# VOWEL REDUCTION IN DUTCH

extended version

by Florina J. Koopmans-van Beinum

## 1. INTRODUCTION

This report is an extended version of the paper read at the Eighth International Congress of Phonetic Sciences in Leeds 1975 on vowel reduction in Dutch as a function of the context. It is a well known fact that there is vowel reduction in different contextual situations. For instance Tiffany (1959) showed differences already between the vowel utterances of trained and untrained speakers, between stressed and unstressed vowels, and between vowels in context and vowels in isolation. Shearme and Holmes (1961) compared vowels in isolated monosyllables with vowels in a continuous context read aloud. Lindblom (1963) investigated the influence of different consonantal environments and varying timing conditions on Swedish vowels, and Delattre (1969) combined an acoustic analysis of vowel reduction with an articulatory one for stressed and unstressed syllables in four languages. But, as far as I know, there has not yet been any systematic analysis of vowels in all possible contextual situations of one speaker, that is to say: vowels produced by one and the same vocal tract.

## 2. MEASUREMENTS

For this purpose measurements were done concerning duration, basic frequency, first formant and second formant of the twelve Dutch vowels of two speakers, one trained and one untrained, in eight different contextual situations, viz.:

| | |
|---|---|
| 1) Vowels spoken in isolation | ( 3x12) |
| 2) Vowels spoken in isolated monosyllabic words | ( 5x12) |
| 3) Vowels in stressed position in a text read aloud | (10x12) |
| 4) Vowels in unstressed position in a text read aloud | (10x12) |
| 5) Vowels in stressed position in a retold story | (10x12) |
| 6) Vowels in unstressed position in a retold story | (10x12) |
| 7) Vowels in stressed position in normal conversation | (10x12) |
| 8) Vowels in unstressed position in normal conversation | (10x12) |

The criterion for "stressed" was in the first place word accent, but a number of syllables marked as stressed in words was dropped owing to the influence of the sentence stress pattern. The judgement was done by two listeners who came practically to the same conclusions. The duration of all vowels, their basic frequency ($F_0$) and their formant frequencies ($F_1$ and $F_2$) were measured directly from the sound curve by means of a rotating reproducing head and oscilloscope. The formant frequencies were measured on the basis of the distribution of the zero-crossing with the principle in mind that the sound curve of a vowel is composed of superimposed natural frequencies of the oral cavity and the larynx.

For every vowel one measuring point was chosen, usually in the middle of the vowel. The duration of each vowel was measured in milliseconds. The starting-point of the vowel was considered to be there where the formant pattern of the vowel was clearly visible for the first time and the end of the vowel was taken to be the point where the pertaining formant pattern disappeared. If the vowel was adjacent to a voiced consonant the vowel proper was isolated with the aid of the gates of the rotating reproducing head. The judgement was made by ear, but also by eye with the aid of the oscilloscope.

No special attention has been paid to the consonantal environment of the vowels in contexts 3 to 8. Every first ten specimens of each vowel were chosen for measuring in the expectation that a random set of data or, rather, a set of data that gives a good reflection of the normal distribution of consonant-vowel-conso-

nant combinations would be the result. Context 2 consisted of four sets of monosyllabic words, read from cards, with the consonants [b]-[t], [b]-[r], [k]-[s], [k]-[r], and one set of monosyllabic words produced by the speakers by naming objects depicted on cards. Here the consonantal environment varied. Although we know that in Dutch vowels before [r] shift in the direction of [œ] or [ə], it was shown some years ago that [r] does not exert its influence on the preceding vowel until the last part of the vowel signal (Koopmans, 1969). Since in the present investigation there was only one measuring point in the middle of the vowel the influence of the consonants is considered to be as small as possible.

Apart from the vowels of the contextual situations 1 to 8, a series of sustained vowels of both speakers was measured ($F_0$, $F_1$ and $F_2$) at five positions in the sound curve.

The reason for including these vowels was twofold: in the first place to complete the speech material of both speakers as much as possible, and in the second place since in the past conclusions often were based on measurements from sustained vowels.

Concerning the two speakers one might ask what is the criterion for trained and untrained. In this case the answer is easy: the trained speaker uses his voice and his pronunciation as part of his profession, for the untrained speaker a careful pronunciation does not play a role in his job.

## 3. DATA PROCESSING

Mean values and standard deviations of the duration, the basic frequency, the first and the second formant were calculated for both speakers in the eight different contextual situations, and for the sustained vowels (no duration measurements).

The Kendall coefficient of concordance (W-test) was calculated for the mean values of the duration in the eight contexts of

both speakers, and for the mean values of $F_0$, to find out if the speakers in these eight situations in a consistent way made use of vowel duration, and of $F_0$.
To get a better insight in the relations between the different contextual situations correlation matrices were computed for the mean durations in the eight contexts, and for mean $F_0$, for both speakers.

## 4. RESULTS

### 4.1 Formant frequencies.

Fig. 1 and Fig. 2 show the mean formant values of the vowels in the formantfield in the eight different contextual situations (numbered 1 to 8) for the trained (Fig. 1) and for the untrained (Fig. 2) speaker.
Fig. 3 shows the distribution in the formantfield of the vowels of context 1 (shaded) and of the vowels of context 8 (non-shaded) for the trained speaker (on top) and for the untrained speaker (at the bottom). The ellipses indicate the areas containing 50% of the realizations under the assumption of a normal bi-variate distribution.
Fig. 4 shows the distribution in the formantfield of the vowels of context 1 (shaded) and of the sustained vowels (non-shaded) for the trained speaker (on top) and for the untrained speaker (at the bottom).
Tables 1 - 16 give the results of the measurements of vowels in the eight contextual situations of the trained speaker (tables 1 - 8) and of the untrained speaker (tables 9 - 16).
Tables 17 and 18 give the results of the measurements on sustained vowels.

4.2 Duration.

In Fig. 5 and 6 the mean values of the vowel duration in the eight contextual situations are rendered by graphs. The points representing the mean values are connected only to distinguish the different contexts.

To determine the association among the eight contextual situations when ranking the vowels according to their duration the Kendall coefficient of concordance W was computed for both speakers apart and in combination (table 19) and the significance of W was tested. For the eight sets of rankings we can test the significance of W by computing the value of $X^2$. The null hypothesis that the rankings of vowel durations in the eight contexts are unrelated, has to be rejected for the speakers separately at a level of $p < 0.001$ ($X^2 \geq 24.3$ with df=7) and also for the contexts 1 to 4 of both speakers together and for the contexts 5 to 8 of both speakers together.

To get a more detailed insight we divided the data: the relation between the contexts 1 to 4 for each of the speakers and the contexts 5 to 8 for each of the speakers. Here the null hypothesis that the rankings of vowel durations are independent has to be rejected at a level of $p < 0.01$ ($W \geq 0.57$ for 12 vowel durations in 4 contexts).

Table 21 gives the correlation matrices for the mean vowel durations in the contextual situations 1 to 8 for each of the two speakers; table 22 gives the same for the situations 1 to 4 for both speakers together, and of the situations 5 to 8 for both speakers together. Almost all correlation coefficients are rather high. It is peculiar that for the trained speaker durations in contexts 6 and 8 are highly correlated, and also the durations in contexts 1, 2, 3, 4, 5 and 7, but the correlations between these two groups are low.

4.3 Basic frequency.

In Fig. 7 and 8 mean values of the basic frequency of the vowels in the eight contextual situations are illustrated by graphs. Here too the points representing the mean values are connected only to distinguish the different contexts.
It is a well-known fact that vowels pronounced in isolated position (context 1) and also vowels spoken in isolated monosyllabic words (context 2) possess their own intrinsic basic frequency. For Dutch this has been demonstrated by Van der Stelt, Blom and van Herpt (1973).
It seemed interesting to determine the association among the eight contextual situations when ranking the vowels for the mean values of their basic frequency. Again the Kendall coefficient of concordance W was computed for both speakers apart and in combination (table 20) and the significance of W was tested.
The null hypothesis that the rankings of the mean values of the basic frequency in the eight contexts are unrelated, has to be rejected for each of the two speakers at a level of $p < 0.001$ ($X^2 \geqslant 24.3$ with df=7) and also for the contexts 1 to 4 of both speakers together and for the contexts 5 to 8 of both speakers together.
The null hypothesis that the rankings of the basic frequency in the contexts 1 to 4 for each of the two speakers are unrelated, has to be rejected at a level of $p < 0.01$ ($W \geqslant 0.57$ for 12 values of basic frequency in 4 contexts), but in contexts 5 to 8 for each of the two speakers we find $W = 0.55$ (trained speaker) and $W = 0.45$ (untrained speaker), so here we have to accept our null hypothesis that the rankings of the basic frequency in contexts 5 to 8 are unrelated.
Table 23 gives the correlation matrices of the mean values of the basic frequency in the contextual situations 1 to 8 for each of the two speakers; table 24 gives the same of the

situations 1 to 4 for both speakers together and of the situations 5 to 8 for both speakers together.

## 5. CONCLUSIONS

Although it is rather premature to draw detailed conclusions on vowel reduction at this stage of the investigation (only two speakers), we can ascertain the following when comparing the results from the eight contextual situations and from the sustained vowels for the two speakers.

### 5.1 Formant frequencies.

5.1.1 Both speakers make progressively smaller contrasts when their vowels are compared from context 1 to 8 (Fig. 1 and 2). The first impression is a formant reduction in the direction of [œ]. The degree of reduction differs for vowels in stressed and in unstressed positions, the greatest reduction being found in contexts 6 and 8, both unstressed syllables and free choice of words.

5.1.2 The degree of reduction differs for the two speakers; the untrained speaker shows a greater reduction than the trained speaker. For both speakers the formant triangle remains distinct in all eight contextual situations, even in unstressed ones, although there is a great overlap in context 8 for the untrained speaker (Fig. 3).

5.1.3 A close comparison of the formant triangles of contexts 1 to 8 (Fig. 1 and 2) does not really show a reduction to the neutral [œ] which is the centroid of the vowel triangle, but the centroids of the vowel triangles of the eight contextual situations seem to be distributed

along the line to the origin.

5.1.4 The expectation that sustained vowels show the greatest contrasts would have made them a logical starting-point for the description of vowel reduction. From Fig. 4 and from tables 17 and 18 however, we can see that in the case of sustained vowels almost all vowels for both speakers have shifted to the origin in comparison with isolated non-sustained vowels. This may point to a maximum length of the vocal tract while sustaining vowels.
There is another striking point concerning the sustained vowels: in several cases the formants of the vowels are multiples of $F_0$.
Besides, when $F_0$ is rather high (which is the case for the trained speaker) we find that $F_0$ and $F_1$ coincide in vowels with a low $F_1$.
All together it is the question whether it is justified to use conclusions drawn from sustained vowels for the description of normal speech.

5.2 Duration.

When comparing the graphs and tables rendering the mean values of the vowel durations in the eight contextual situations (Fig. 5 and 6), we can establish the following.

5.2.1 Both speakers make their vowels progressively shorter from context 1 to 8, with the restriction that in unstressed positions in connected speech vowels are generally shorter than in stressed positions. So none of the speakers uses a longer vowel duration as a compensation for the reduction of formant values.

5.2.2 The difference between long vowels [a], [o], [ø], [e] and short vowels [ɛ], [œ], [ɑ], [ɪ], [ɔ] in contexts 1 and 2 is considerably greater for the trained speaker than for the untrained speaker. For both speakers the

difference between long and short vowels becomes very small in unstressed positions.

5.2.3 In connected speech the so-called vowels of intermediate length [y], [u] and [i] do not differ in duration from the short vowels.

5.2.4 The Kendall coefficient of concordance as well as the matrices of correlations points to a behaviour as regards duration which is the same for both speakers. The high correlation between the vowel durations in contexts 6 and 8 of the trained speaker and the low correlations with the rest may be the result of his ability to bring a great deal of variation in his speaking.

