proof that this proportion corresponds to reality. For in these syllables o, a and e are not permitted, only u, i and ə are. In other words the oppositions based on degree of aperture u-o, i-e and ə-a are neutralized, while the triangular character of the vowel system is preserved. Graphically, this may be presented as follows:

The orthographic representation of the "indeterminate vowel" in Bulgarian is ъ, "yer". We prefer to transcribe this vowel, conventionally, as /ă/ rather than /ə/ in order to distinguish it from true weak schwa. This is a typographical measure that enables us to keep an open mind as to the actual phonetic character of /ă/.

We also have a methodological goal. It has long been well-known that the Bell model (presumed high-mid-low and front-central-back tongue positions for vowels) fails to offer a correct or even an adequate description of vowel articulation. This has not impeded work in phonology so long as interest has been concentrated on abstract relations between units, without regard to physical data. Provided units are

uniquely classified it does not matter what labels the classifying features bear. The Bell model breaks down when it is held to represent physiological fact (see further Wood 1975a, 1982a). This is a particularly severe drawback when speech production is to be related to phonology, for example when a production model requires phonological directives to control speech directly (as is the case in the model of Chomsky & Halle 1968), or when a continuous link is to be established between phonology, motor control, articulation, sound production and perceptual cues in the speech wave (as in the various models of the late Roman Jakobson).

For this introductory report we shall present Bulgarian vowel reduction in the traditional and familiar terminology of the Bell model, but our analysis of the problem and our subsequent reports on the phonological and phonetic processes involved will be framed in terms that more closely reflect current knowledge of speech production.

Phonetic and phonological descriptions of Bulgarian have been published by Scatton (1975), Stojkov (1966), Tilkov (1970, 1982) and Tilkov & Bojadžiev (1981). Various dialect, morphological, sociolinguistic and stylistic aspects of vowel reduction in Bulgarian have been treated by Bojadžiev (1980), Ivančev (1980), Janakiev (1960), Pašov (1980a, 1980b) and Stojanov (1968). Pašov (1980a) has reviewed earlier grammars on the subject. Lockwood (1972) uses the Bulgarian vowel alternations between stressed and unstressed syllables as a language example in a theoretical discussion of the role of markedness in conventional generative phonology and in stratificational phonology.

2. PHONOLOGICAL VOWFL REDUCTION IN BULGARIAN

The following alternations occur in informal Bulgarian speech between stressed and non-stressed vowels:

	STRESSED	NON-STRESSED
/i/	i	i
/e/	e, ɛ	i
/u/	u	u
/o/	o, ɔ	u
/ă/	ɐ, ɜ, ə	ɐ, ɜ, ə
/a/	a	ɐ, ɜ, ə

The reductions are easily discerned in morphological stress alternations such as the following examples (stressed syllables are indicated by an acute accent, compared vowels are underlined):

	STRESSED	NON-STRESSED	
/í/-/i/	/i̲ m e/	/i̲ m e n á/	name(s)
	[í̲ m i]	[i̲ m i n á]	
/é/-/e/	/s é̲ l o/	/s e̲ l á/	village(s)
	[s é̲ l u]	[s i̲ l á]	

/á/ -/a/	/r á b o t a/	/r a b ó t n i k/	work(er)
	[r á b u t ă]	[r ă b ó t n i k]	
/ó/-/o/	/ó n z i/	/o n á z i/	that: m (f)
	[ó n z i]	[u n á z i]	
/ú/-/u/	/b ú k v a/	/b u k v á r/	letter/ABC
	[b ú k v ă]	[b u k v á r]	
/ǎ́/-/ă/	/k r ǎ́ č m a/	/k r ă č m á r/	tavern(er)
	[k r ǎ́ č m ă]	[k r ă č m á r]	

The extent of vowel reduction varies considerably, depending on stylistic, dialect and morphological constraints.

Non-stressed /a/ is most likely to be reduced, the reduction of /o/ is quite common, but in CSB /e/ is frequently not reduced.

Vowel reduction is avoided in very formal speech and is not heard, for example, in the speech of radio announcers (Pašov 1980a). This contrasts completely with Russian where the norm requires reduction, non-reduction being looked upon as rustic.

While speakers are subject to social pressures to adapt their speech in this respect towards the norm, it should be noted that the triggering factor is said to be style rather than social class. This is something that Bulgarians are taught at school (cf. Gyllin 1982). The same speaker can vary vowel reduction from occasion to occasion depending on the formality

of the situation. Different individuals vary also in how far they succeed in living up to the norm. We believe that this merits a sociolinguistic study comparable to Labov's study of New York speech (Labov 1972). Reading aloud is a formal situation and, typically, one of our informants remarked that while he was reading our word lists he felt the presence of a schoolmaster standing behind him.

