The Bulgarian Stressed and Unstressed Vowel System. A Corpus Study.

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Abstract

The reduction of the six Bulgarian vowels (i, ɛ, a, ɜ, ɔ, u) to a four- or (in some dialects) three-vowel subsystem (i, (ɜ), ɜ, u) in unstressed syllables is generally accepted. But a number of studies disagree on the exact nature of the reduction process. Claims differ as to whether or not /a/ merges phonetically with /ɜ/, and /ɔ/ with /u/, or whether the assumed neutralized oppositions take a phonetically intermediate quality ([ɐ] and [o]). Previous acoustic analyses have been based on very few, and almost exclusively male speakers. The present study uses all the men's and women's vowels from the Babel contemporary standard Bulgarian (CSB) read speech corpus. Mid-vowel F1 and F2 values were normalized to remove inter-speaker differences and statistical comparisons of stressed and unstressed vowel productions performed. Results confirm the raising of unstressed /a/ and /ɔ/ reported previously, but raising is found to affect all vowels when unstressed except /i/. Unstressed /a/ and /ɔ/ are raised to the quality of stressed /ɜ/ and /u/ respectively (effectively neutralizing the opposition), but remain distinct from unstressed /ɜ/ and /u/, which are raised from their stressed vowel positions. The mechanism underlying the reduction process is discussed.

Index Terms: vowel reduction, stress, neutralization

1. Introduction

Despite a number of phonetic analyses of vowel reduction in Bulgarian [1-10] the exact nature of the reduction process remains anything but clear. Considerable differences in the vowel formant values reported, coupled with the small number of speakers (1 to 4) analyzed, make it difficult to reach a convincing conclusion. It is generally accepted that in CSB the six stressed Bulgarian vowels /i, ɛ, a, ɜ, ɔ, u/ are reduced to a subsystem of four (three in some dialects) /i, (ɛ), ɜ, u/ in unstressed positions. Opinions differ, however, as to the phonetic quality of the unstressed vowels, and consequently theories of the reduction process diverge. Several authors [3, 8, 9] see a phonological reduction process where the /a/-/ɜ/ opposition is neutralized in a schwa-like mid-central [ə], /ɔ/-/u/ is neutralized in [u] and, in the dialects with a three-vowel subsystem, /ɛ/-/i/ is neutralized in [i]. This implies target undershoot in unstressed non-close front and back vowels with a resistance to such undershoot in close and mid-central vowels. Bojadziev, among others, reports that unstressed /a/ is neutralized in all dialects, whereas complete and consistent reduction of /e/ and /o/ is restricted to eastern dialects [7]. the Bulgarian Academy Grammar [5] and the Handbook of the International Phonetics Association [11] on the other hand, identify an intermediate quality for the reduced vowels, with /ɛ/-/i/ neutralizing to [e], /ɔ/-/u/ neutralizing to [o]. Since the Handbook of the IPA describes the usual /ɜ/ is as a more retracted, closer [ɤ], the neutralization of /a/-/ɜ/ in [ə] also represents an intermediate quality. This implies additional defined targets for the unstressed vowels, since the undershoot explanation for /ɛ/, /a/ and /ɔ/ is confronted with a degree of *over*shoot for /i/, /ɤ/ and /u/. Wood & Petturrson suggest an articulatorily economical explanation, which sees the unstressed vowels as products of reduced mandibular opening, with no change to the oral or pharyngeal configuration [9]. The present study addresses these different views with a more substantial amount of speech material, produced by more speakers, both women and men, than has hitherto been analysed.

2. Material and Methods

The material analyzed was continuous speech (sentences and short passages) taken from the Bulgarian Babel database [12]. The material had been read by 20 speakers (12 male and 8 female) who were characterized as CSB speakers. The overall length of the analysed material is about 40 minutes. All stressed and unstressed vowels in non-palatalized contexts were manually segmented on the basis of the synchronized microphone signal and spectrogram. F1 and F2 were measured at the vowel mid-points using praat scripts. After discarding tokens which did not allow reliable spectral analysis, 5537 remained for further processing. Given the nature of the texts, these were unequally distributed over the six stressed vowels and the six corresponding unstressed vowels (see Table 2).