5.3 Basic frequency.

When comparing the graphs and tables rendering the mean values of the basic frequency of the vowels in the eight contextual situations (Fig. 7 and 8), we can conclude:

5.3.1 The trained and the untrained speaker behave differently as regards their basic frequency.
The most striking point is the high values of $F_0$ in the contexts 3 and 4 of the trained speaker, whereas the untrained speaker uses high $F_0$ values in contexts 1 and 2. This is due to the fact that the former is a professional reader and has trained himself in reading in a higher voice because he knows he is more intelligible that way.

5.3.2 The significantly high coefficient of concordance W for both speakers in the contexts 1 to 4 seems to indicate that even in a text read aloud vowels keep their intrinsic basic frequency, a surprising fact that may be associated with the special, unnatural reading intonation, particularly striking in the reading of the untrained speaker.

At this point the correlation matrices give some differentiation between the two speakers: for the trained speaker context 3 is not highly correlated with contexts 1, 2 and 4 (resp. 0.3, 0.1, 0.0).

5.3.3 In contexts 5 to 8 the two speakers are using their basic frequency in a different way, even so that there are negative correlations between them for which we cannot give a satisfying explanation. A multivariate analysis may give more clearness here.

## 6. DISCUSSION

The results of this investigation confirm that vowel reduction can be described as a function of the contextual situation and training of the speaker. It appears not only in formant values, but we also observed a reduction in vowel duration and basic frequency.

But a lot of questions are still open. There is the question of the influence of the adjacent consonants. Further we can ask if there is any association between vowel reduction and the pause-filling vowel-like "uh" (Annan, 1971). Then we have the problem of the sustained vowels and their deviating relation to vowel reduction. Besides we have to investigate the connection between duration, basic frequency and formants, and finally to try to relate this acoustic analysis to an articulatory model.

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TABLE 1 trained speaker: vowels spoken in isolation.

| | M.DUR. | SD.DUR. | M.$F_0$ | SD.$F_0$ | M.$F_1$ | SD.$F_1$ | M.$F_2$ | SD.$F_2$ |
|---|---|---|---|---|---|---|---|---|
| u | 200.0 | 30.0 | 160.0 | 34.6 | 316.6 | 16.0 | 783.3 | 23.0 |
| o | 350.0 | 70.0 | 116.6 | 33.2 | 421.6 | 25.6 | 861.6 | 131.7 |
| ɔ | 180.0 | 70.0 | 123.3 | 27.5 | 600.0 | 17.3 | 1030.0 | 137.4 |
| ɑ | 163.3 | 35.1 | 123.3 | 31.7 | 658.3 | 32.5 | 1260.0 | 65.5 |
| a | 350.0 | 62.4 | 111.6 | 33.2 | 691.6 | 49.3 | 1398.3 | 59.2 |
| y | 253.3 | 50.3 | 131.6 | 37.8 | 291.6 | 5.7 | 1901.6 | 91.1 |
| ø | 323.3 | 70.9 | 126.6 | 24.6 | 425.0 | 17.3 | 1715.0 | 90.9 |
| œ | 150.0 | 10.0 | 135.0 | 26.4 | 443.3 | 38.8 | 1573.3 | 75.7 |
| i | 176.6 | 5.7 | 140.0 | 44.4 | 293.3 | 17.5 | 2503.3 | 45.0 |
| I | 170.0 | 43.5 | 138.3 | 31.7 | 403.3 | 25.1 | 2258.3 | 158.7 |
| e | 286.6 | 49.3 | 126.6 | 25.6 | 393.3 | 18.9 | 2220.0 | 121.2 |
| ɛ | 170.0 | 10.0 | 130.0 | 21.7 | 653.3 | 10.4 | 1965.0 | 60.6 |

TABLE 2 trained speaker: vowels spoken in isolated monosyllabic words.

| | M.DUR. | SD.DUR. | M.$F_0$ | SD.$F_0$ | M.$F_1$ | SD.$F_1$ | M.$F_2$ | SD.$F_2$ |
|---|---|---|---|---|---|---|---|---|
| u | 168.0 | 70.4 | 145.0 | 0.0 | 308.0 | 14.4 | 809.0 | 58.1 |
| ɑ | 222.0 | 38.9 | 123.0 | 7.5 | 407.0 | 38.3 | 817.0 | 58.4 |
| ɔ | 98.0 | 16.4 | 131.0 | 4.1 | 506.0 | 62.7 | 959.0 | 85.7 |
| ɑ | 118.0 | 24.8 | 120.0 | 6.1 | 657.0 | 17.8 | 1266.0 | 35.7 |
| a | 226.0 | 37.1 | 123.0 | 14.4 | 712.0 | 6.7 | 1437.0 | 15.6 |
| y | 142.0 | 53.1 | 135.0 | 25.4 | 296.0 | 14.7 | 1861.0 | 141.7 |
| ø | 192.0 | 54.0 | 125.0 | 22.6 | 372.0 | 49.9 | 1614.0 | 52.6 |
| œ | 88.0 | 21.6 | 142.0 | 6.7 | 451.0 | 21.9 | 1446.0 | 54.1 |
| i | 130.0 | 54.7 | 144.0 | 10.8 | 292.0 | 6.7 | 2470.0 | 67.0 |
| I | 100.0 | 15.8 | 128.0 | 4.4 | 385.0 | 30.0 | 2156.0 | 133.4 |
| e | 220.0 | 74.4 | 128.0 | 6.7 | 392.0 | 47.9 | 2129.0 | 93.0 |
| ɛ | 120.0 | 24.4 | 131.0 | 12.9 | 605.0 | 41.6 | 1741.0 | 54.8 |

TABLE 3 trained speaker: vowels in stressed position in a text read aloud.

| | M.DUR. | SD.DUR. | M.$F_0$ | SD.$F_0$ | M.$F_1$ | SD.$F_1$ | M.$F_2$ | SD.$F_2$ |
|---|---|---|---|---|---|---|---|---|
| u | 70.0 | 22.2 | 174.5 | 48.5 | 341.5 | 36.0 | 826.5 | 121.7 |
| o | 125.0 | 31.7 | 166.5 | 33.5 | 421.0 | 28.3 | 876.5 | 104.2 |
| ɔ | 77.0 | 8.2 | 172.5 | 25.4 | 440.0 | 46.0 | 1035.0 | 142.8 |
| ɑ | 67.5 | 10.8 | 155.5 | 35.7 | 612.0 | 39.1 | 1093.0 | 78.1 |
| a | 140.0 | 21.6 | 146.5 | 36.6 | 648.5 | 29.8 | 1344.0 | 121.9 |
| y | 86.5 | 27.3 | 143.5 | 33.1 | 306.0 | 38.8 | 1774.0 | 165.3 |
| ø | 107.0 | 44.2 | 185.5 | 38.8 | 414.5 | 64.0 | 1624.5 | 192.1 |
| œ | 65.5 | 18.9 | 166.5 | 28.8 | 423.5 | 44.0 | 1509.0 | 158.1 |
| i | 78.0 | 25.1 | 158.5 | 33.5 | 322.0 | 25.6 | 2450.0 | 57.7 |
| I | 72.0 | 17.5 | 170.5 | 23.8 | 387.0 | 17.9 | 2280.0 | 170.2 |
| e | 136.0 | 42.4 | 152.0 | 14.7 | 399.0 | 20.2 | 2143.0 | 129.7 |
| ɛ | 87.5 | 13.1 | 173.5 | 25.9 | 590.0 | 53.1 | 1779.5 | 208.0 |

TABLE 4 trained speaker: vowels in unstressed position in a text read aloud.

| | M.DUR. | SD.DUR. | M.$F_0$ | SD.$F_0$ | M.$F_1$ | SD.$F_1$ | M.$F_2$ | SD.$F_2$ |
|---|---|---|---|---|---|---|---|---|
| u | 75.5 | 24.0 | 142.5 | 30.1 | 341.5 | 39.2 | 923.5 | 143.4 |
| o | 84.0 | 29.8 | 121.5 | 23.6 | 400.5 | 55.1 | 1011.5 | 137.3 |
| ɔ | 73.0 | 19.4 | 133.5 | 21.7 | 453.5 | 52.0 | 1001.5 | 114.3 |
| ɑ | 81.0 | 21.8 | 128.0 | 23.1 | 596.5 | 43.0 | 1153.0 | 107.9 |
| a | 91.5 | 32.6 | 133.0 | 26.4 | 630.5 | 45.9 | 1388.0 | 126.5 |
| y | 70.5 | 25.3 | 138.5 | 29.2 | 300.5 | 39.6 | 1835.5 | 179.4 |
| ø | 88.5 | 31.1 | 134.5 | 29.5 | 387.5 | 36.2 | 1603.5 | 113.0 |
| œ | 63.5 | 15.1 | 132.0 | 20.3 | 424.0 | 40.4 | 1442.0 | 211.2 |
| i | 69.0 | 13.7 | 134.0 | 23.0 | 323.0 | 27.3 | 2399.0 | 106.6 |
| I | 68.5 | 17.0 | 123.5 | 20.0 | 409.0 | 41.6 | 2086.5 | 212.1 |
| e | 86.0 | 21.7 | 130.5 | 36.2 | 409.0 | 51.3 | 2053.0 | 179.0 |
| ɛ | 70.0 | 28.2 | 133.5 | 26.2 | 558.5 | 69.1 | 1634.0 | 118.4 |

TABLE 5 trained speaker: vowels in stressed position in a retold story.

| | M.DUR. | SD.DUR. | M.$F_0$ | SD.$F_0$ | M.$F_1$ | SD.$F_1$ | M.$F_2$ | SD.$F_2$ |
|---|---|---|---|---|---|---|---|---|
| u | 76.0 | 24.5 | 118.0 | 16.5 | 328.5 | 34.4 | 913.5 | 157.0 |
| o | 100.5 | 23.1 | 110.5 | 26.7 | 468.5 | 45.0 | 1140.0 | 163.0 |
| ɔ | 75.0 | 19.7 | 115.5 | 20.0 | 489.5 | 30.9 | 1007.0 | 118.7 |
| ɑ | 70.5 | 13.6 | 105.5 | 17.0 | 626.5 | 62.8 | 1273.5 | 67.1 |
| a | 131.0 | 30.7 | 93.0 | 7.8 | 661.0 | 50.1 | 1383.0 | 97.0 |
| y | 84.5 | 34.3 | 127.5 | 34.5 | 331.5 | 47.8 | 1655.0 | 268.1 |
| ø | 110.5 | 46.2 | 136.0 | 25.1 | 404.0 | 57.5 | 1519.5 | 199.9 |
| œ | 78.0 | 17.5 | 116.0 | 25.2 | 446.5 | 33.2 | 1500.0 | 117.9 |
| i | 95.5 | 49.1 | 128.5 | 23.9 | 311.0 | 31.4 | 2475.0 | 58.9 |
| I | 74.0 | 33.4 | 113.5 | 15.2 | 385.5 | 32.3 | 2059.5 | 144.8 |
| e | 92.0 | 36.1 | 118.5 | 29.1 | 428.5 | 45.3 | 1944.5 | 94.2 |
| ɛ | 77.0 | 21.6 | 111.5 | 18.4 | 577.0 | 43.2 | 1632.5 | 146.3 |

TABLE 6 trained speaker: vowels in unstressed position in a retold story.