Janakiev (1960) points out that Bulgarians cannot spell non-stressed vowels properly unless they know the etymology. Pašov (1980b) has recorded numerous examples of misspelt non-stressed vowels from university entrance examination papers to degree courses in Bulgarian by above average applicants. Pašov underlines that an above average school result is no guarantee that a student can master the spelling of weak vowels. The spelling mistakes occur in both directions (i.e. they include hypercorrect forms) and are more frequent for /i-e/ and /u-o/ than for /ă-a/. He also gives surprising examples of proof-reading errors from official publications and even from the Academy of Sciences spelling dictionary.

Ivančev (1980) has studied rhymes in Bulgarian poetry. Pure rhymes are based on identical vowel sounds and writers who avoid vowel reduction in their own speech should be less likely to rhyme non-stressed /e, o, a/ with non-stressed /i, u, ă/ respectively. It turns out that pure rhymes between reduced /o/ and /u/ and between reduced /e/ and /i/ are very frequent. In contrast, the late 19th century poet Penčo Slavejkov has frequently rhymed non-stressed /o/ with non-stressed /a/. Ivančev records no fewer than 141 examples, e.g:

.....dvata	the two	.....kogato	when
.....zlato	gold	....vratata	the doorway

but Slavejkov has only once rhymed non-stressed /o/ with non-stressed /u/:

....prez ramo	over the shoulder
....čestta mu	the honour to him

Ivančev attributes the numerous reduced /a-o/ rhymes to

Slavejkov's own pronunciation, and takes them as evidence that Slavejkov's /o/ was pronounced with little lip rounding. But they could also be a contrived breach of convention that was intended to shock the reader.

There is a strong dialect component in the tendency to reduce non-stressed vowels. Bojadžiev (1980) among others reports that non-stressed /a/ is neutralized without exception in all dialects whereas the reduction of /e/ and /o/ is limited to eastern dialects. From this fact Bojadžiev draws the conclusion that the reduction of /a/ on the one hand and of /e, o/ on the other consists of two phonologically distinct processes. Similar vowel reductions occur in neighbouring parts of the Balkans. For example they occur in NE but not southern Greek and in E but not central Macedonian.

Pašov (1980a) notes several morphological exceptions. Typical examples are:

tense:	/mólix/	[mólix]	I asked
	/mólex/	[mólex]	I was asking
		(weak /e/ not reduced)	
person:	/dovédox/	[duvédox]	I led
		(final weak /o/ not reduced)	
vocative:	/sin/	[sin]	son (basic form)
	/síne/	[síne]	son!
		(final weak /e/ not reduced)	
	/stánko/	[stánku]	Stanko (basic form)
	/stánko/	[stánko]	Stanko! (vocative)
	(vocative final weak /o/ not reduced)		

The unreduced vocative ending is often reinforced by being lengthened:

[síne:]	son!
[stánko:]	Stanko!

3. PROBLEMS AND RULES

Phonetic data obtained from the literature (Scatton 1975, Stojkov 1966, Tilkov 1970, Tilkov & Bojadžiev 1981, Tilkov 1982) is unfortunately contradictory. This data is reviewed in detail in section 4. In this section we will present various alternative standpoints and see how they affect the possible solutions.

At first sight the task is simple: there is one set of units that is subject to reduction

/e, o, a/

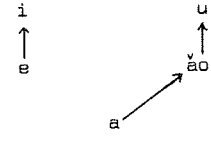
and one set that is not

/i, u, ă/

But what are the defining features for each set and what are the differentiating features?

The ultimate solution is dependent on the classification of /ă/. The following possibilities can all be derived from the published phonetic data reviewed in the next section.

3.1 Is /ă/ a mid back unrounded vowel (i.e. an [ɣ-ʌ]-like spread-lip vowel corresponding to rounded [o-ɔ])? In traditional terms this gives



All non-high vowels except /ă/ shift up one step, i.e. unrounded back has to be excluded (Table I).

Table I. Feature matrix for vowel reduction according to the solution in 3.1. The brackets enclose the features that are affected by reduction. At this stage the specifications are redundant.

	e	i	o	u	a	ă
high	(-	+)	(-	+)	-	-
low	-	-	-	-	(+	-)
front	+	+	-	-	-	-
back	-	-	+	+	(-	+)
round	-	-	+	+	-	-

The rule

$$[+\text{low}] \longrightarrow \begin{bmatrix} -\text{low} \\ +\text{back} \end{bmatrix} \;/\; \underline{\qquad} \; [-\text{stress}] \qquad \text{(I)}$$

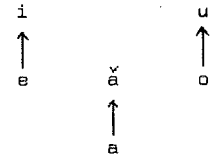
will raise and back a, and

$$\begin{bmatrix} -\text{high} \\ \alpha\text{front} \\ -\alpha\text{back} \\ -\alpha\text{round} \end{bmatrix} \longrightarrow [+\text{high}] \;/\; \underline{\qquad} \; [-\text{stress}] \qquad \text{(II)}$$

will raise e and o but not ă.

The two different rules reflect two different phonetic processes. The complexity of the rules reflects the need to back /a/ and to exclude /ă/. (Scatton's classification - /a/ low back and /ă/ mid back - is a variant of this solution.)