The formant values were normalized by using the difference between each speaker's average value for each vowel and the group average for the same vowel as normalization factor. I.e. the individuals' vowel spaces were projected onto the group vowel space, in effect aligning the vowel triangle centroids and correcting for dispersion differences. This reduced the scatter round each vowel mean which stemmed from inter-speaker differences, making the statistical determination of possible vowel merging or remaining distinctive quality in unstressed vowels more precise.

A MANOVA was performed with vowel and speaker as independent variables and F1, F2 and duration as dependent variables. The Levene test of equal variance revealed significant variance differences across vowels, requiring a series of t-tests with Bonferroni correction (α=0,0167) for the pairwise comparison of the vowels.

In view of the dominant F1 shift (open to close) of stressed to corresponding unstressed vowel that is apparent from nearly all previous studies, intra-vowel correlations between F1 and vowel duration were calculated for all vowels to determine the strength of any stress-independent

link between vowel height and duration. This has strong implications for any theoretical interpretation of vowel reduction.

3. Results

The MANOVA showed highly significant main effects of vowel on F1 and F2 ($p<0.001$ in both cases), absolutely no effect of speaker, indicating the efficacy of the normalization process, and consequently no speaker-vowel interaction.

Table 2 shows the group-mean F1 and F2 values for each of the vowels. This reveals the general pattern of F1 reduction from stressed to unstressed and the more varied degree and direction of the F2 shift.

Table 2. *Means and standard deviations per vowel category /i, ɛ, a, ɜ, ɔ, u/ and stress*

Vowel		*n*	F1		F2	
			M	*SD*	*M*	*SD*
[+str]	/i/	368	393	68	2233	327
	/ɛ/	411	615	97	1862	251
	/a/	553	773	116	1447	188
	/ɜ/	158	579	100	1472	197
	/ɔ/	343	688	99	1090	176
	/u/	108	446	77	1069	168
[-str]	/i/	657	384	64	2170	351
	/ɛ/	860	500	101	1843	276
	/a/	1205	564	107	1520	254
	/ə/	202	545	101	1504	234
	/ɔ/	631	461	81	1077	213
	/u/	41	434	73	1099	216

3.1. Reductions and neutralizations

In Table 3 the significance levels of the relevant pair-wise vowel comparisons are shown.

Reduction in the front vowels results in the following groupings and formant value hierarchy (low to high formant values from left to right):

F1: $i_{[-str]} = i_{[+str]} < \varepsilon_{[-str]} < \varepsilon_{[+str]}$

F2: $\varepsilon_{[-str]} = \varepsilon_{[+str]} < i_{[-str]} < i_{[+str]}$

As would be predicted for CSB speakers, the front vowels do not undergo neutralization. In terms of vowel height, unstressed /i/ is numerically 'higher' than stressed /i/ but not significantly so. The mid-open position shows significant /ɛ/-raising, but not sufficient to merge with stressed or unstressed /i/. Unstressed /i/ has significantly lower F2 values than stressed /i/.

The central vowels are traditionally said to show neutralization and this is confirmed in the vowel-pair comparisons for vowel height:

F1: $ɜ_{[-str]} < ɜ_{[+str]} = a_{[-str]} < a_{[+str]}$

F2: $a_{[+str]} < ɜ_{[+str]} = ɜ_{[-str]} = a_{[-str]}$

Unstressed /a/ is raised and merges with stressed /ɜ/ but unstressed /ɜ/ is also raised and remains distinct from unstressed /a/. As far as F2 is concerned, unstressed /a/ again groups with the mid-central vowels, with higher F2 values than stressed /a/.