| | M.DUR. | SD.DUR. | M.$F_0$ | SD.$F_0$ | M.$F_1$ | SD.$F_1$ | M.$F_2$ | SD.$F_2$ |
|---|---|---|---|---|---|---|---|---|
| u | 64.0 | 23.6 | 119.0 | 26.9 | 346.5 | 39.5 | 1061.5 | 198.8 |
| o | 64.5 | 20.0 | 101.0 | 11.4 | 452.0 | 58.8 | 1188.5 | 188.9 |
| ɔ | 50.5 | 8.9 | 113.0 | 26.8 | 488.5 | 44.0 | 1038.5 | 101.1 |
| ɑ | 55.5 | 12.1 | 93.5 | 9.4 | 571.5 | 62.0 | 1261.5 | 93.3 |
| a | 56.0 | 17.1 | 98.5 | 9.1 | 514.0 | 112.3 | 1487.5 | 157.5 |
| y | 54.0 | 16.4 | 118.5 | 28.5 | 346.0 | 59.5 | 1730.5 | 181.9 |
| ø | 99.5 | 34.9 | 106.0 | 16.2 | 452.5 | 52.3 | 1491.0 | 169.7 |
| œ | 56.5 | 14.9 | 120.0 | 20.6 | 433.5 | 35.2 | 1514.5 | 135.5 |
| i | 51.5 | 17.3 | 99.5 | 11.6 | 319.5 | 25.4 | 2329.0 | 113.9 |
| I | 51.0 | 20.7 | 100.5 | 20.3 | 387.0 | 38.5 | 1953.5 | 125.1 |
| e | 61.0 | 14.4 | 107.5 | 23.8 | 475.0 | 43.8 | 1847.0 | 86.3 |
| ɛ | 51.5 | 15.9 | 96.0 | 14.2 | 522.0 | 76.4 | 1599.0 | 149.6 |

TABLE 7 trained speaker: vowels in stressed position in normal conversation.

| | M.DUR. | SD.DUR. | M.$F_0$ | SD.$F_0$ | M.$F_1$ | SD.$F_1$ | M.$F_2$ | SD.$F_2$ |
|---|---|---|---|---|---|---|---|---|
| u | 63.0 | 17.6 | 115.0 | 35.9 | 325.5 | 15.8 | 903.0 | 153.9 |
| o | 90.0 | 19.4 | 104.0 | 21.7 | 428.5 | 34.4 | 1079.0 | 120.5 |
| ɔ | 57.0 | 13.3 | 98.0 | 12.7 | 461.0 | 63.4 | 993.5 | 151.6 |
| ɑ | 77.5 | 21.2 | 91.5 | 16.8 | 608.5 | 42.6 | 1238.0 | 78.2 |
| a | 105.0 | 24.0 | 99.0 | 16.6 | 642.0 | 23.9 | 1429.0 | 129.9 |
| y | 73.0 | 20.0 | 115.0 | 26.7 | 320.5 | 15.8 | 1764.0 | 155.7 |
| ø | 101.5 | 48.7 | 138.5 | 50.1 | 454.0 | 85.6 | 1534.5 | 130.1 |
| œ | 69.5 | 16.0 | 115.0 | 26.5 | 405.0 | 32.3 | 1464.0 | 108.4 |
| i | 96.0 | 33.7 | 100.5 | 26.5 | 309.0 | 16.9 | 2370.0 | 152.1 |
| I | 67.0 | 13.3 | 112.0 | 18.8 | 379.0 | 36.1 | 2109.5 | 137.2 |
| e | 107.0 | 17.0 | 97.0 | 13.1 | 440.5 | 53.0 | 1948.0 | 137.9 |
| ɛ | 69.0 | 19.1 | 88.5 | 5.2 | 575.0 | 82.8 | 1648.5 | 169.5 |

TABLE 8 trained speaker: vowels in unstressed position in normal conversation.

| | M.DUR. | SD.DUR. | M.$F_0$ | SD.$F_0$ | M.$F_1$ | SD.$F_1$ | M.$F_2$ | SD.$F_2$ |
|---|---|---|---|---|---|---|---|---|
| u | 50.5 | 17.7 | 101.0 | 16.4 | 338.0 | 24.2 | 989.0 | 280.0 |
| o | 66.5 | 26.0 | 105.5 | 18.3 | 417.0 | 46.3 | 1162.0 | 248.7 |
| ɔ | 48.0 | 11.3 | 93.0 | 18.2 | 443.0 | 69.2 | 1045.0 | 123.7 |
| ɑ | 57.5 | 17.8 | 89.5 | 12.5 | 548.5 | 67.8 | 1295.5 | 151.0 |
| a | 55.0 | 12.6 | 84.0 | 7.7 | 565.5 | 67.9 | 1490.0 | 119.0 |
| y | 48.5 | 22.2 | 95.0 | 10.8 | 331.5 | 39.8 | 1687.0 | 215.2 |
| ø | 83.0 | 24.1 | 105.0 | 23.6 | 456.0 | 37.1 | 1673.5 | 247.5 |
| œ | 60.0 | 13.1 | 105.5 | 27.0 | 407.5 | 40.6 | 1466.5 | 142.9 |
| i | 52.0 | 9.1 | 98.5 | 15.4 | 323.0 | 26.4 | 2170.0 | 255.7 |
| I | 43.0 | 8.2 | 93.0 | 8.8 | 383.5 | 31.9 | 1918.0 | 152.4 |
| e | 56.5 | 16.3 | 107.0 | 21.4 | 402.5 | 35.8 | 1846.0 | 146.8 |
| ɛ | 63.0 | 26.5 | 88.5 | 10.2 | 540.0 | 42.4 | 1524.5 | 136.9 |

TABLE 9 untrained speaker: vowels spoken in isolation.

| | M.DUR. | SD.DUR. | M.$F_0$ | SD.$F_0$ | M.$F_1$ | SD.$F_1$ | M.$F_2$ | SD.$F_2$ |
|---|---|---|---|---|---|---|---|---|
| u | 226.6 | 11.5 | 160.0 | 36.0 | 316.6 | 5.7 | 773.3 | 92.5 |
| o | 256.6 | 25.1 | 140.0 | 27.8 | 443.3 | 83.1 | 875.0 | 108.9 |
| ɔ | 173.3 | 23.0 | 151.6 | 23.0 | 468.3 | 11.5 | 906.6 | 95.0 |
| ɑ | 190.0 | 26.4 | 148.3 | 30.1 | 685.0 | 75.6 | 1216.6 | 110.1 |
| a | 250.0 | 26.4 | 145.0 | 22.9 | 750.0 | 73.9 | 1338.3 | 87.7 |
| y | 210.0 | 26.4 | 145.0 | 22.9 | 298.3 | 29.2 | 1760.0 | 52.9 |
| ø | 243.3 | 32.1 | 146.6 | 23.6 | 465.0 | 31.2 | 1521.6 | 88.9 |
| œ | 193.3 | 23.0 | 153.3 | 29.2 | 466.6 | 38.1 | 1515.0 | 61.4 |
| i | 183.3 | 40.4 | 160.0 | 22.9 | 296.6 | 18.9 | 2335.0 | 172.9 |
| I | 183.3 | 20.8 | 151.6 | 18.9 | 378.3 | 25.6 | 2143.3 | 159.4 |
| e | 240.0 | 43.5 | 148.3 | 27.5 | 425.0 | 36.0 | 2056.6 | 188.7 |
| ɛ | 210.0 | 26.4 | 148.3 | 24.6 | 588.3 | 100.1 | 1896.6 | 98.0 |

TABLE 10 untrained speaker: vowels spoken in isolated monosyllabic words.

| | M.DUR. | SD.DUR. | M.$F_0$ | SD.$F_0$ | M.$F_1$ | SD.$F_1$ | M.$F_2$ | SD.$F_2$ |
|---|---|---|---|---|---|---|---|---|
| u | 150.0 | 17.3 | 161.0 | 15.1 | 325.0 | 15.8 | 761.0 | 49.6 |
| o | 178.0 | 14.8 | 148.0 | 13.0 | 454.0 | 42.7 | 942.0 | 95.2 |
| ɔ | 108.0 | 22.8 | 157.0 | 22.5 | 533.0 | 36.8 | 1052.0 | 74.2 |
| ɑ | 120.0 | 18.7 | 154.0 | 19.4 | 638.0 | 18.5 | 1281.0 | 34.3 |
| a | 204.0 | 11.4 | 129.0 | 15.1 | 707.0 | 17.8 | 1385.0 | 62.8 |
| y | 136.0 | 23.0 | 159.0 | 12.9 | 307.0 | 28.8 | 1679.0 | 34.1 |
| ø | 180.0 | 21.2 | 154.0 | 10.2 | 459.0 | 70.4 | 1513.0 | 97.1 |
| œ | 108.0 | 21.6 | 159.0 | 14.7 | 438.0 | 34.9 | 1490.0 | 96.6 |
| i | 140.0 | 12.2 | 153.0 | 23.0 | 302.0 | 24.1 | 2264.0 | 193.5 |
| I | 124.0 | 24.0 | 161.0 | 12.9 | 394.0 | 17.1 | 1977.0 | 51.4 |
| e | 180.0 | 25.4 | 147.0 | 10.9 | 430.0 | 58.7 | 1928.0 | 121.3 |
| ɛ | 124.0 | 15.1 | 142.0 | 13.0 | 560.0 | 36.2 | 1754.0 | 121.9 |

TABLE 11 untrained speaker: vowels in stressed position in a text read aloud.

| | M.DUR. | SD.DUR. | M.$F_0$ | SD.$F_0$ | M.$F_1$ | SD.$F_1$ | M.$F_2$ | SD.$F_2$ |
|---|---|---|---|---|---|---|---|---|
| u | 61.0 | 12.8 | 133.0 | 26.6 | 349.0 | 96.4 | 948.0 | 150.8 |
| o | 112.0 | 22.9 | 105.5 | 12.1 | 426.5 | 49.1 | 885.5 | 89.4 |
| ɔ | 72.0 | 23.9 | 128.0 | 18.2 | 446.0 | 49.3 | 936.5 | 117.1 |
| ɑ | 75.0 | 15.8 | 124.0 | 19.8 | 548.5 | 35.1 | 1096.0 | 98.2 |
| a | 134.0 | 12.6 | 110.0 | 17.9 | 665.0 | 44.7 | 1268.0 | 52.6 |
| y | 79.0 | 34.4 | 125.5 | 23.8 | 322.5 | 32.3 | 1715.0 | 220.9 |
| ø | 122.0 | 44.2 | 128.0 | 22.5 | 423.0 | 51.7 | 1360.5 | 122.4 |
| œ | 58.0 | 16.1 | 117.5 | 23.3 | 407.0 | 27.6 | 1433.5 | 124.5 |
| i | 71.5 | 19.1 | 125.5 | 21.1 | 295.5 | 10.6 | 2298.0 | 78.5 |
| I | 65.0 | 9.7 | 129.0 | 16.4 | 381.5 | 24.2 | 2207.0 | 183.3 |
| e | 109.0 | 23.3 | 123.5 | 21.0 | 409.0 | 46.6 | 2034.0 | 107.6 |
| ɛ | 71.0 | 9.9 | 130.5 | 24.6 | 554.0 | 65.7 | 1710.0 | 197.4 |

TABLE 12 untrained speaker: vowels in unstressed position in a text read aloud.

| | M.DUR. | SD.DUR. | M.$F_0$ | SD.$F_0$ | M.$F_1$ | SD.$F_1$ | M.$F_2$ | SD.$F_2$ |
|---|---|---|---|---|---|---|---|---|
| u | 68.5 | 32.2 | 125.0 | 22.6 | 306.5 | 40.6 | 967.0 | 176.3 |
| o | 63.0 | 27.1 | 101.0 | 6.5 | 419.5 | 47.8 | 1056.5 | 143.4 |
| ɔ | 54.0 | 17.7 | 119.5 | 32.0 | 405.5 | 73.7 | 903.0 | 65.4 |
| ɑ | 59.0 | 25.5 | 108.0 | 19.3 | 504.0 | 85.8 | 1170.0 | 205.1 |
| a | 75.5 | 40.1 | 106.0 | 20.7 | 530.5 | 98.8 | 1384.0 | 200.1 |
| y | 60.0 | 30.1 | 98.5 | 17.4 | 311.5 | 45.1 | 1587.5 | 180.7 |
| ø | 97.0 | 38.3 | 98.5 | 6.2 | 430.0 | 58.7 | 1491.5 | 136.2 |
| œ | 70.0 | 39.7 | 103.0 | 18.5 | 372.0 | 34.2 | 1452.0 | 138.8 |
| i | 57.0 | 14.9 | 108.5 | 22.8 | 321.5 | 32.4 | 2174.0 | 119.7 |
| I | 66.0 | 9.6 | 117.0 | 20.5 | 387.5 | 73.9 | 2103.0 | 178.8 |
| e | 79.0 | 17.2 | 108.0 | 27.2 | 415.5 | 63.7 | 2021.5 | 132.5 |
| ɛ | 46.0 | 12.6 | 118.5 | 22.3 | 464.5 | 112.9 | 1639.0 | 143.7 |