3.2 Alternatively, is /ă/ a mid central vowel, akin to [ɜ] or [ə] (the Trubetskoy solution quoted in the introduction)? This gives



Again, all non-high vowels except /ă/ shift up one step, but /a/ does not have to be backed now (Table II). Mid central has to be excluded.

Table II. Feature matrix for vowel reduction according to the solution in 3.2. The brackets enclose the features that are affected by reduction.

	e	i	o	u	a	ă
high	(-	+)	(-	+)	-	-
low	-	-	-	-	(+	-)
front	+	+	-	-	-	-
back	-	-	+	+	-	-
round	-	-	+	+	-	-

The rule

$$[+\text{low}] \longrightarrow [-\text{low}] \;/\; \underline{\qquad}\; [-\text{stress}] \qquad \text{(III)}$$

will raise a, and

$$\begin{bmatrix} -\text{high} \\ \alpha\text{front} \\ -\alpha\text{back} \end{bmatrix} \longrightarrow [+\text{high}] \;/\; \underline{\qquad}\; [-\text{stress}] \qquad \text{(IV)}$$

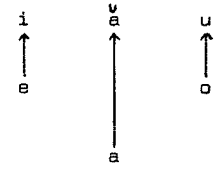
will raise e, o but not mid central ă.

There are still two different processes for /e, o/ and /a/ respectively, and /ă/ still has to be excluded.

3.3 Is /ă/ a high (perhaps central) vowel (Table III)?

Table III. Feature matrix for vowel reduction according to the first solution in 3.3. The brackets enclose the features that are affected by reduction.

	e	i	o	u	a	ă
high	(-	+)	(-	+)	(-	+)
low	-	-	-	-	(+	-)
front	+	+	-	-	-	-
back	-	-	+	+	-	-
round	-	-	+	+	-	-



This offers a seductively simple rule: non-high vowels become high (implying that low becomes non-low):

$$[-\text{high}] \longrightarrow [+\text{high}] \;/\; \underline{\qquad} \;[-\text{stress}] \qquad (V)$$

But this solution is the least likely since /ă/ is not usually looked upon as a high vowel.

And yet the simple structure of this solution tempts us to ask again: is there one simple feature that differentiates the reducing set from the non-reducing set? The feature that comes to mind is the degree of jaw-opening: is the jaw opening narrower for /i, u, ă/ and more open for /e, o, a/? There is some evidence that it could be.

We shall then need to reintroduce a feature that we can call open with the original meaning it once had with reference to the degree of mouth opening depending on the jaw angle (Wood 1982b). With the Bell vowel model generally accepted at the end of the 19th century, the degree of mouth opening was disregarded as a parameter and the terms close and open were instead associated with the openness of the passage betwen the tongue and the hard palate, thus becoming synonymous with high and low. This is understandable since the mandible position is a component of tongue height (for palatal vowels at least) and it is virtually impossible to reconcile a mouth opening feature with the Bell tongue features. For example, if [open]⟶[close], then the tongue features have to be respecified too (perhaps [+low]⟶[-low] or [-high]⟶[+high]).

But what we may be faced with in Bulgarian vowel reduction is unmodified lingual activity combined with a narrower jaw opening. This is easier to express (and is physiologically more plausible) in terms of the basic tongue postures (see Fig. 3 and Wood 1979, 1982a):

	palatal	labio-velar	low pharyngeal
close	i	u	ă
	↑	↑	↑
open	e	o	a

If /a/ and /ă/ differ only in mandibular depression, we have the matrix given in Table IV.

Table IV. Feature matrix for vowel reduction according to the second solution in 3.3. The brackets enclose the features that are affected by reduction.

	e	i	o	u	a	v a
palatal	+	+	-	+	-	-
velar	-	-	+	+	-	-
pharyngeal	-	-	+	-	+	+
open	(+	-)	(+	-)	(+	-)
round	-	-	+	+	-	-

This gives the following very general rule:

$$[+\text{open}] \longrightarrow [-\text{open}] \;/\; \underline{\qquad}\; [-\text{stress}] \qquad \text{(VI)}$$

In the next section the phonetic data published in the literature will be reviewed and interpreted in relation to these possible solutions.

4. PHONETIC DATA

X-ray profiles

Tilkov has published two sets of x-ray profiles (Tilkov 1970, Tilkov & Bojadziev 1981, Tilkov 1982).

The profiles for /ă, a, o/ are reproduced in Fig. 1. Tilkov's interpretation of the /ă/ profile is that the vocal tract is more or less uniform throughout its length except for a slight narrowing in the pharynx. This narrowing is not so extreme as for /a/ but he notes an evident affinity. He concludes that /ă/ is a back vowel (in the sense that it is formed in the

