ROLE OF INDIVIDUAL VARIABILITY IN THE FIRST FORMANT (F1) FOR VOWEL SHIFTING IN RP

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ABSTRACT

This paper examines the variability of first formant (F1) values in each speaker for potential reasons of shifting RP English vowel /æ/ in relation to /iː, e, ɑː, ʌ, ɜː/ across different age groups by using hierarchical cluster analysis to show proximity variations in F1 between certain vowels for each speaker.

The data used in this study are (1) published data comprising of multiple speakers who belong to different age groups and (2) F1 values are obtained with acoustic analysis from three published recordings spoken by three male RP speaking phoneticians in relation to F1 values of their own cardinal vowels for reference.

Results show different variation types are found within the same age group and the same type of variability is observed in different age groups. Some speakers show /æ/-/ɑː/ proximity; some show /æ/-/ʌ/ proximity and some speaker show /æ/-/e/-/ɜː/ closeness across different age groups.

This study shows individual difference patterns of proximity in /æ/ in relation to other vowels and the implication of individual differences in vowel shifting.

Keywords: the first formant (F1), RP, cardinal vowels, vowel shifting, within-speaker variation

1. INTRODUCTION

Lowering of /æ/ in RP appears be well-established [3] p. 83, [14] p. 292 claims, '[i]t may even be the case for some speakers that /æ/ and /ʌ/ are merged, variably, at least'. This study examines these propositions focusing on F1 as it is related to vowel height/openness when formant frequencies are plot in conventional F1 against F2 (or F2-1) charts. However, it is an issue on the point raised in [9] regarding placing central vowels in a formant vowel plot in relation to traditional vowel quadrilateral. This study examines synchronic within-speaker variations of F1 of /æ/ relative to /iː, e, ɑː, ʌ, ɜː/ in the different age groups for RP.

To see speaker-internal variability difference patterns of /æ/ in relation to /iː, e, ɑː, ʌ, ɜː/, this study uses hierarchical cluster analysis to show proximity or closeness between values in F1 across different vowels in each speaker without F2.

To obtain F1 values without factors phonetic environments, this study also examines vowels spoken in isolation from materials for EFL purposes by trained phoneticians. Since vowel quality description by trained observers utilises Cardinal Vowels (CVs) as reference points, e.g. [10], CVs spoken by the same trained phoneticians were examined acoustically as a reference.

2. THE METHOD

The present study comprised of two types of analysis: cluster analysis with data sets from published materials [8] and acoustic data and statistical analysis of vowels by British school RP speaking phoneticians from recordings [5, 6, 12] in relation to CVs spoken by them.

2.1. Data sets for statistical analysis

2.1.1. Materials and speakers

Speakers labelled S1-1, S1-2, S2-1, S2-2, S3-1, S3-2, S4-1, S4-2, correspond to the same RP male speakers in [8]. S1 group members were born in 1928-1938; S2 group in 1946-1951; S3 in 1961-1966 and S4 in 1976-1981.

2.1.2. Hierarchical cluster analysis

Unlike discriminant analysis, information about external categories to which variables belong is not required. Euclidean distance with Ward method in hierarchical cluster analysis using *R* [13] was used. Result for each speaker was obtained in a dendrogram.

2.2. Acoustic analysis vowels by RP speaking phoneticians

2.2.1. Materials and subjects

Measurements of formants of the RP vowels were

made from three published copyrighted EFL materials [5, 6, 12] spoken by three male RP speaking trained phoneticians. This selection is based on the fact that two of them (ACG and JDO) learnt the CV system from Daniel Jones himself. And all of them are trained phoneticians within the tradition of the teaching of Daniel Jones.

Phonetician 1 (ACG): 1917-1985 [15].
Phonetician 2 (JDO): 1919-1998 [19:x].
Phonetician 3 (JCW): 1939 - Present [16].

Phoneticians 1 and 2 were born earlier than any of the speakers in [8] and recording was published in 1975 [6] and 1980 [12] respectively.

In all cases vowels pronounced in isolation were elicited. Recordings were played by an analog cassette player and sampled at 22.05kHz, 24 bits using Roland Edirol UA-1EX with Audacity 1.3 Beta [1].

2.2.2. Cardinal vowels

For comparison, F1 of the CVs 1-5 [i-e-ɛ-a-ɑ] spoken by three Phoneticians 1, 2 and 3 were obtained. For Phoneticians 1 and 2, data in mel [11]: 88-89 were converted to Hz using a formula (2) derived from (1) technical mel scale by Fant [4]. Set 1 for Phonetician 1 (ACG) and set 8 for Phonetician 2, (JDO) were chosen from [11].