TABLE 13 untrained speaker: vowels in stressed position in a retold story.

| | M.DUR. | SD.DUR. | M.$F_0$ | SD.$F_0$ | M.$F_1$ | SD.$F_1$ | M.$F_2$ | SD.$F_2$ |
|---|---|---|---|---|---|---|---|---|
| u | 58.0 | 14.7 | 101.5 | 13.9 | 344.0 | 25.5 | 1026.0 | 88.4 |
| o | 122.0 | 30.0 | 105.5 | 23.1 | 471.0 | 44.1 | 1028.0 | 136.5 |
| ɔ | 69.0 | 23.7 | 98.5 | 15.1 | 435.0 | 45.0 | 976.5 | 60.0 |
| ɑ | 81.5 | 26.4 | 101.5 | 11.3 | 536.5 | 90.2 | 1225.0 | 189.2 |
| a | 88.5 | 29.8 | 107.0 | 17.9 | 588.5 | 46.7 | 1169.5 | 137.7 |
| y | 95.0 | 14.9 | 111.0 | 14.4 | 299.5 | 37.2 | 1758.5 | 158.1 |
| ø | 122.5 | 34.8 | 108.5 | 16.3 | 388.0 | 23.7 | 1355.0 | 120.5 |
| œ | 78.5 | 57.0 | 104.0 | 8.7 | 399.0 | 28.3 | 1501.0 | 105.1 |
| i | 83.0 | 28.3 | 106.5 | 17.9 | 322.5 | 21,7 | 2027.5 | 124.2 |
| I | 68.0 | 16.6 | 111.0 | 16.4 | 388.5 | 38.9 | 1845.5 | 197.2 |
| e | 96.0 | 44.5 | 100.0 | 13.9 | 525.5 | 54.0 | 1721.0 | 115.7 |
| ɛ | 79.0 | 16.6 | 106.5 | 17.3 | 502.5 | 58.6 | 1622.0 | 98.1 |

TABLE 14 untrained speaker: vowels in unstressed position in a retold story.

| | M.DUR. | SD.DUR. | M.$F_0$ | SD.$F_0$ | M.$F_1$ | SD.$F_1$ | M.$F_2$ | SD.$F_2$ |
|---|---|---|---|---|---|---|---|---|
| u | 44.0 | 22.8 | 93.5 | 14.9 | 319.0 | 48.4 | 1097.5 | 169.6 |
| o | 64.0 | 36.5 | 94.5 | 19.6 | 459.0 | 52.2 | 1298.5 | 238.4 |
| ɔ | 62.0 | 22.0 | 99.5 | 8.6 | 449.0 | 48.9 | 1003.0 | 60.7 |
| ɑ | 50.0 | 15.0 | 92.5 | 6.3 | 489.0 | 41.2 | 1351.0 | 282.5 |
| a | 67.5 | 30.4 | 92.5 | 8.5 | 532.0 | 96.3 | 1269.5 | 205.9 |
| y | 51.5 | 30.6 | 104.0 | 20.3 | 349.5 | 55.2 | 1540.5 | 182.8 |
| ø | 90.5 | 33.6 | 102.0 | 19.0 | 380.0 | 70.5 | 1450.5 | 141.7 |
| œ | 49.0 | 18.0 | 98.0 | 12.2 | 381.5 | 27.8 | 1564.5 | 117.8 |
| i | 48.0 | 15.4 | 96.5 | 7.4 | 342.5 | 45.3 | 1915.0 | 120.4 |
| I | 58.0 | 18.8 | 101.5 | 15.1 | 371.5 | 32.0 | 1791.5 | 146.1 |
| e | 81.5 | 20.0 | 94.0 | 11.0 | 447.5 | 73.4 | 1741.5 | 180.1 |
| ɛ | 54.0 | 34.3 | 103.0 | 17.0 | 428.0 | 72.1 | 1618.0 | 178.9 |

TABLE 15 untrained speaker: vowels in stressed position in normal conversation.

| | M.DUR. | SD.DUR. | M.$F_0$ | SD.$F_0$ | M.$F_1$ | SD.$F_1$ | M.$F_2$ | SD.$F_2$ |
|---|---|---|---|---|---|---|---|---|
| u | 75.0 | 23.6 | 109.5 | 15.8 | 336.0 | 34.0 | 990.0 | 115.3 |
| o | 111.0 | 28.4 | 106.5 | 15.4 | 459.0 | 46.5 | 1135.0 | 146.0 |
| ɔ | 69.0 | 22.3 | 103.0 | 26.1 | 457.5 | 53.6 | 1083.5 | 144.3 |
| ɑ | 76.0 | 26.3 | 107.5 | 11.6 | 532.5 | 41.9 | 1225.0 | 162.3 |
| a | 114.0 | 33.3 | 107.0 | 15.3 | 571.5 | 41.2 | 1226.0 | 101.4 |
| y | 83.0 | 22.1 | 105.5 | 15.8 | 310.5 | 20.7 | 1680.0 | 116.6 |
| ø | 97.0 | 29.0 | 113.0 | 29.8 | 456.5 | 49.2 | 1421.0 | 100.3 |
| œ | 70.0 | 11.5 | 109.5 | 23.3 | 408.0 | 22.0 | 1478.0 | 103.4 |
| i | 85.0 | 24.6 | 114.5 | 18.4 | 315.0 | 31.6 | 2062.5 | 115.9 |
| I | 63.0 | 15.6 | 108.0 | 19.6 | 386.5 | 28.6 | 1849.0 | 156.3 |
| e | 114.0 | 31.3 | 103.0 | 24.0 | 491.0 | 43.8 | 1768.0 | 151.7 |
| ɛ | 63.5 | 23.3 | 114.0 | 19.5 | 456.0 | 44.3 | 1726.0 | 101.5 |

TABLE 16 untrained speaker: vowels in unstressed position in normal conversation.

| | M.DUR. | SD.DUR. | M.$F_0$ | SD.$F_0$ | M.$F_1$ | SD.$F_1$ | M.$F_2$ | SD.$F_2$ |
|---|---|---|---|---|---|---|---|---|
| u | 65.0 | 30.6 | 111.0 | 18.9 | 338.5 | 38.6 | 992.5 | 134.8 |
| o | 75.5 | 44.6 | 91.5 | 11.7 | 448.0 | 45.5 | 1083.5 | 105.6 |
| ɔ | 52.0 | 16.8 | 98.0 | 22.8 | 451.0 | 37.1 | 1147.0 | 115.7 |
| ɑ | 48.0 | 22.8 | 107.5 | 19.0 | 468.5 | 50.1 | 1316.0 | 241.2 |
| a | 73.0 | 38.8 | 107.5 | 24.6 | 511.5 | 89.5 | 1254.5 | 151.6 |
| y | 58.0 | 20.4 | 100.5 | 10.6 | 363.5 | 49.1 | 1649.0 | 170.5 |
| ø | 86.0 | 22.2 | 99.5 | 10.6 | 437.0 | 38.6 | 1473.5 | 110.7 |
| œ | 50.5 | 25.4 | 102.5 | 17.0 | 393.0 | 18.4 | 1557.0 | 91.6 |
| i | 49.0 | 16.6 | 110.0 | 15.9 | 314.5 | 29.6 | 1951.5 | 129.1 |
| I | 57.0 | 20.5 | 94.0 | 6.5 | 386.0 | 20.6 | 1854.5 | 99.5 |
| e | 51.5 | 30.3 | 102.0 | 10.0 | 444.0 | 57.5 | 1632.5 | 204.4 |
| ɛ | 54.0 | 17.7 | 94.5 | 17.3 | 453.5 | 24.9 | 1659.0 | 199.3 |

TABLE 17 trained speaker: sustained vowels.

| | $M.F_0$ | $SD.F_0$ | $M.F_1$ | $SD.F_1$ | $M.F_2$ | $SD.F_2$ |
|---|---|---|---|---|---|---|
| u | 158.8 | 4.7 | 260.0 | 33.5 | 555.0 | 11.1 |
| o | 157.2 | 2.6 | 368.0 | 37.3 | 660.0 | 33.5 |
| ɔ | 151.4 | 0.8 | 580.0 | 11.1 | 1065.0 | 82.1 |
| ɑ | 151.6 | 2.6 | 653.0 | 18.9 | 1195.0 | 44.7 |
| a | 150.4 | 3.9 | 670.0 | 45.2 | 1335.0 | 37.9 |
| y | 161.2 | 4.0 | 160.0 | 0.0 | 1595.0 | 67.0 |
| ø | 155.8 | 4.0 | 332.0 | 27.0 | 1513.0 | 89.9 |
| œ | 157.2 | 2.6 | 376.0 | 20.1 | 1384.0 | 8.9 |
| i | 164.0 | 2.7 | 165.0 | 0.0 | 2395.0 | 27.3 |
| I | 155.0 | 2.2 | 325.0 | 0.0 | 2040.0 | 9.3 |
| e | 160.2 | 7.7 | 337.0 | 26.8 | 2184.0 | 117.3 |
| ɛ | 155.0 | 2.2 | 620.0 | 11.1 | 1760.0 | 48.7 |

TABLE 18 untrained speaker: sustained vowels.

| | $M.F_0$ | $SD.F_0$ | $M.F_1$ | $SD.F_1$ | $M.F_2$ | $SD.F_2$ |
|---|---|---|---|---|---|---|
| u | 116.4 | 2.0 | 324.0 | 14.3 | 769.0 | 77.9 |
| o | 115.0 | 2.1 | 428.0 | 62.2 | 754.0 | 44.6 |
| ɔ | 114.6 | 2.6 | 480.0 | 26.2 | 726.0 | 15.1 |
| ɑ | 114.2 | 1.3 | 605.0 | 81.4 | 1066.0 | 11.4 |
| a | 114.6 | 5.0 | 847.0 | 52.8 | 1250.0 | 28.2 |
| y | 116.2 | 1.7 | 238.0 | 8.3 | 1544.0 | 21.9 |
| ø | 115.8 | 1.4 | 363.0 | 44.9 | 1509.0 | 55.7 |
| œ | 114.0 | 1.2 | 415.0 | 13.6 | 1445.0 | 71.5 |
| i | 114.8 | 2.2 | 233.0 | 7.5 | 2203.0 | 103.7 |
| I | 114.6 | 2.6 | 362.0 | 22.5 | 2075.0 | 44.9 |
| e | 113.8 | 2.1 | 298.0 | 107.9 | 2101.0 | 73.3 |
| ɛ | 113.2 | 2.9 | 470.0 | 45.6 | 1872.0 | 84.4 |

TABLE 19 The Kendall coefficient of concordance for the mean vowel duration.

| CONTEXTS | SPEAKER | W | $X^2$ | df |
|---|---|---|---|---|
| 1 - 8 | trained | 0.89 | 74.9 | 7 |
| 1 - 8 | untrained | 0.85 | 71.1 | 7 |
| 1 - 4 | trained | 0.94 | - | 3 |
| 5 - 8 | trained | 0.77 | - | 3 |
| 1 - 4 | untrained | 0.92 | - | 3 |
| 5 - 8 | untrained | 0.75 | - | 3 |
| 1 - 4 / 1 - 4 | trained / untrained | 0.91 | 76.4 | 7 |
| 5 - 8 / 5 - 8 | trained / untrained | 0.70 | 58.5 | 7 |

TABLE 20 The Kendall coefficient of concordance for the mean $F_0$.

| CONTEXTS | SPEAKER | W | $X^2$ | df |
|---|---|---|---|---|
| 1 - 8 | trained | 0.84 | 70.2 | 7 |
| 1 - 8 | untrained | 0.82 | 69.0 | 7 |
| 1 - 4 | trained | 0.64 | - | 3 |
| 5 - 8 | trained | *) 0.55 | - | 3 |
| 1 - 4 | untrained | 0.91 | - | 3 |
| 5 - 8 | untrained | *) 0.45 | - | 3 |
| 1 - 4 / 1 - 4 | trained / untrained | 0.87 | 73.0 | 7 |
| 5 - 8 / 5 - 8 | trained / untrained | 0.44 | 36.7 | 7 |

*) not significant at a level of $p < 0.01$.