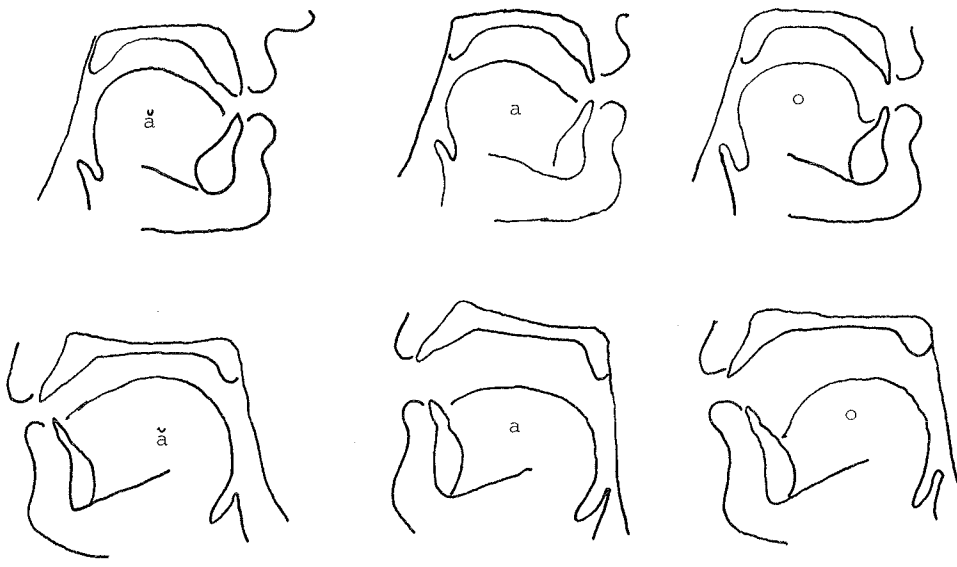


Fig. 1. Profile tracings of /ă, a, o/ after Tilkov & Bojadziev (1981) (above) and Tilkov (1970, 1982) (below).

pharynx, not in the Bell sense).

We have compared the tongue postures relative to the mandible in Tilkov's profiles (Fig. 2). This comparison isolates the lingual manoeuvres the speaker has used for the various vowels. As Figs. 2 and 3 show, the tongue assumes one out of a small set of typical tongue postures relative to the mandible. Each posture can be interpreted in terms of the underlying muscular activity (Fig. 3, for further details see Wood 1979). The tongue forms a major constriction at one of four places in the vocal tract: along the hard palate for [i-ɛ] and [ʏ-œ]-like vowels, along the soft palate for [u-ʊ] and [ɯ]-like vowels, in the upper pharynx for [o-ɔ] and [ɤ-ʌ]-like vowels and in the lower pharynx for [æ-ɑ]-like vowels.

In Fig. 2 we have compared the posture for Bulgarian /ă/ with the palatal /i-e/ posture, the low pharyngeal /a/ posture, the upper pharyngeal /o/ posture and the velar /u/ posture taken from the Tilkov profiles. The result of the comparison is similar for both of Tilkov's sets of profiles.

Firstly, Fig. 2a shows that the tongue is less bunched relative to the mandible for the palatal vowels /e/ and /i/. This is typical of the tense-lax palatal [i, e] vs [ɪ, ɛ] contrast (Wood 1975b, 1982b). In Tilkov's profiles, /i/ is close (narrower jaw opening) and tenser (tongue bunched more towards the hard palate) while /e/ is open (larger jaw opening) and laxer (tongue less bunched towards the palate). Compared with these palatal /i, e/ postures, the /ă/ posture is not raised anteriorly towards the hard palate but bulges posteriorly towards the pharynx. This indicates activity in the glosso-pharyngei (superior pharyngeal constrictors) as illustrated in Fig. 3. The Tilkov /ă/ profiles are thus associated with a retracting manoeuvre and not with a palatal manoeuvre. This confirms the usual view that /ă/ is not a palatal vowel.

Figure 2b confirms the similarity of the /ă/ and /a/ postures noted by Tilkov. This similarity favours the alternative solution 3.3. But in both examples, the tongue is higher posteriorly for /ă/ than for /a/, suggesting styloglossal or glossopharyngeal activity rather than hyoglossal (i.e. activity directed towards the velum or upper pharynx rather than lower pharynx).

Figure 2c shows that there is a very close similarity between the /ă/ and /o/ postures. The only essential difference is that the tongue blade is depressed for /o/ but not for /a/, which modifies the anterior mouth cavity. This suggests that /ă/ is a spread-lip [ɣ-ʌ]-like vowel corresponding to rounded [o-ɔ], an interpretation that favours solution 3.1 above.

