ACOUSTIC CHARACTERISATION OF SCHWA: A COMPARATIVE STUDY

Sally A R Bates

Department of Linguistics, Edinburgh University

ABSTRACT

This paper presents results from a comparative acoustic study of the contextual variability displayed by the twelve monophthongs in Southern British Standard English. These indicate a hierarchy of vowel robustness which, in general, parallels the hierarchy of inherent vowel duration. Maximal context-dependency for schwa supports the proposal that it has no independent phonetic target but is completely unspecified for tongue position.

INTRODUCTION

The principle aim of the investigation was to assess the magnitude and patterns of contextual variability displayed by schwa, the central or 'reduced' vowel in English, in the light of the proposal that it may be completely unspecified for tongue position [1]. Following their study of schwa tokens in /pVpə'pVpə/ sequences, Browman & Goldstein reject a targetless analysis in favour of a co-production account of schwa's variability. They claim that schwa is characterised by an active gesture but that this gesture is completely overlapped by the gesture for a following full vowel. However, in a more recent study which examines coarticulatory effects on Dutch schwa in 'VCəC and Cə'CV nonsense words, Van Bergem [2] presents evidence in support of a targetless analysis. The present investigation represents an extension of Browman & Goldstein's and Van Bergem's work insofar as it examines schwa in a more comprehensive range of contexts and in meaningful connected speech data. It also provides a comparative framework in which to assess schwa's variability and its targeted/targetless status.

A second objective was to address the question of whether the full vowels vary inherently with respect to the extent to which they are susceptible to coarticulatory effects. Stevens' [3] quantal theory of speech production predicts greater acoustic stability for the point vowels /i, ɑ, u/ than for the non-point vowels. According to Stevens, these vowels are articulated in those regions of the vocal tract where articulatory perturbations have minimal effects on the acoustic output. Recasens [4] proposes that front vowels are inherently more stable than back vowels because they involve a greater degree of mechanical constraint on the tongue-body during their production. These proposals are further explored in a quantitative evaluation of the relative context-dependency shown by the vowels /i, ɪ, ɛ, a, ɜ, ɑ, ʌ, ɒ, ɔ, o, u/. The data comprises over 8000 vowel tokens, including over 2000 schwa tokens. These are taken from 660 phonemically balanced sentences read by one male speaker.

STATISTICAL ANALYSIS AND RESULTS

The overall degree of context-dependency shown by different vowels was assessed in a series of multiple regression analyses. The predictor variables were preceding context (lhs) and following context (rhs), characterised by formant values averaged over the initial and final 10 ms of the vowel, and vowel duration (dur). The dependent variable was either F1 or F2 sampled at the durational vowel midpoint. The results are presented in Tables 1 and 2. The R^2 value represents the total proportion of variance in the dependent variable that is accounted for jointly by the predictor variables. The β values indicate the relative weighting of the unique contributions made by the individual predictors. All R^2 values are significant at $p < .01$. With few exceptions, the β values are also significant at $p < .01$. Those values which are not significant are italicised and emboldened.

Schwa displays the highest levels of context-dependency. The mid-high, lax vowels /ɪ/ and /ʊ/ display a comparable degree of context-dependency along F2 and, in the case of /ɪ/, along F1 also. Following schwa and the mid-high, lax vowels, the tense vowel /u/ and the mid-low, lax vowels /ʌ/ and /ɛ/, in descending order, show the highest R^2 values. The low back vowels /ɑ/ and /ɔ/ show the least overall context-dependency followed, in ascending order, by the low, front vowel /a/, the mid-low, back vowel /ɒ/ and the tense vowels /ɜ/ and /i/. All vowels display a lower absolute amount of context-dependency along F1. However, with the exception of /ʊ/, the rank ordering of vowels from least to most context-dependent is similar for both F2 and F1.

The β values indicate generally greater carryover than anticipatory coarticulation. One-way analyses of variance performed on the same data, also show greater differentiation in vowel midpoint value as a function of preceding compared with following consonantal place of articulation for all vowels except /ə/ and /ɪ/. Schwa and /ɪ/ both show a slightly greater degree of differentiation in midpoint value as a function of following consonantal place of articulation (see [5]).

CONCLUSION

The results of the regression analysis provide strong support for the theory that schwa is unspecified for tongue position. Given that 100% prediction accuracy is unlikely owing to the presence of random variability, 92% explained variance arguably denotes maximal context-dependency along F2. The total proportion of explained F1 variance is also high and comparable to the levels of explained F2 variance reported for /ə/ by Van Bergem [2] (between 72% and 79%). This finding provides empirical support for Keating's [6] phonetic underspecification hypothesis. A strong interaction of context effects through schwa, highly linear first and second formant trajectories and a comparable range in onset, midpoint and offset value for the same schwa data reported by Bates [5] also support the characterisation of schwa as a phonetically transparent segment which is interpolated through by the trajectory between adjacent specified segments.