TABLE 21

Correlation matrices of the mean vowel durations in the contextual situations 1 to 8 for each of the two speakers.

Trained speaker

| CONT. 1 | CONT. 2 | CONT. 3 | CONT. 4 | CONT. 5 | CONT. 6 | CONT. 7 | CONT. 8 | |
|---|---|---|---|---|---|---|---|---|
| 1.000 | 0.922 | 0.899 | 0.829 | 0.841 | 0.533 | 0.721 | 0.469 | CONT. 1 |
| | 1.000 | 0.901 | 0.860 | 0.768 | 0.471 | 0.769 | 0.403 | CONT. 2 |
| | | 1.000 | 0.802 | 0.803 | 0.302 | 0.794 | 0.359 | CONT. 3 |
| | | | 1.000 | 0.714 | 0.547 | 0.723 | 0.481 | CONT. 4 |
| | | | | 1.000 | 0.426 | 0.817 | 0.423 | CONT. 5 |
| | | | | | 1.000 | 0.436 | 0.824 | CONT. 6 |
| | | | | | | 1.000 | 0.472 | CONT. 7 |
| | | | | | | | 1.000 | CONT. 8 |

Untrained speaker

| CONT. 1 | CONT. 2 | CONT. 3 | CONT. 4 | CONT. 5 | CONT. 6 | CONT. 7 | CONT. 8 | |
|---|---|---|---|---|---|---|---|---|
| 1.000 | 0.902 | 0.808 | 0.570 | 0.658 | 0.564 | 0.763 | 0.817 | CONT. 1 |
| | 1.000 | 0.906 | 0.635 | 0.610 | 0.639 | 0.721 | 0.914 | CONT. 2 |
| | | 1.000 | 0.611 | 0.749 | 0.792 | 0.706 | 0.895 | CONT. 3 |
| | | | 1.000 | 0.487 | 0.734 | 0.643 | 0.548 | CONT. 4 |
| | | | | 1.000 | 0.669 | 0.630 | 0.702 | CONT. 5 |
| | | | | | 1.000 | 0.571 | 0.625 | CONT. 6 |
| | | | | | | 1.000 | 0.526 | CONT. 7 |
| | | | | | | | 1.000 | CONT. 8 |

TABLE 22 Correlation matrices of the mean vowel durations in contexts 1 to 4 of both speakers together and in contexts 5 to 8 of both speakers together.

Contexts 1 to 4

| tr. 1 | tr. 2 | tr. 3 | tr. 4 | untr.1 | untr.2 | untr.3 | untr.4 | |
|---|---|---|---|---|---|---|---|---|
| 1.000 | 0.922 | 0.899 | 0.829 | 0.895 | 0.921 | 0.938 | 0.583 | tr. 1 |
| | 1.000 | 0.901 | 0.860 | 0.938 | 0.969 | 0.869 | 0.551 | tr. 2 |
| | | 1.000 | 0.802 | 0.829 | 0.894 | 0.922 | 0.456 | tr. 3 |
| | | | 1.000 | 0.777 | 0.858 | 0.907 | 0.600 | tr. 4 |
| | | | | 1.000 | 0.902 | 0.808 | 0.570 | untr. 1 |
| | | | | | 1.000 | 0.906 | 0.635 | untr. 2 |
| | | | | | | 1.000 | 0.611 | untr. 3 |
| | | | | | | | 1.000 | untr. 4 |

Contexts 5 to 8

| tr. 5 | tr. 6 | tr. 7 | tr. 8 | untr.5 | untr.6 | untr.7 | untr.8 | |
|---|---|---|---|---|---|---|---|---|
| 1.000 | 0.426 | 0.817 | 0.423 | 0.604 | 0.576 | 0.688 | 0.814 | tr. 5 |
| | 1.000 | 0.436 | 0.824 | 0.644 | 0.685 | 0.772 | 0.384 | tr. 6 |
| | | 1.000 | 0.472 | 0.680 | 0.651 | 0.412 | 0.873 | tr. 7 |
| | | | 1.000 | 0.752 | 0.593 | 0.620 | 0.373 | tr. 8 |
| | | | | 1.000 | 0.669 | 0.630 | 0.702 | untr. 5 |
| | | | | | 1.000 | 0.571 | 0.625 | untr. 6 |
| | | | | | | 1.000 | 0.526 | untr. 7 |
| | | | | | | | 1.000 | untr. 8 |

TABLE 23 Correlation matrices of the mean values of the basic frequency in the contextual situations 1 to 8 for each of the two speakers.

Trained speaker

| CONT. 1 | CONT. 2 | CONT. 3 | CONT. 4 | CONT; 5 | CONT. 6 | CONT. 7 | CONT. 8 | |
|---|---|---|---|---|---|---|---|---|
| 1.000 | 0.801 | 0.315 | 0.514 | 0.435 | 0.465 | 0.290 | 0.264 | CONT. 1 |
| | 1.000 | 0.103 | 0.612 | 0.433 | 0.619 | 0.181 | 0.292 | CONT. 2 |
| | | 1.000 | -0.000 | 0.339 | 0.066 | 0.425 | 0.296 | CONT. 3 |
| | | | 1.000 | 0.358 | 0.564 | 0.250 | -0.040 | CONT. 4 |
| | | | | 1.000 | 0.408 | 0.629 | 0.593 | CONT. 5 |
| | | | | | 1.000 | 0.494 | 0.470 | CONT. 6 |
| | | | | | | 1.000 | 0.508 | CONT. 7 |
| | | | | | | | 1.000 | CONT. 8 |

Untrained speaker

| CONT. 1 | CONT. 2 | CONT. 3 | CONT. 4 | CONT. 5 | CONT. 6 | CONT. 7 | CONT. 8 | |
|---|---|---|---|---|---|---|---|---|
| 1.000 | 0.460 | 0.591 | 0.585 | -0.257 | -0.094 | 0.590 | 0.365 | CONT. 1 |
| | 1.000 | 0.530 | 0.155 | -0.027 | 0.332 | -0.020 | -0.022 | CONT. 2 |
| | | 1.000 | 0.573 | -0.052 | 0.457 | 0.146 | 0.271 | CONT. 3 |
| | | | 1.000 | -0.398 | -0.071 | 0.104 | 0.024 | CONT. 4 |
| | | | | 1.000 | 0.565 | -0.287 | 0.401 | CONT. 5 |
| | | | | | 1.000 | -0.556 | 0.254 | CONT. 6 |
| | | | | | | 1.000 | 0.153 | CONT. 7 |
| | | | | | | | 1.000 | CONT. 8 |

TABLE 24 Correlation matrices of the mean values of the basic frequency in contexts 1 to 4 of both speakers together and in contexts 5 to 8 of both speakers.

Contexts 1 to 4

| tr. 1 | tr. 2 | tr. 3 | tr. 4 | untr.1 | untr.2 | untr.3 | untr.4 | |
|---|---|---|---|---|---|---|---|---|
| 1.000 | 0.801 | 0.315 | 0.514 | 0.816 | 0.651 | 0.667 | 0.520 | tr. 1 |
| | 1.000 | 0.103 | 0.612 | 0.800 | 0.470 | 0.389 | 0.301 | tr. 2 |
| | | 1.000 | 0.000 | 0.233 | 0.343 | 0.394 | 0.351 | tr. 3 |
| | | | 1.000 | 0.476 | 0.136 | 0.513 | 0.215 | tr. 4 |
| | | | | 1.000 | 0.460 | 0.591 | 0.585 | untr. 1 |
| | | | | | 1.000 | 0.530 | 0.155 | untr. 2 |
| | | | | | | 1.000 | 0.573 | untr. 3 |
| | | | | | | | 1.000 | untr. 4 |

Contexts 5 to 8

| tr. 5 | tr. 6 | tr. 7 | tr. 8 | untr.5 | untr.6 | untr.7 | untr.8 | |
|---|---|---|---|---|---|---|---|---|
| 1.000 | 0.408 | 0.629 | 0.593 | 0.211 | 0.535 | -0.023 | 0.320 | tr. 5 |
| | 1.000 | 0.494 | 0.470 | -0.161 | 0.201 | 0.129 | -0.284 | tr. 6 |
| | | 1.000 | 0.508 | 0.420 | 0.363 | -0.035 | 0.217 | tr. 7 |
| | | | 1.000 | -0.173 | -0.052 | -0.098 | -0.012 | tr. 8 |
| | | | | 1.000 | 0.565 | -0.287 | 0.401 | untr. 5 |
| | | | | | 1.000 | -0.556 | 0.254 | untr. 6 |
| | | | | | | 1.000 | 0.153 | untr. 7 |
| | | | | | | | 1.000 | untr. 8 |

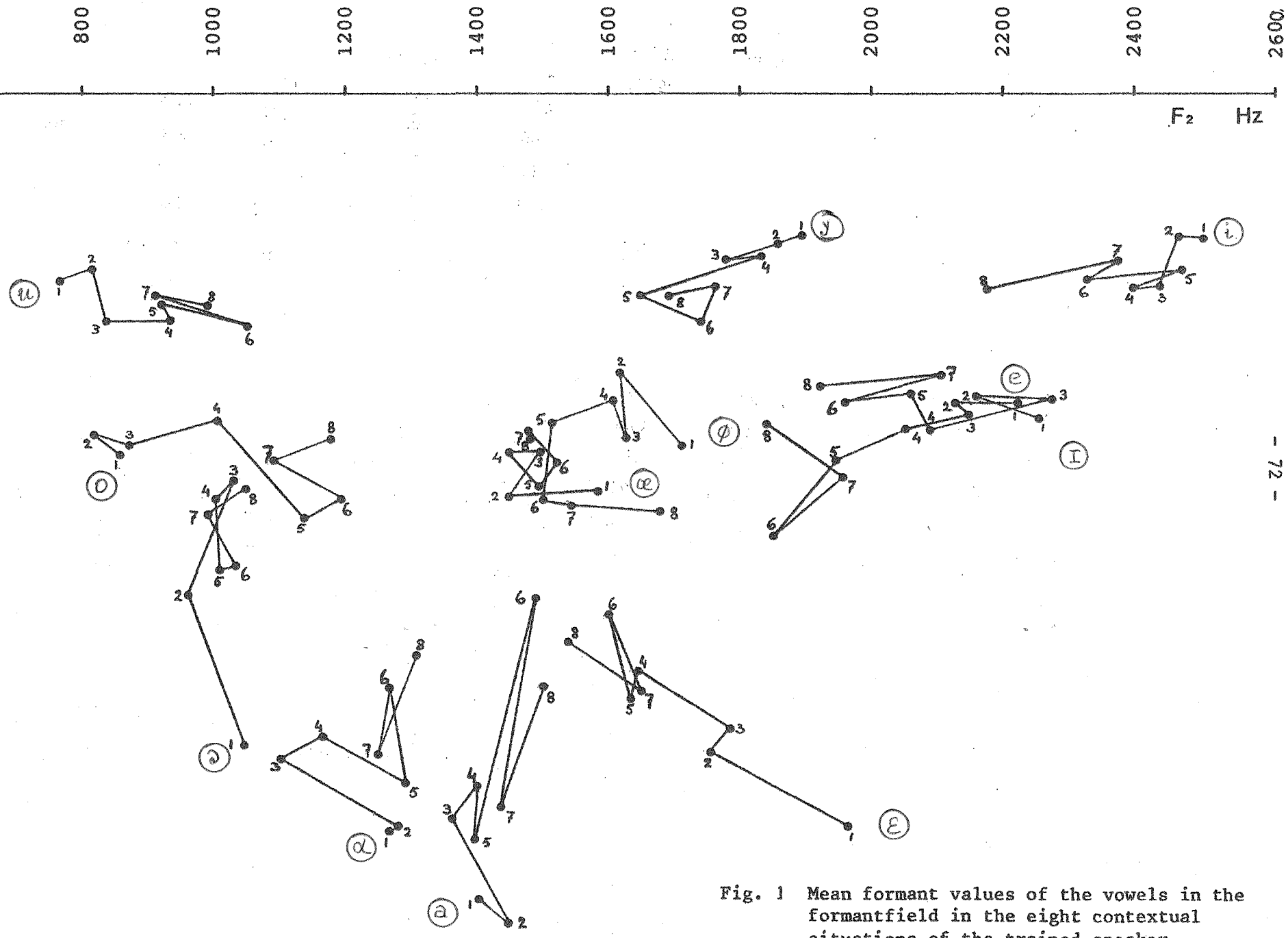



Fig. 1 Mean formant values of the vowels in the formantfield in the eight contextual situations of the trained speaker.