Table 3. *Probabilities and significance levels of vowel comparisons*

Vowel pair	Sig. F1	Sig. F2
$/a/_{[+str]}$ vs. $/a/_{[-str]}$	.000	.000
$/a/_{[+str]}$ vs. $/ɜ/_{[-str]}$	.000	.000
$/a/_{[+str]}$ vs. $/ɜ/_{[+str]}$	.000	.000
$/a/_{[-str]}$ vs. $/ɜ/_{[-str]}$	.000	n.s.
$/a/_{[-str]}$ vs. $/ɜ/_{[+str]}$	n.s.	n.s.
$/ɜ/_{[-str]}$ vs. $/ɜ/_{[+str]}$	.000	n.s.
$/ɔ/_{[-str]}$ vs. $/ɔ/_{[+str]}$	.000	n.s.
$/ɔ/_{[-str]}$ vs. $/u/_{[-str]}$	.003	n.s.
$/ɔ/_{[-str]}$ vs. $/u/_{[+str]}$	n.s.	n.s.
$/ɔ/_{[+str]}$ vs. $/u/_{[+str]}$	.000	n.s.
$/ɔ/_{[+str]}$ vs. $/u/_{[-str]}$	.000	n.s.
$u/_{[-str]}$ vs. $/u/_{[+str]}$	n.s.	n.s.
$/i/_{[+str]}$ vs. $/i/_{[-str]}$	n.s.	.000
$/i/_{[+str]}$ vs. $/ɛ/_{[+str]}$	.000	.000
$/i/_{[+str]}$ vs. $/ɛ/_{[-str]}$	.000	.000
$/i/_{[-str]}$ vs. $/ɛ/_{[+str]}$	.000	.000
$/i/_{[-str]}$ vs. $/ɛ/_{[-str]}$	.000	.000
$/ɛ/_{[+str]}$ vs. $/ɛ/_{[-str]}$	.000	n.s.

The back vowels pattern similarly to the central vowels in that unstressed /ɔ/ is raised, no longer distinct from stressed /u/. Also unstressed /u/ is raised and remains distinct from unstressed /ɔ/, though, as an already high vowel, it does not have the same scope for raising as unstressed /ɜ/. Thus it is not significantly different from stressed /u/:

F1: $(u_{[-str]} = u_{[+str]})$ & $(u_{[+str]} = ɔ_{[-str]}) < ɔ_{[+str]}$

F2: $u_{[+str]} = ɔ_{[-str]} = u_{[-str]} = ɔ_{[+str]}$

There are no significant shifts in F2.

3.2. Reductions correlated with Duration

As stated in the Introduction, the degree to which F1 lowering is linked to shorter vowel duration has strong implications for a theory of vowel reduction and our understanding of speech production (cf. also [9]). Table 4 shows average durations for stressed and unstressed vowels for the two genders.

Table 4. *Vowel duration averages for women's and men's stressed and unstressed vowels*

vowel		duration male		duration female	
		M	SD	M	SD
[+str]	/i/	66,48	17,87	88,70	24,22
	/ɛ/	85,20	18,01	111,49	28,34
	/a/	94.20	22.37	122,85	27,57
	/ɜ/	64,05	15,83	89,84	28,10
	/ɔ/	88.95	18,26	114,74	24,67
	/u/	57,68	16,28	85,13	23,58
[-str]	/i/	55,67	19,84	66,05	24,98
	/ɛ/	52,98	18,80	62,02	19,73
	/a/	58,59	16,63	64,10	23,45
	/ɜ/	55,78	16,53	62,52	19,64
	/ɔ/	53,55	16,43	62,70	21,69
	/u/	59,54	17,13	65,23	22,39

Table 5 gives the Pearson r values for stressed and unstressed vowels. The overall message from Tables 4 and 5 is that there is indeed a general tendency *within* vowel categories for F1 to be lower for shorter vowel durations. However, although statistically significant for all except the close vowels, the effect is numerically weak. Even the strongest correlations – for the two mid-central vowels (/a/$_{[-str]}$ and /ɜ/$_{[+str]}$) – r^2 only predicts 10.3% and 14.8%, respectively, of the variance. Given correlation coefficients for non-close vowels, it is not surprising that for the close vowels, where the proximity of the tongue to the palate constrains further approximation, duration-dependent F1 lowering is quasi random.