(1) $$technical\ mel = \frac{1000}{log2} \log\ 1 \quad f/1000$$

(2) $$f = 1000 \times \exp\ mel/\frac{1000}{log2} - 1$$

Calculation by R [13] was made in two steps.

```
> tt <- 1000/log(2) # tt or any letters other than
    used for functions.
> 1000*(exp(1000/tt)-1)
```

For CVs 1-5 [i-e-ɛ-a-ɑ], and vowel [æ] that is between half-open and open, by Phonetician 3, the copyrighted recordings of 1979 version of the IPA, which was recorded in 1987 [18] and 1993 version recorded in 1995 [17] were employed.

2.2.3. Measurements

One token from each vowels by each Phonetician was measured due to 1) distribution imbalance of each vowel across the Phoneticians in their recordings and 2) results of preliminary auditory impressionisic analysis of the tokens and visual spectrographic examinations of formants of all vowel types spoken by the three Phoneticians. F1 frequencies were obtained by manually placing the cursor at midpoint in each wide-band spectrogram using *Praat* [2]. The frequency was obtained with the aid of formant tracking. The same procedure with all the tokens measured were done in two separate days for confirmation. All tokens were re-sampled at 10kHz. Frequencies obtained were rounded.

3. RESULTS AND DISCUSSION

3.1. Hierarchical cluster analysis

Choice of methods (Ward's, complete linkage, group average, single linkage or other) is one of the issues and there is no easy way of choosing it and different methods could produce different results. Vertical axis in a dendrogram shows how far the similarity is between the two tokens.

S1-1 and S1-2 show different proximity patterns. S1-1 has closer openness between /ɑː/ and /ʌ/. Unlike S1-2, /æ/ is closer to /e/ or /ɜː/ but less to /ɑː/ in proximity. It is also noticeable the height of /ʌ/ shows some variability. Since this is a synchronic study of within speaker variations, it is impossible to show such variability is due to personal change such as reported in [7] or this speaker's idiosynchratic behaviour of /ʌ/.

A cluster comprising of /e/ and /ɜː/ in S1-2 has much farther F1 proximity to /æ/ belonging to the clusters of /ɑː/ and /ʌ/ than S1-1.

Figure 1: Dendrogram for S1-1.

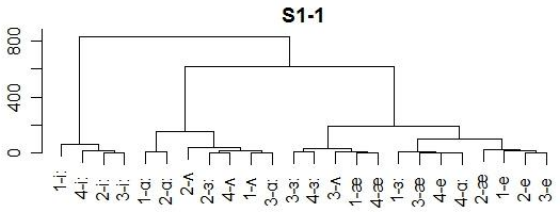
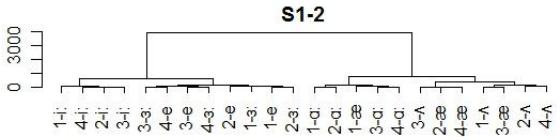


Figure 2: Dendrogram for S1-2.



/æ/ has more variability in F1 in S2-1 than in S2-2. /æ/ in S2-1 is /æ/-/ɑː/-/ʌ/. /æ/ in S2-2 appears to comprise own cluster. But one token make a cluster with /ɑː/ remotely. This is not clear whether it is /æ/-/ɑː/ or /æ/ separate pattern.

Figure 3: Dendrogram for S2-1.

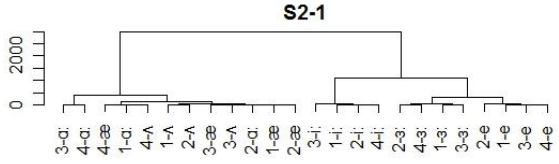


Figure 4: Dendrogram for S2-2.

/æ/ in S3-1 seems to be very separated from cluster of /ɑː/ and /ʌ/. One token of /æ/ belongs to the cluster very far. Situation is similar to S2-2 but S3-1 is more spread. This is interpreted that within the S3-1's vowel space /æ/ is distinctively apart from /ɑː/ and /ʌ/. Variability in F1 in S3-2 is greater S2-2. The /æ/ separation is also seen in S4-1 and S4-2. However, in S4-1 and S4-2 /ʌ/ does not cluster to each other. S4-2 is clearly /æ/ separate type.

Figure 5: Dendrogram for S3-1.

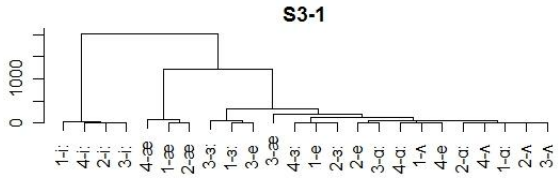


Figure 6: Dendrogram for S3-2.