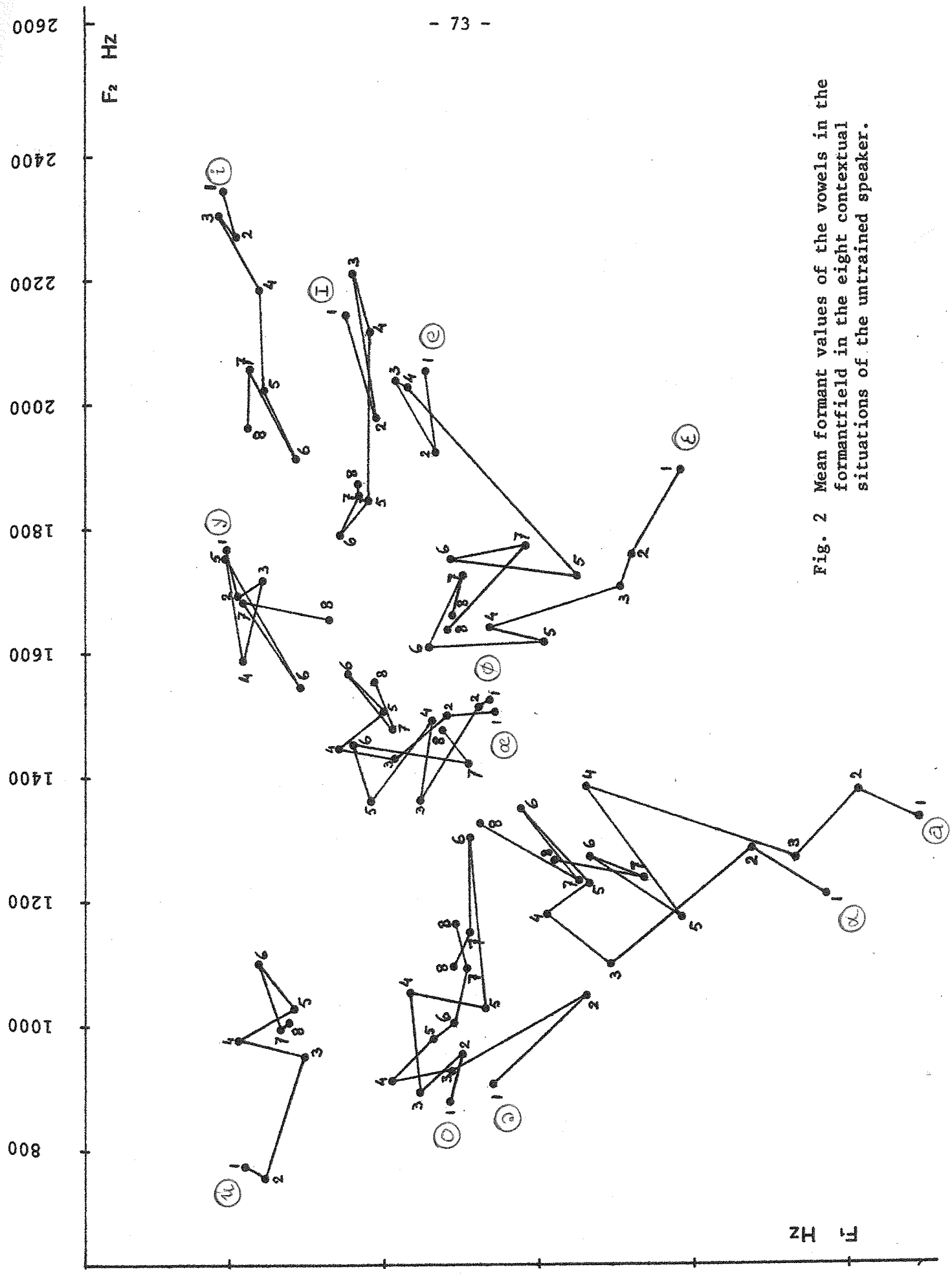
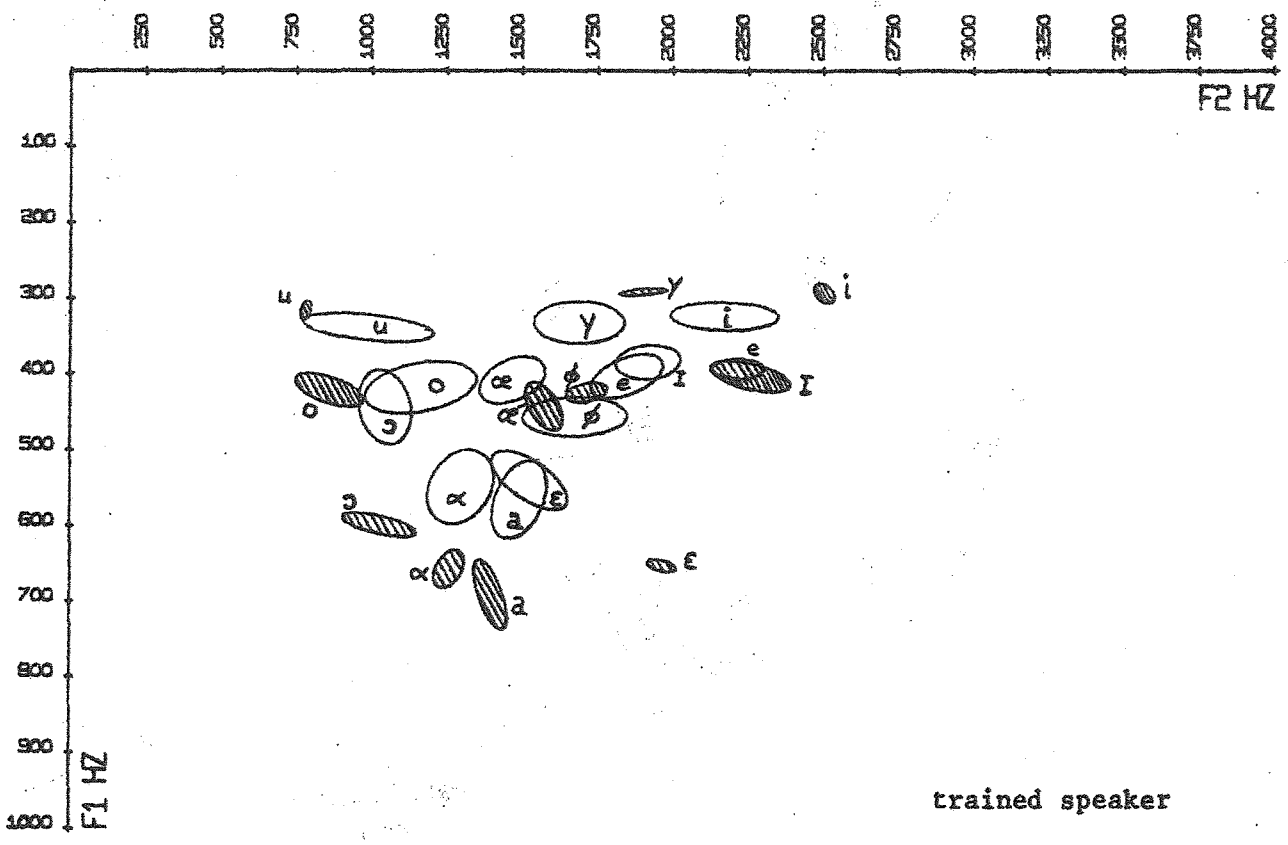



Fig. 2 Mean formant values of the vowels in the formantfield in the eight contextual situations of the untrained speaker.