Table 5. *Pearson correlations for F1 with duration*

Vowel	r	Sig.	n
a$_{[+str]}$	.158**	(.000)	553
a$_{[-str]}$	.321**	(.000)	1205
ɜ$_{[+str]}$	.385**	(.000)	158
ɜ$_{[-str]}$	.140*	(.024)	202
i$_{[+str]}$	.045	n.s.	368
i$_{[-str]}$	-.016	n.s.	657
ɛ$_{[+str]}$	.157**	(.001)	411
ɛ$_{[-str]}$	.227**	(.000)	860
u$_{[+str]}$	.109	n.s.	108
u$_{[-str]}$	.013	n.s.	41
ɔ$_{[+str]}$	.107*	(.024)	343
ɔ$_{[-str]}$	.151**	(.000)	631

Compared to the massive 'phonological' vowel movement from stressed to unstressed (see Figure 1), these intra-category, duration dependent shifts in F1 are very small. The evidence points therefore to two distinct processes: on the one hand, a universal, articulatory phonetic, time-driven undershoot, and on the other, a phonological reduction with defined targets for the unstressed vowels.

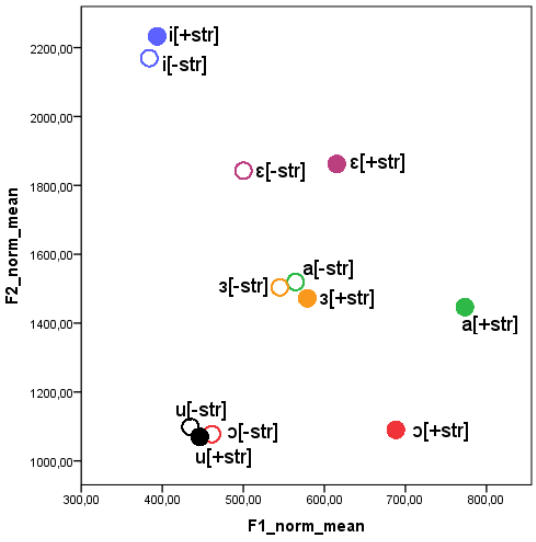

Figure 1: *Group average F1/F2 vowel plot*

Though the diachronic development of a phonological 'reduction rules' is not completely understood, the fact that both phonological vowel raising and articulatory undershoot only apply to non-high vowels is strong evidence for the assumed link between the two (cf. [9]).

4. Discussion and Conclusions

It is relatively clear from the results of our analyses which of the theoretical models of Bulgarian vowel reduction appears more plausible for the CSB material examined here. There are no indications that high vowels are lowered to merge with raised low vowels in an intermediate vowel quality as the Bulgarian Academy Grammar [5] and Handbook of the [11] report. The general pattern is one of low and mid vowel raising, as [3, 8, 9] have reported. This results in the neutralization of the low central with the mid-central vowel and of the mid back with the close back vowel. Articulatory undershoot of the mid-central vowel means that its unstressed counterpart remains numerically but not perceptually distinct from the raised unstressed /a/.

Interestingly, even in the front vowel series, which in CSB, in contrast to e.g. eastern Bulgarian dialects, retains a vowel height opposition, there is a clear raising of unstressed /ɛ/. This suggests an unfinished reduction process, since the resultant unstressed vowel has an intermediate mid-close /e/ quality. There is, however no lowering of the unstressed /i/ to merge with the unstressed /ɛ/.

Pettersson & Wood [9] argue, and in fact demonstrate that reduction is continuous, not categorical. Their linear regression evidence is, however, less than convincing, since a regression calculated across categories separated along one dimension (here F1) will inevitably emerge as significant. We argue in our results section with reference to the means shown in Figure 1 that, while there is significant intra-category variance, stemming from consonantal context and, in the case of the stressed vowels from varying degrees of phrasal accentuation, it is small in comparison with the stressed-to-unstressed shift. This is underlined by the two F1/F2 scatter plots in Figure 2a, b below. The greater scatter of the individual unstressed vowels in Figure 2b (a general feature of unstressed vowels) cannot disguise the fact that the cores of the central and back distributions are separate from those of the corresponding stressed vowel distributions, as the highly significant F values demonstrate.

Contrary to the claims of the Bulgarian Academy Grammar [5] our results show that the reduction process applies to the back vowels as strongly as it does to the central vowel group. Again, scrutiny of Figure 2a, b in conjunction with Figure 1 provides convincing evidence. In addition we note that the /u/ vowels in our data are fronted, as also reported in [3]. This contrasts with the findings of [1, 5 and 9], where /u/ was clearly more retracted. It is unclear whether this reflects dialectal variation or an on-going fronting process in CBS.