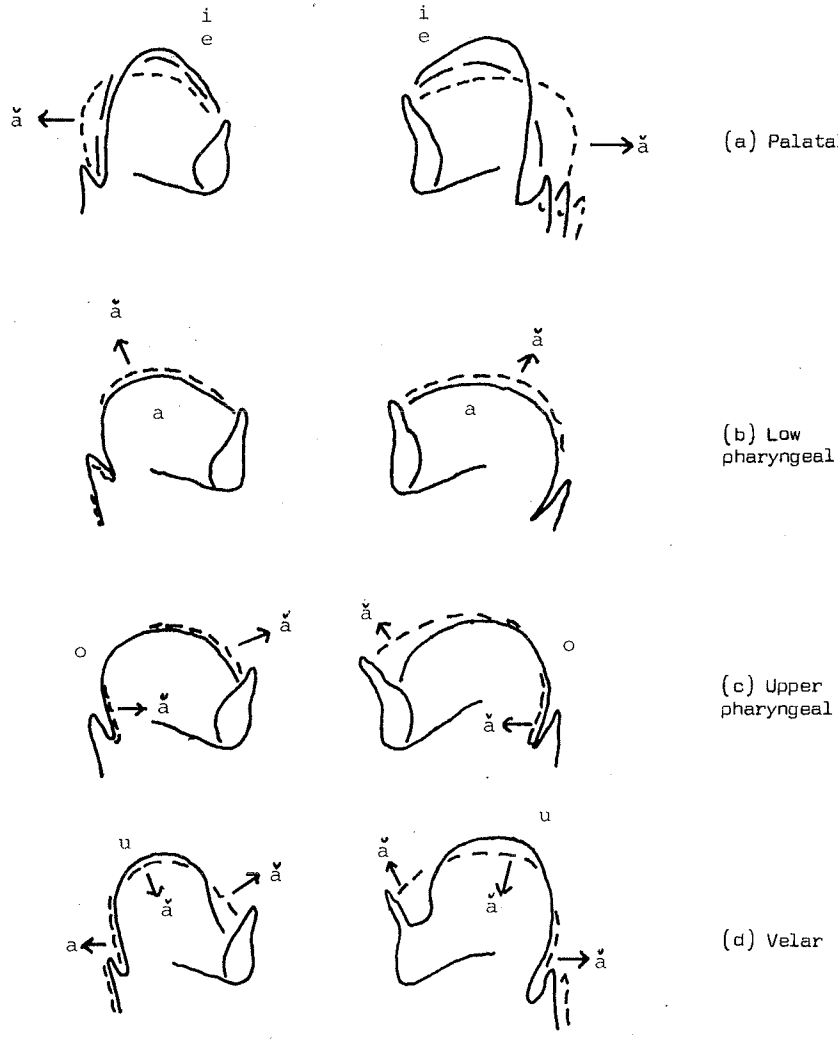
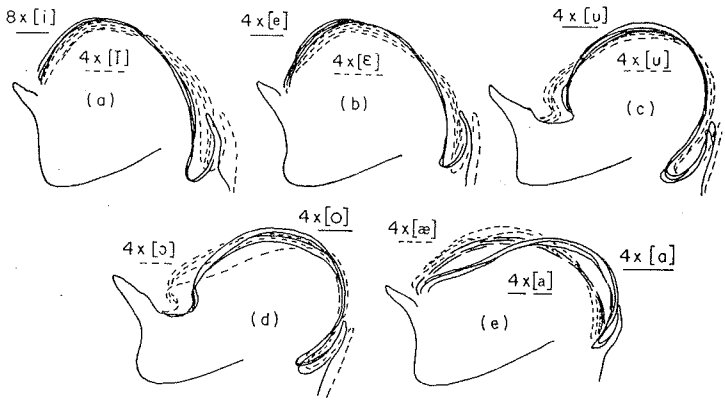
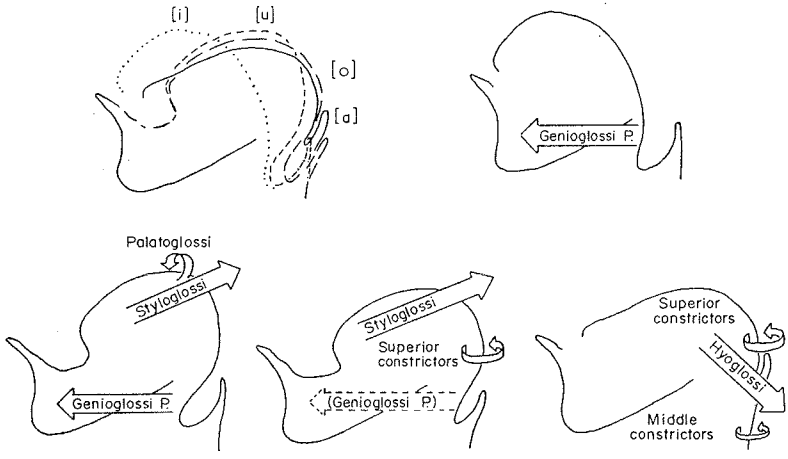


Fig. 2. Comparison of tongue posture of /a/ with the four basic tongue postures relative to the mandible (cf. Fig. 3) after Tilkov & Bojadziev's (left) and Tilkov's (right) profiles.



The positions of the tongue relative to the mandible for stressed vowels by the Egyptian Arabic subject.



The directions of contraction of the extrinsic muscles of the tongue and of the pharyngeal constrictors, arranged according to their presumed activity for the formation of the four constriction locations.

Fig. 3. Typical postures of the tongue relative to the mandible for vowels (above) and the associated muscular activity (below). From Wood (1979).

Fig. 4. Profile tracings of /ă, a, o/ after Stojkov (1966).