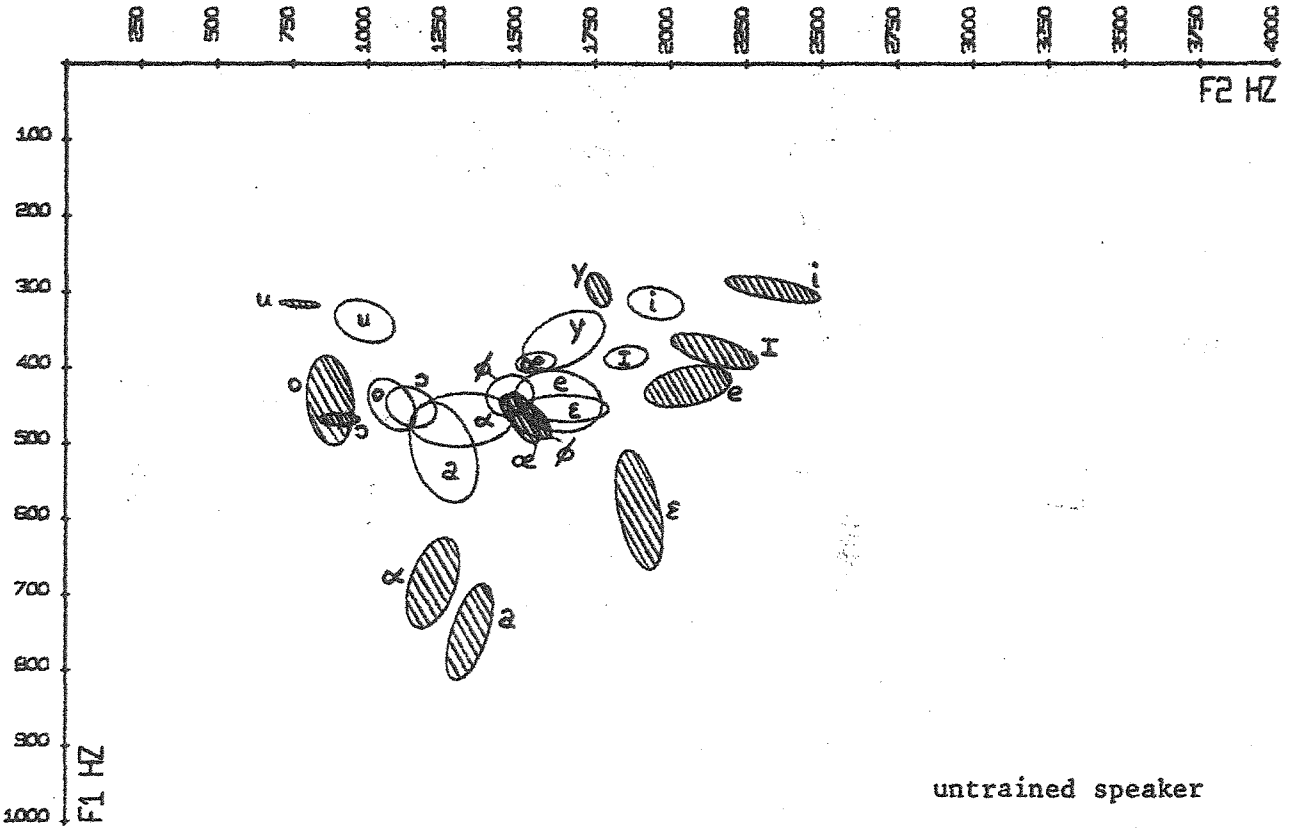
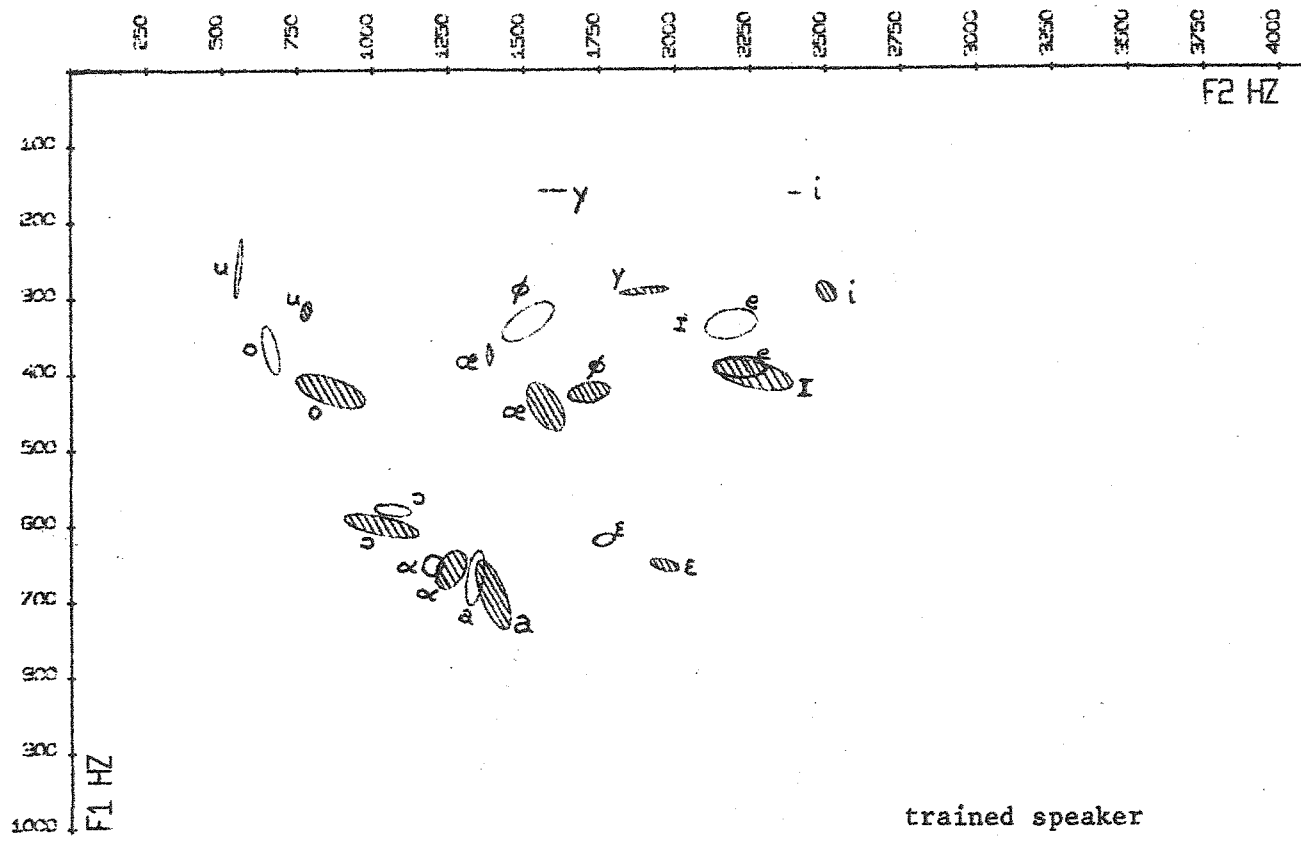




Fig. 3 Ellipses of the formant areas of vowels spoken in isolation (shaded) and of vowels in unstressed position in normal conversation (non-shaded).



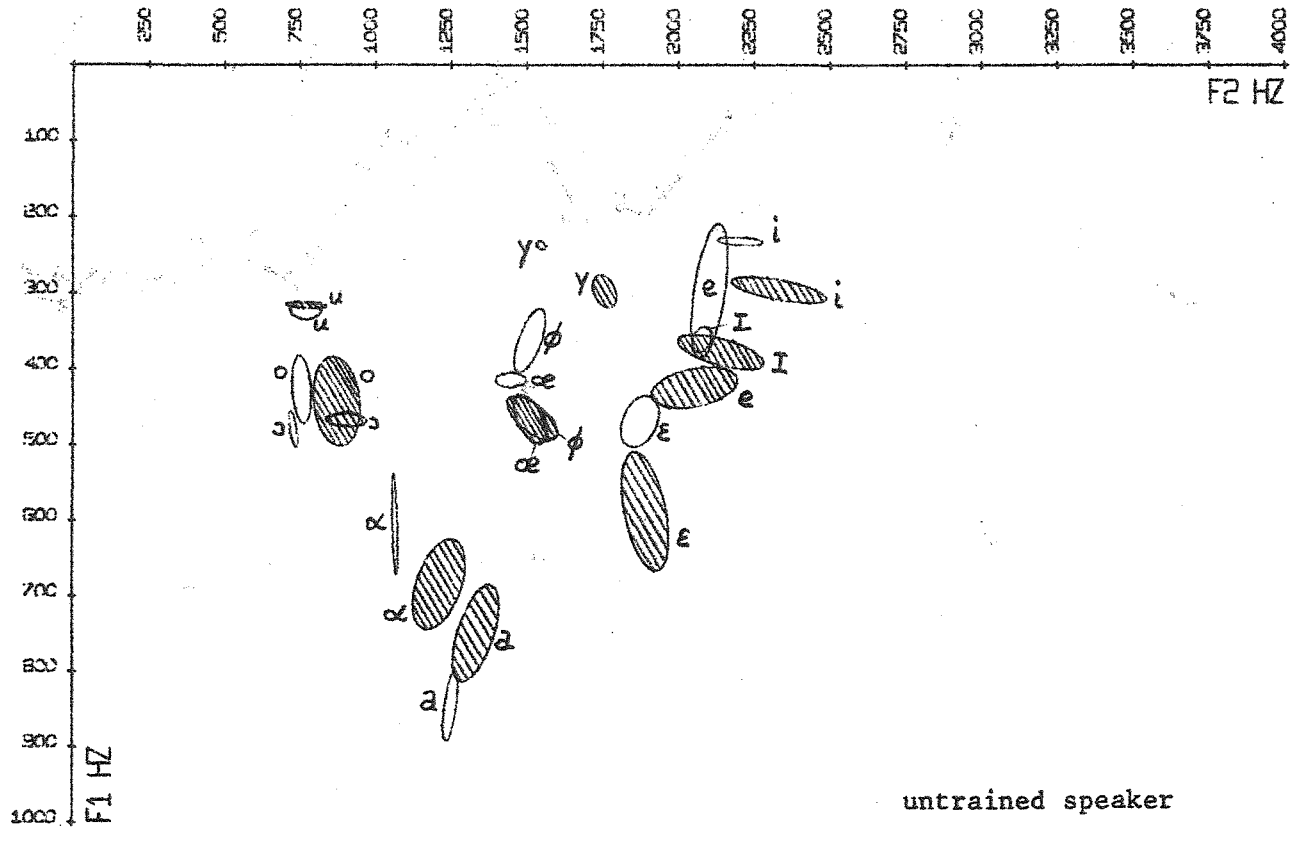




Fig. 4 Ellipses of the formant areas of vowels spoken in isolation (shaded) and of sustained vowels (non-shaded).

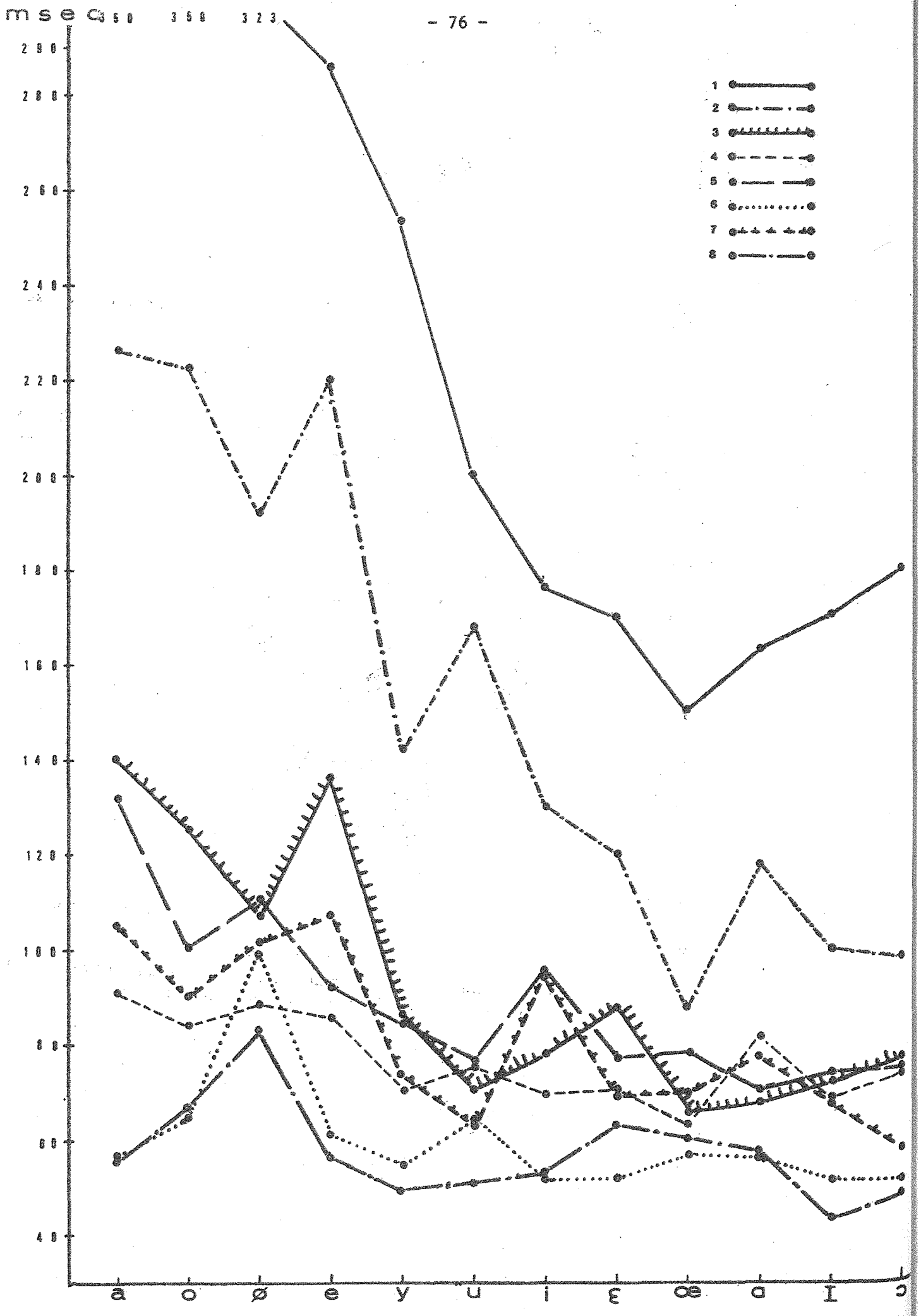



Fig. 5 Mean values of the vowel durations in the eight contextual situations of the trained speaker.

