Stability of Vowel Systems

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1.0 Introduction.

1.1 Investigations concerning the position of formants have, as a rule, been carried out by having the vowels of a vowel-system pronounced once by a large number of informants. This led to the position that quite a bit had become known as regards the distributions of F_0, F_1, and F_2 amongst speakers, but that little information was gained about the distribution which an individual speaker presents. This investigation was designed to gain more insight in the distribution of individual speakers.

2.0 Type of Investigation.

2.1 As will be gathered from the above the investigation aimed primarily at data-collecting.

2.2 The data thus obtained were subjected to a number of analyses, which are, however, by no means exhaustive.

3.0 Method.

3.1.0 General Remarks.

3.1.1 Two types of variation can be distinguished:

1. variations appearing with great intervals of time (long replication)
2. variations appearing with short intervals of time (short replications)

3.1.2 An investigation was carried out on:

1. vowels spoken in isolation (vowels)
2. vowels isolated from words spoken in isolation (words).

3.1.3 The group of testees consisted of:

1. five male speakers
2. five female speakers

No selection was carried out as regards, for instance, the absence of dialect characteristics as this is irrelevant in connection with the stability of vowel systems.

3.1.4 Five recordings were made of each speaker with an interval of a fortnight. During each recording session the 12 vowels of Dutch (in isolation and in isolated words) were uttered. This was repeated once per session. At the end of the five sessions there were therefore 10 productions available for each speaker as regards the vowel system in isolated vowels and 10 productions of the vowel system for vowels in words spoken in isolation.

3.2.0 Test Procedure.

3.2.1 In view of the large number of recording sessions (50) the test was automatized. The stimulus material was written on slides which were projected on to a screen situated in a sound-proof cubicle via a noise-isolating window.

3.2.2 The series of stimulus-slides was composed as follows:
Slide 1: "Name the month of the year."
During the naming of months the recorder was adjusted to the right level.

Slide 2: "Your name."
This to identify the recording with.

Slides 3 - 14 inclusive contained the following words.

biet [bit], bit [bɪt], buut [byt]
boet [but], beet [bet], bed [bɛt]
peut [pøt], bot [bɔt], boot [bot]
put [pœt], bad [bat], baat [bɑt]

All words are CVC combinations of which the consonants are plosives.

Slides 15 - 26 inclusive contained the following written vowels, of which the phonetic transcription, included here, was not on the slides.

ie = [i], i = [I], uu = [y]
oe = [u], ee = [e], e = [ɛ]
eu = [ø], o = [ɔ], oo = [o]
u = [œ], a = [a], aa = [ɑ]

3.2.3 The slides 3 - 14 inclusive and 15 - 26 inclusive were presented to the subjects in random permutation with five second intervals. The presentation of slides 3 - 26 inclusive was repeated once per session.

3.2.4 The procedure was repeated five times per speaker with an interval of a fortnight per session.

4.0 Measurements.

4.1 Copies of the original recordings were made for measuring purposes. Formants (F_1 and F_2) and periodicity (F_o) were measured with the aid of a rotating reproducing head[4].

4.2 The vowels were lifted out of the words and were made visible on the screen of a storage oscilloscope. Isolated vowels were made visible with the aid of the same apparatus.

4.3 The formants, defined as natural frequencies of the oral cavity and the larynx, were measured from the sound curve[3) + 5)].

5.0 Data Analysis.

5.1 The values of the measurements obtained for F_o, F_1, and F_2 were not obtained from mutually independent samples, so that the values of F_o, F_1 and F_2 must be regarded as a multivariate description of a vowel. The statistical analysis must, therefore, be done with multivariate techniques. As our main interest was the dispersions and the positions of the centroids the data were processed with the multivariate analysis of variance program MANOVA.[1) + 2)]

5.2 A 'MANOVA' was executed on each of the following data-sets

1. Vowels spoken in isolation by males (VM)
2. Vowels spoken in isolation by females (VF)
3. Vowels lifted from words spoken in isolation by males (WM)
4. Vowels lifted from words spoken in isolation by females (WF)

5.3 The analyses were executed for a complete four (4) factor design.

The pertaining factors are:

1. T = testees (5 levels)
2. V = vowels (12 levels)
3. L = long replication (5 levels)
4. S = short replication (2 levels).

5.4 All tests of significance were executed on a 5% level.

6.0 Results.

6.1.0 Dispersions.

The results of the tests of homogeneity of dispersions of the main effects can be found in table 6 - I.

6 - I. Dispersions of main effects.*1)

	T	V	L	S
VM	+	+	-	-
VF	-	+	-	-
WM	+	+	-	-
WF	+	+	-	-

*1) + = significantly varying dispersions
- = identical dispersions.

6.1.1 The appearance of significantly differing dispersions for the T-effect means that testees produce mutually differing vowel systems.

6.1.2 The appearance of significantly differing dispersions for the V-effect means that the vowels show differing dispersions (both in size and in the orientation of the scatter diagram).

6.1.3 For the effects of L and of S no differing dispersions were found. This means that the moment when an investigation is carried out is immaterial for the total orientation and the size of the vowel system of a speaker. The conclusion that may be drawn from this is that an investigation may be interrupted and continued at another moment as the structure of the system remains the same.

6.2.0 Centroids.

6.2.1 Testing of the equality of centroids may, strictly speaking, only be done when the dispersions of different groups are equal. Because of the fact that the test on equality of centroids is robust, this pilot investigation was tested, none the less, on equality of centroids.[1] This procedure is quite common; in the case of an analysis of variance on uni-variables equality of variances are seldom tested. The dissimilarity of the dispersions means that a further analysis, with a discriminant analysis for instance, is not permitted. The test on equality of centroids has great power whereby small differences in a large amount of material lead easily to significant results.