Finally, Fig. 2d compares /ă/ and /u/. The tongue is less raised relative to the mandible and the tongue root protrudes more into the lower pharynx for /ă/ than for /u/. The tongue blade is also less depressed for /ă/. These lingual differences are typical for the tense-lax [u-ʊ] contrast (see Wood 1975b) and are related to the levels of activity in the styloglossi and posterior fibres of the genioglossi. There is thus a possible lingual affinity between /ă/ and /u/ that would favour a variant of the first solution 3.3 above: /ă/ as a high (possibly back) vowel, corresponding to /u/. This is not an interpretation that native Bulgarian speakers would intuitively accept.

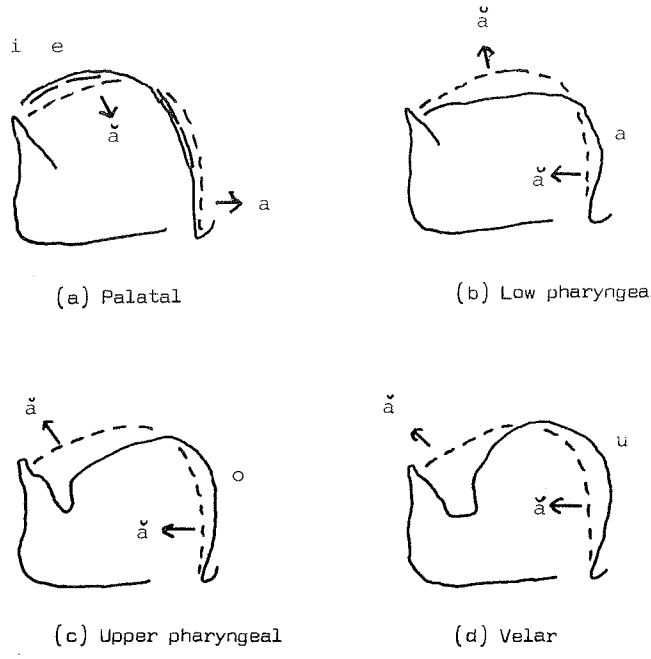


Fig. 5. Comparison of tongue posture of /ă/ and the four basic tongue postures relative to the mandible (cf Figs. 2 and 3) after Stojkov's profiles.

Stojkov (1966) has also published x-ray tracings. The profiles for /ă, a, o/ are reproduced in Fig. 4 and our comparisons of the tongue postures are given in Fig. 5.

The pharyngeal region and the position and attitude of the epiglottis are identical on all of Stojkov's profiles, which indicates that he has only paid attention to the mouth region.

Stojkov's own interpretation of this data is that the tongue is similar for /ă/ and /a/, but somewhat higher and raised anteriorly for /ă/. Figure 4 clearly shows the anterior raising of the tongue for /ă/. Indeed, this profile is more reminiscent of a palatal [ɪ-ɛ] profile rather than a pharyngeal [a] profile. Figure 4 shows a straight back to the tongue for

/a/ with no bulge in the pharynx (typical for palatal vowels).

Firstly, Fig. 5a shows that the Stojkov /ă/ posture is very similar to the /i, e/ posture. The tongue is less bunched for /ă/ as though it were a lax counterpart to /i, e/ (less activity in the posterior fibres of the genioglossi). This suggests another variant of solution 3.3 above, /ă/ as a high (possibly front) vowel similar to lax [ɪ]. This would be a novel interpretation, contrary to the usual view that Bulgarian /ă/ is central or back and contrary to the evidence of the Tilkov profiles.

Figure 5b shows no affinity between /ă/ and low pharyngeal /a/. The tongue is clearly raised anteriorly for /ă/, emphasizing the palatal character just noted.

Similarly, Fig. 5c shows no affinity between /ă/ and upper pharyngeal /o/, the tongue being more anterior for /ă/. This again points to the palatal character of this particular /ă/ profile.

Finally, Fig. 5d also shows an /ă/ posture that is more anterior than the velar /u/ posture.

The Stojkov /ă/ profile is thus radically different from the Tilkov /ă/ profiles. However, it is difficult to know how much confidence to place in Stojkov's profiles in view of his lack of attention to pharyngeal detail.

Acoustical data

Tilkov's (1982 and Tilkov & Bojadziev 1981) and Stojkov's (1966) acoustical F1 and F2 charts are reproduced in Fig. 6.