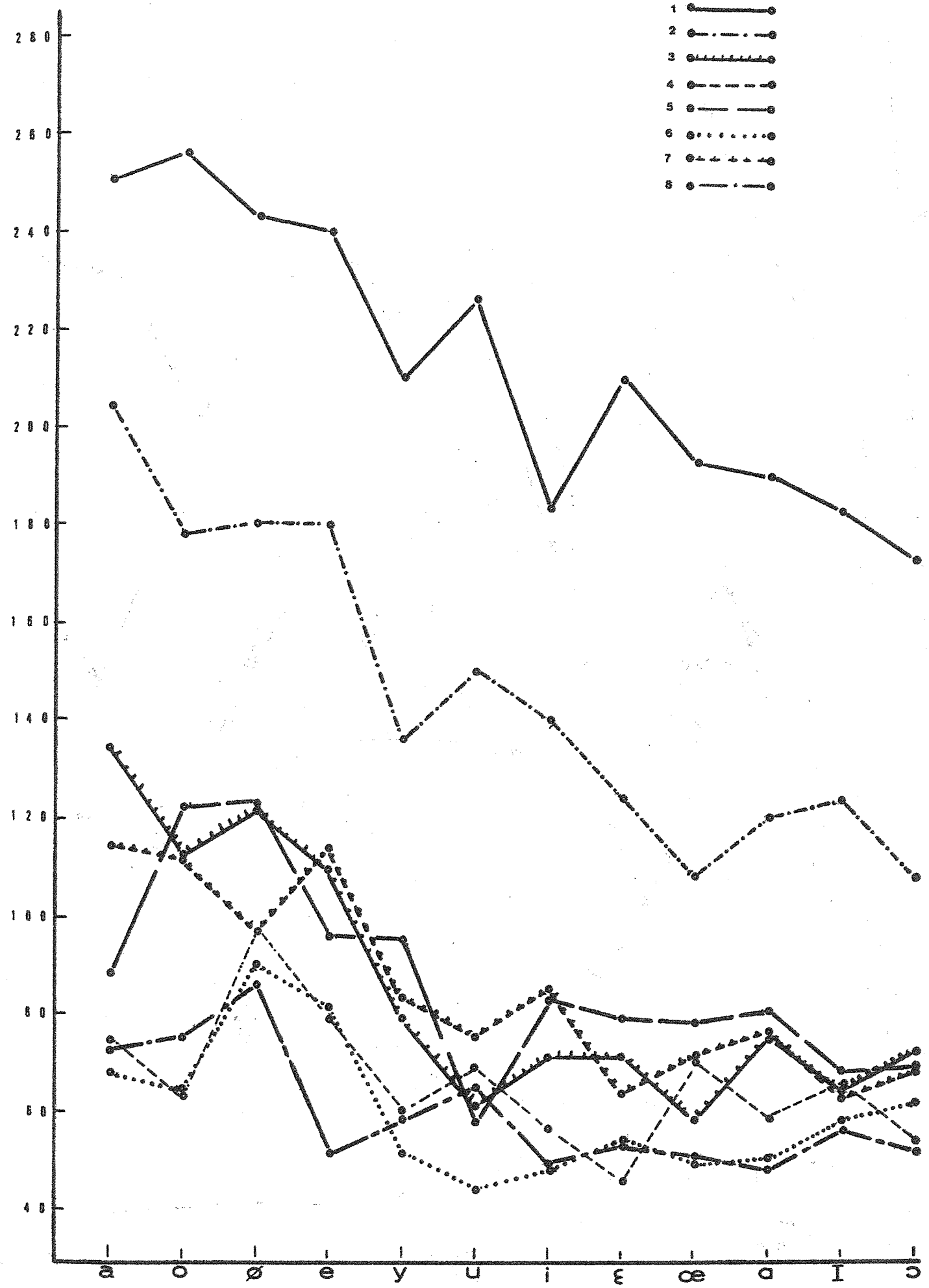



Fig. 6 Mean values of the vowel durations in the eight contextual situations of the untrained speaker.

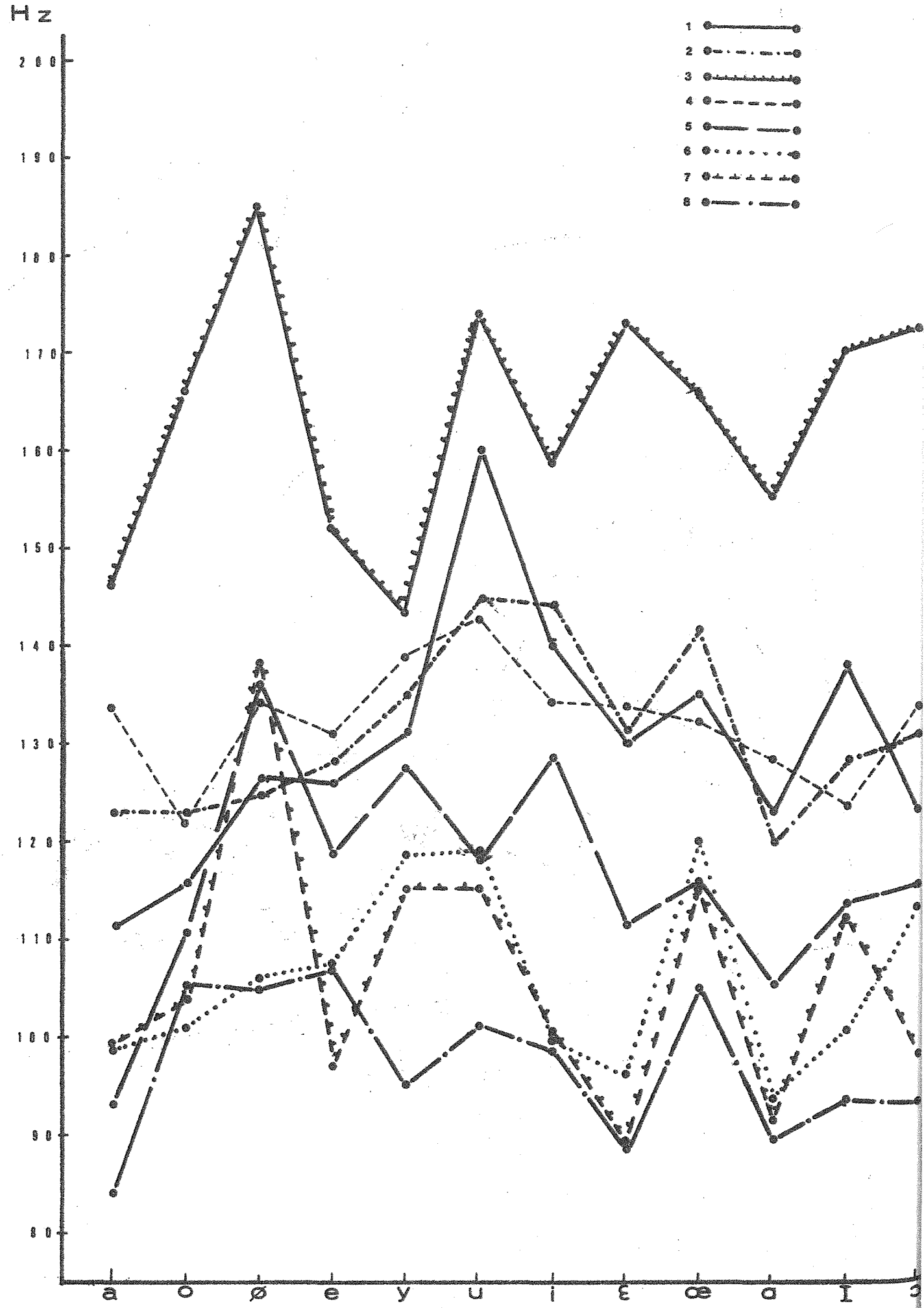



Fig. 7 Mean values of the basic frequency of the vowels in the eight contextual situations of the trained speaker.

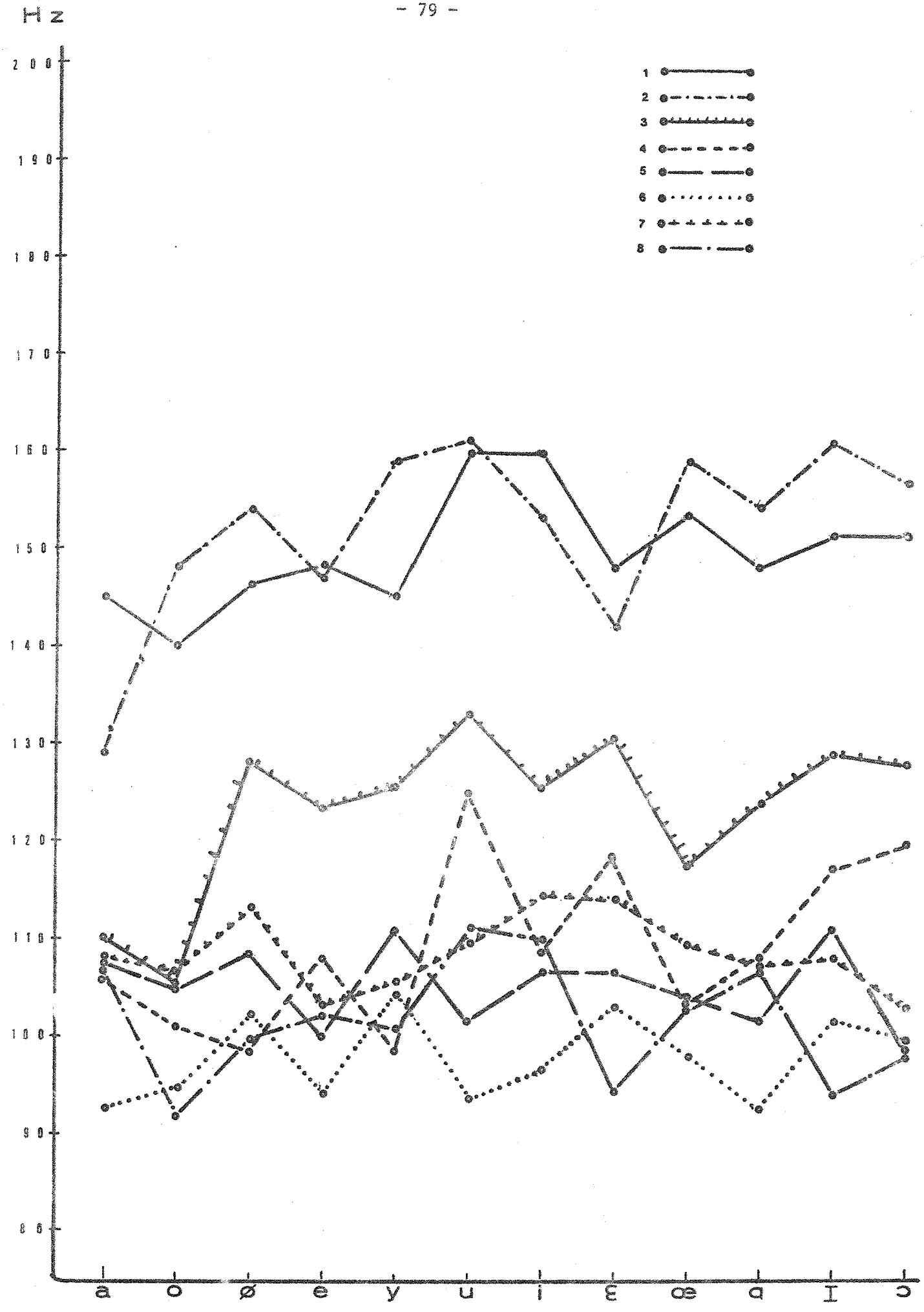



Fig. 8 Mean values of the basic frequency of the vowels in the eight contextual situations of the untrained speaker.