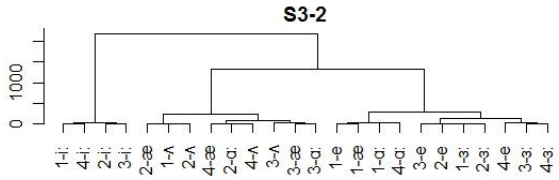


Figure 7: Dendrogram for S4-1.

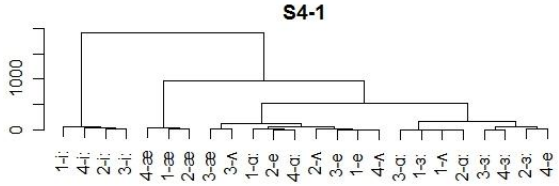


Figure 8: Dendrogram for 4-2.

3.2. RP speaking phoneticians' vowels

In cases of recordings by Phoneticians, outliers may not need to be considered for RP vowels. As they are trained speakers and materials are produced well under control for EFL purposes. However, cases for CVs are not straightforward. Values from ACG and JDO were converted from mel to Hz and acoustic data in the original source may have been better with the present standard of recording device. Recordings themselves were judged and supervised by Daniel Jones and chose 31 sets out of 92 sets recorded by the total of eleven trained phoneticians who were fully acquainted with the CV system [11] p. 77-78.

All Phoneticians share that the proximity of /æ/ is smaller to /ʌ/ than to /ɑː/. RP /æ/ in ACG shows closeness to RP /æ/-/e/-/ʌ/-/ɜː/. This is similar to S1-1 but ACG is clearly older. This is different from JDO and JCW. Their RP /æ/ show more similarity to CV4 /a/ and RP /ʌ/. It is not because of age group differences since ACG and JDO were born only in two year distance. However, this might be due to smaller sample size.

Table 1: Frequencies of F1 (RP) from three recordings made for EFL.

	iː	e	æ	ɑː	ʌ	ɜː
ACG	276	601	601	652	618	550
JDO	311	533	857	687	857	533
JCW	396	584	824	635	806	533

Table 2: Converted F1 frequencies from mel of cardinal vowels 1-5 by Phoneticians 1 and 2 [11]. Set 1 for Phonetician 1 (ACG); Set 8 for Phonetician 2 (JDO). Obtained values in Hz are rounded. Data of Phonetician 3 (JCW) from the recording [17, 18].

	CV1	CV2	CV3	ASH	CV4	CV5
	i	e	ɛ	æ	a	ɑ
ACG	315	419	676	---	993	753
JDO	181	400	580	---	959	664
JCW 1987	242	362	635	721	755	481
JCW 1995	311	430	618	722	943	567

Figure 9: Dendrogram for ACG.

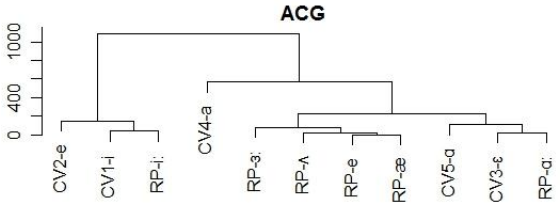


Figure 10: Dendrogram for JDO.

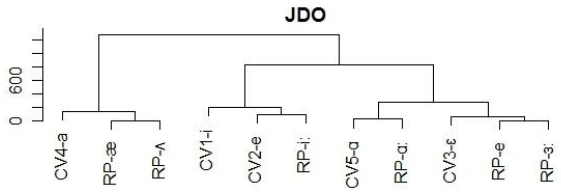
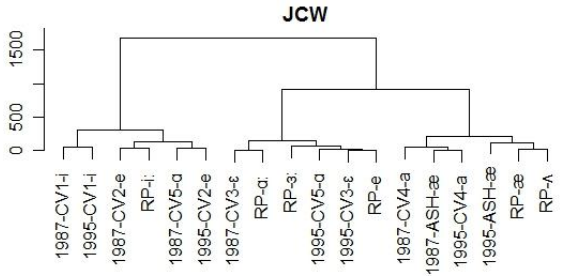


Figure 11: Dendrogram for JCW.



4. CONCLUSION

Across different age groups, some speakers show /æ/-/ʌ/ proximity in F1 (JDO, JCW) and some show /æ/-/ɑː/. Some show /æ/-/e/-/ɜː/ (S1-1, ACG). Some show /æ/ clear separation (S4-2) and some less so distinct separation (S2-2, S3-1, S4-1). Some show proximity /æ/-/ɑː/-/ʌ/ more variances (S1-2).

Results do not show the lowering of /æ/ directly but it shows proximity in F1. However, it shows closeness in F1 in relation to other vowels /iː/ or /ɑː/. Perceptual test is necessary to validate how F1 alone contributes to perceptual height quality. This study supports findings of [10].

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