Table 1: Regression results for F2
'lhs' denotes preceding context, 'rhs', following context and 'dur', duration.
β values which fail to attain significance at p < .01 are italicized and emboldened

	R^2	F-value	df.		β value	
				lhs	rhs	dur
i	.5294	246.77	658	.48	.32	.44
ɪ	.8963	3747.83	1301	.57	.50	.14
ɛ	.6973	343.94	448	.52	.53	.18
a	.4155	75.35	318	.53	.43	.09
ə	.9166	8057.98	2199	.57	.52	.02
ɜ	.5192	51.48	143	.61	.36	*.02*
ɑ	.1119	6.69	181	.24	*-.10*	-.21
ʌ	.5785	129.94	284	.71	.40	-.18
ɔ	.3770	50.22	249	.49	*.05*	-.46
ɒ	.4449	91.63	343	.56	.18	-.43
ʊ	.9024	283.53	92	.57	.49	-.16
u	.7569	210.64	203	.52	.53	*.04*

Table 2: Regression results for F1

	R^2	F-value	df.		β value	
				lhs	rhs	dur
i	.3923	141.61	658	.45	.36	-.17
ɪ	.7328	1194.72	1307	.53	.48	.08
ɛ	.4209	109.02	450	.35	.46	.38
a	.3633	61.44	323	.50	.22	.54
ə	.7372	2049.44	2192	.55	.43	.17
ɜ	.3818	29.43	143	.29	.31	.44
ɑ	.1320	8.77	173	.31	.15	.23
ʌ	.4355	72.77	283	.39	.33	.49
ɔ	.0650	5.76	249	.23	*-.11*	*-.02*
ɒ	.3359	57.66	342	.41	.32	.32
ʊ	.3428	16	92	*.13*	.47	.22
u	.4514	55.69	203	.28	.52	*-.14*

Evidence that the full vowels vary inherently with respect to degree of context-dependency is also consistent with Keating's [7] proposal that segments may show varying degrees of underspecification along a given dimension. According to Keating's window model of coarticulation, segments are characterised by the full range of contextual variability they exhibit. Segments with a full or narrow specification for a given feature show less overall variability along the corresponding phonetic dimension(s) than segments which are less narrowly specified. The results reported here indicate a continuum of phonetic underspecification. Broadly speaking, this ranges from the inherently long vowels /ɑ, ɔ, a/ which may be thought of as the most narrowly specified and hence least contextually variable, to the less narrowly specified and more contextually variable short vowels /ɛ, ʌ, ʊ/, to schwa and /ɪ/ which have the shortest intrinsic durations and which, being completely unspecified, show maximal context-dependency.

The comparable level of context-dependency observed for /ɪ/ as for schwa accords with its status as the other reduced vowel in English. The near maximal context-dependency along F2 for /ʊ/ may also be attributed to its lexical distribution. A high proportion of /ʊ/ tokens occur in words which carry relatively little semantic weight such as the modal verb forms "could, would, should" or the prepositions "to, into" and the pronoun "you" in which it alternates with [u]. Phonetic vowel reduction is closer to diachronic fossilisation in these function words than in words which carry a heavier semantic load.

Greater acoustic stability for the more peripheral vowels (i.e. /ɑ, a, i/) and for the back, rounded vowels /ɔ, ɒ/ compared with the more central vowels (i.e. /ɪ, ɛ, ʌ, ʊ/) accords with Stevens' [3] quantal predictions. The high context-dependency observed for /u/ may be attributed to the effects of lip-rounding coupled with its fronted realisation by the present speaker. The results do not support Recasens (1991) proposal that front vowels are inherently more stable than back vowels.

REFERENCES

[1] Browman, C. P. & Goldstein, L. (1992), Targetless schwa: an articulatory analysis. In Ladd, B. and Docherty, G. J. (Eds.), *Labphon II*, 26-67. Cambridge University Press, Cambridge.

[2] Van Bergem, D. (1994), A model of coarticulatory effects on the schwa. *Speech Communication*, vol. 14, 143-162.

[3] Stevens, K. N. (1989), On the quantal nature of speech. *Journal of Phonetics*, vol. 17, 3-45.

[4] Recasens, D. (1991), An electropalatographic and acoustic study of consonant-to-vowel coarticulation. *Journal of Phonetics*, vol. 19, 177-192.

[5] Bates, S. (forthcoming). Towards a definition of schwa: an acoustic investigation of vowel reduction in English. *Phd thesis*. University of Edinburgh.

[6] Keating, P. (1988), Underspecification in phonetics. *Working papers in Phonetics*, vol.69. University of California Linguistics Club.

[7] Keating, P. (1990), The window model of coarticulation. In Kingston, J. and Beckman, M. E. (Eds.), *Papers in Laboratory Phonology I: Between Grammar and Physics of Speech*. Cambridge University press, Cambridge.