6.2.2 In the first place all effects have been tested against the highest interaction (TVLS) on the hypothesis of similarity of centroids. The results of these tests are given in table 6 - II.

6 - II. Testing of effects against highest interaction.*1)

	T	V	TV	L	TL	VL	TVL	S	TS	VS	TVS	LS	TLS	VLS
VF	+	+	+	+	+	+	+	-	-	-	-	+	+	-
VM	+	+	+	+	+	+	+	+	+	-	-	-	+	-
WF	+	+	+	+	+	+	+	-	-	-	-	-	+	-
WM	+	+	+	+	+	+	+	+	+	-	-	-	+	-

*1) + = significant effect
- = identical centroids.

On account of these results the pooling of the following effects was decided upon:

S + TS + VS + TVS + LS + TLS + VLS + TVLS = Error.
TLS was included in the Error, as the phenomenon where the different testees show varying deviations between the two productions per session for the different sessions, is, after all, an experimental variation which is to be expected. In this experiment female speakers keep their vowel systems constant in a short replication, this in contrast to male speakers. For males also the TS-effect is significant. This means that either men show different deviations or that the significant S-effect is caused by one or more testees. The analysis shows too that the S-effect is small and that the significance of the result is probably caused by the slightly greater range in the average F_2-values for males. On account of this it was decided to include S and TS into the Error term. So that this term was composed out of the S-effect and all its interactions. However, it is important to investigate in a further experiment, if there is a systematic difference between men and women in short replications, or if the absence of significant T- and S-effects in women has been caused by the a-selectness of the female sample. (Two out of the five women were speech-therapists).

6.2.3 When tested against the pooled Error term the following effects, viz T , V , TV , L , TL , VL , and TVL are significant for all four sub-divisions of this experiment.

6.3.0 Interpretation.

6.3.1 T-effect.
The centroids of the average vowel systems of the speakers are different.

6.3.2 V-effect.
The centroids of the different vowels, averaged over the subjects, are different.

6.3.3 TV-effect.
Except for the fact that the centroids of vowel systems are different for the speakers, which may point to a translation of conform systems, the speakers show individual deviation for the various vowels.

6 - III. Average values for F_0, F_1, and F_2.

	VV			VM		
	F0	F1	F2	F0	F1	F2
[I]	243	449	2347	148	369	2095
[y]	251	323	1836	151	289	1733
[ɑ]	233	822	1265	134	741	1182
[e]	238	487	2154	133	455	2038
[i]	248	304	2599	149	286	2257
[a]	236	703	1049	137	666	1026
[ɔ]	238	618	947	140	575	969
[ə]	243	508	1651	142	508	1656
[o]	236	485	953	138	488	900
[u]	257	369	756	152	318	736
[ø]	236	460	1635	139	454	1761
[ɛ]	233	700	1911	140	601	1834

	WV			WM		
	F0	F1	F2	F0	F1	F2
[I]	249	399	2238	146	379	2131
[y]	258	313	1836	152	299	1778
[ɑ]	238	837	1267	133	736	1217
[e]	243	467	2114	139	436	1979
[i]	259	303	2477	151	291	2399
[a]	239	703	1078	138	637	1062
[ɔ]	245	559	978	146	546	996
[ə]	259	531	1580	154	518	1683
[o]	242	472	953	140	473	996
[u]	257	341	827	152	339	828
[ø]	253	446	1667	148	444	1651
[ɛ]	238	654	1656	141	589	1733

6.3.4 L-effect.
For the long replication deviations occur in the position of the centroid of the vowel system when averaged over all speakers.

6.3.5 TL-effect.
Except for the fact that the centroids of the vowel system when averaged over the speakers are different for the long replication, a fact which may point to a translation of the vowel system, the speakers also show individual translations for their particular systems. (a non-significant TL-effect combined with a significant L-effect would point to a common trend).

6.3.6 VL-effect.
Except for the fact that the centroids of vowel systems, when averaged over the speakers, are different for the long replication, the shifts occur for individual vowels differently.

6.3.7 TVL-effect.
Each speaker has his own VL-effect, in other words the shift signalled in 6.3.6 is dissimilar for the different speakers.

6.4.0 Average values for F_0, F_1, and F_2.

6.4.1 The average values of F_0, F_1, and F_2 for the four sub-divisions of the investigation are given in Table 6 - III.

6.4.2 Conspicuous differences in pitch can be seen in Table 6 - III for the various vowels. As these values are the averages of 10 productions of five speakers it might be supposed that any given deviations from the average pitch would have been levelled out. As there is a Spearman Rank correlation of 0.92 ($P < .01$) between the pitch levels for the vowels of females and the vowels of males the hypothesis seems justified that each vowel has its own particular pitch.

7.0 Literature.

1) Blom, J.G. (1972), 'Multivariate Variantie Analyse', Interne Publicatie no. 36, Institute of Phonetic Sciences, Amsterdam.

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3) Koopmans - van Beinum, F.J. (1970), 'Vergelijkend Fonetisch Klinkeronderzoek', Interne Publicatie no. 26, Institute of Phonetic Sciences, Amsterdam.

4) Mol, H., van der Stelt, J.M. 'Segmentator' (still to be published)

5) 'Syllabus Akoestische Fonetiek' (1969), Interne Publicatie no. 25, Institute of Phonetic Sciences, Amsterdam.