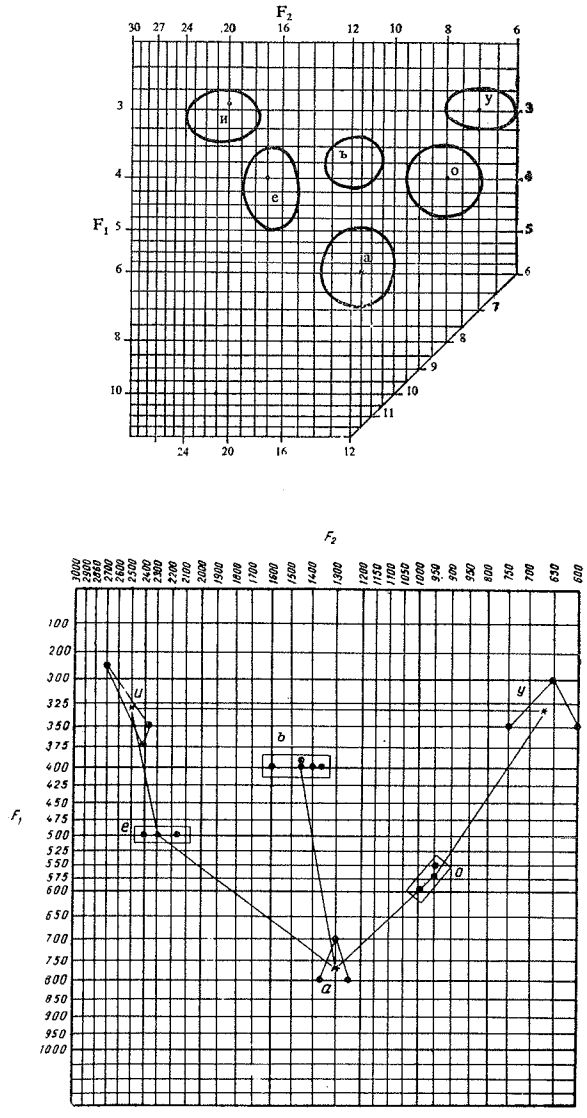


Fig. 6. Acoustical vowel charts from Tilkov & Bojadziev (above) and Stojkov (below).

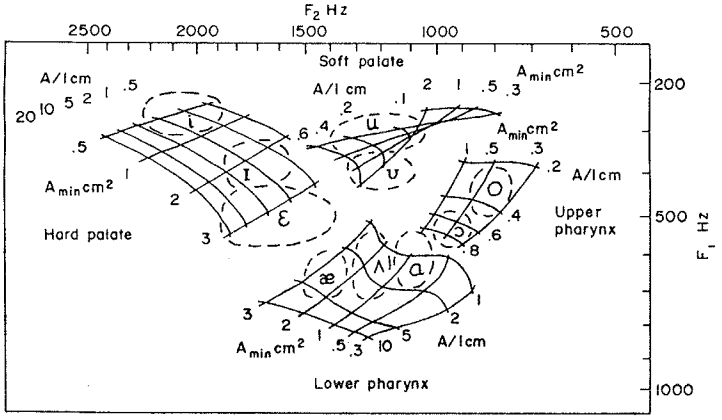
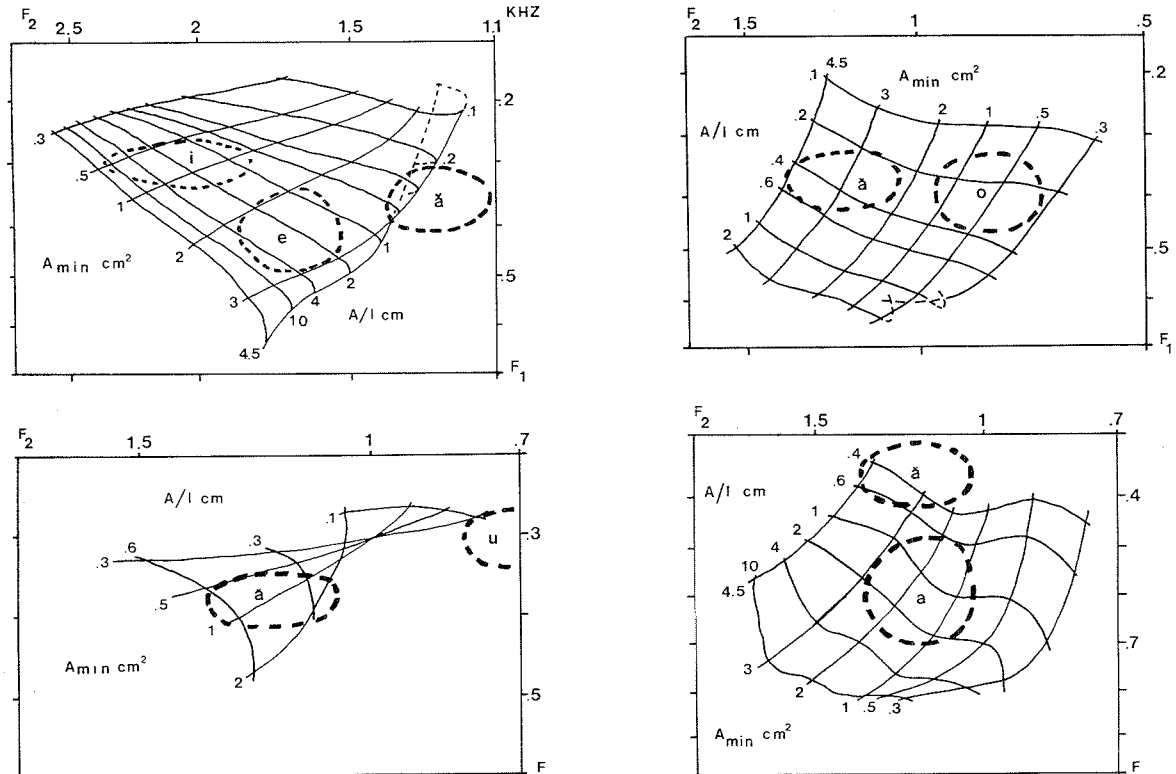