Past studies have also failed to consider possible gender differences. Our vowel duration measurements reveal systematically shorter vowel durations for the men ($p < 0.001$, cf. Table 4). In addition, there are three durational different sub-groups for the women speakers,

with the six stressed vowels falling into two groups and all the unstressed vowels in the third:

/a, ɔ, ɛ/$_{[+str]}$ > /ɜ, i, u/$_{[+str]}$ > /i, u, a, ɔ, ɛ, ɛ /$_{[-str]}$

By contrast, the men have no such separation of unstressed from stressed vowels, though the three vowels in the sub-group with the longest average duration (/a, ɔ, ɛ /$_{[+str]}$) is the same as the women's longest sub-goup (c.f. Table 4).

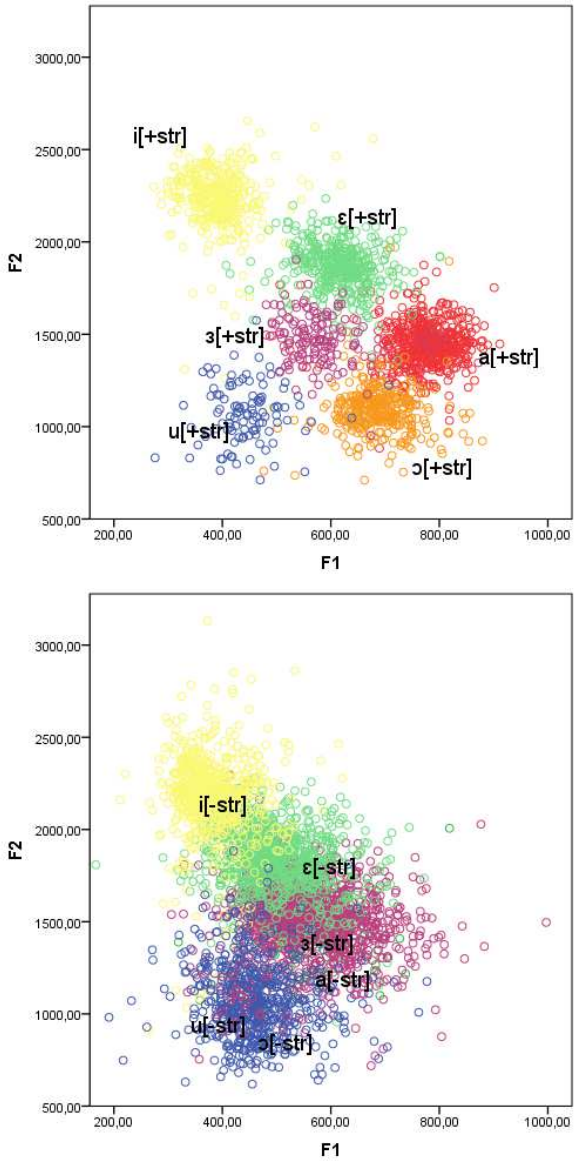

Figure 2a, b: *F1/F2 scatter plots for stressed (top) and unstressed (bottom) CSB vowels*

This first representative instrumental study of CSB has gone a considerable way towards clarifying the unstressed vowel-reduction processes. Work in the past has tended to focus on the Bulgarian dialects [13] and the standard variant has been neglected. Indeed, studies which purport to investigate 'Bulgarian' have also used speakers with a non-standard regional background [3, 10].

A final implication of the results of this study concern the dissemination of information about a standard national language variant, in this case CSB. The 'definitive' description of 'Standard Bulgarian' pronunciation should presumably be the account published in the Handbook of the International Phonetics Association. Thorough and careful as the analysis by [11] is, the data analysed is anything but representative (this is not a criterion stipulated for language descriptions in the Handbook). We have already commented on the reduction patterns identified there, which disagree with our more representative results. The choice of /ɤ/ for the stressed mid-central vowel is also misleading, since it implies a backness quality which is certainly not borne out by our results. The /ɜ/ is located robustly midway between /ɛ/ and /ɔ/.

5. References

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