Fig. 7. The frequencies of F1 and F2 generated by the three-parameter model for the four preferred constriction locations, based on nomograms by Stevens & House (1955) (distance from the source to the constriction 12 cm for hard palate, 8.5 cm for soft palate, 6.5 cm for upper pharynx, 4.5 cm for lower pharynx). The superimposed vowel areas are from a sample of Southern British English speech recorded from the radio. From Wood (1979).

It has long been known that judgments of vowel height and backness are more closely correlated with the frequencies of F1 and F2 respectively than with the position of the tongue in the vertical and horizontal planes (see Joos 1948, Lindau 1978), such that high is synonymous with low F1, low with high F1, front with high F2 and back with low F2. The position of /ă/ on the charts reproduced in Fig. 6 is central and midway between /e/ and /o/ (F1 about 350-400 Hz and F2 about 1100-1300 Hz). This would favour solution 3.2 above (/ă/ as a mid central vowel).

A rough articulatory interpretation of these spectra can be obtained by referring them to the Stevens & House (1955) three-parameter model nomograms. Figure 7 shows how the degree of constriction (A_{min} sq cm) and the degree of mouth opening (A/l cm) influence the frequencies of F1 and F2 at the four d_o



(a) Hard palate (above) (b) Soft palate (below) (c) Upper pharynx (above) (d) Lower pharynx (below)

Fig. 8 Comparison of F_1 and F_2 of Bulgarian vowels (Tilkov) and the Stevens and House three-parameter model nomograms for the four basic vowel configurations (cf. Fig. 7)

values corresponding to the four relevant constriction locations. In Fig. 8 Tilkov's Bulgarian vowels have been superimposed on the same grid, for comparison.

Firstly, Fig. 8a confirms that the /ă/ F1/F2 spectrum is hardly likely to be derived from a palatal configuration. Considerable lip rounding (A/l 0.2-0.5 cm) would be needed to lower F2 of a palatal vowel to below 1500 Hz, whereas /ă/ is a spread-lip vowel. This confirms that the Stojkov x-ray profile for /ă/ should be taken with caution.

Figure 8b shows that the F1 and F2 of /ă/ can be reached from a velar configuration with less rounding than for /u/ (A/l 0.3-0.6 cm against 0.1 cm for /u/) and with a more open velar passage (A_{min} 0.5-2 sq cm). The larger velar opening would be obtained by lowering the tongue body relative to the mandible (which is also a possible interpretation of Tilkov's x-ray data, see Fig. 2d and the discussion above, and represents the first solution 3.3 above). This would make /ă/ a spread-lip counterpart to /u/.

Figure 8c shows that the F1 and F2 of /ă/ can also be reached by widening a constricted upper pharynx (A/l >2 sq cm would raise F2 beyond 1000 Hz). This is also a possible interpretation of the x-ray data (cf. Tilkov's /ă/ and /o/ profiles in Fig. 1 and the discussion above) and represents solution 3.1 above. This would make /ă/ a spread-lip counterpart to /o/.

Finally, Fig. 8d shows that the F1 and F2 of /ă/ can also be reached from a low pharyngeal configuration by narrowing the mouth opening (A/l <0.6 cm against 0.6-3 cm for /a/), e.g. by not lowering the mandible so far as for /a/, and by widening the constricted lower pharynx (A_{min} >2 sq cm). This is also a possible interpretation of the x-ray data (cf. Tilkov's /ă/ and /a/ profiles in Fig. 1) and represents the second solution 3.3 above. This would make /ă/ a close (narrower jaw opening) counterpart of open /a/ (larger jaw opening).

5. CONCLUSION

A complete account of phonological vowel reduction is dependent on the analysis of /ă/, see for example how the different possible solutions outlined in section 3 affect the formulation of the rules governing the vowel alternations between stressed and non-stressed syllables.

The analysis of the published x-ray data and an articulatory interpretation of the published F1 and F2 frequencies of /ă/ yielded several possible solutions: the /ă/ configuration can be achieved by modifying any of the three non-palatal configurations and may be related to velar [u], upper pharyngeal [o] or low pharyngeal [a]. Thus, /ă/ may be a spread-lip counterpart to rounded [u] or [o] or a close counterpart (narrow jaw opening) to open (large jaw opening) [a]. The solution least favoured by Bulgarians is that based on velar [u] and the solution that is usually preferred is the one related to low pharyngeal [a].

An articulatory interpretation of spectral data based on more than two formants should narrow the choice between possible solutions.

It is our intention to pursue this question further by articulatory analysis of cinefluorographic motion films, by acoustical analysis of spectrographic data and and by computer modelling of individual articulatory manoeuvres.

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