ACOUSTIC ANALYSIS OF TENSE AND LAX VOWELS IN GERMAN.*)

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For more than half a century it has been discussed what is meant by the terms "tense" and "lax" vowels. With the exception of a paper by A.L. Fliflet (1), who does not measure formant frequencies but rather estimates the different general appearance of the spectrograms, I am not aware of a published analysis of the acoustic differences between tense and lax vowels made with modern apparatus (e.g. the Sonagraph). The main purpose of the research summarized here was, therefore, to attempt to find relevant differences between the acoustic patterns of the tense and the lax vowels in modern German "Hochsprache" with as exact measurements of their formant-frequencies as possible.

The vowel-system of German is usually considered as falling in two groups: 8 "long" and 7 "short" vowel phonemes. In IPA transcription these may be rendered as follows:

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I:  i:  y:  u:        II: ɪ  ʏ  ʊ
    e:  ø:  o:            ɛ  œ  ɔ
    ɛ:    a:                 a
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It is usual to symbolize the latter set of vowels in German as follows:

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(II)  ì  ỳ  ù
      è  ø̀  ò
         à
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These symbols will be used in the following.

Vowels of group I are usually long, those of group II are always short. Vowels of group I <u>may</u>, however, be short (e.g. ['zi:] but [zi 'kòmt] , but they remain distinct from those of group II.

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A more significant difference seems to be, therefore, the tense/lax-difference, vowels of group I being always tense, those of group II always lax.

(It is doubtful if there is a tense/lax difference between [a:] and [a] , and an opposition of this kind will not be considered in the following.)

Briefly the main theories about the tense/lax-problem viewed from the articulatory and acoustic aspects may be described as follows:

(i) There is a difference in the tongue-form: vowels of group I have a convex tongue-form, those of group II have a more flattened tongue. (2)

(ii) The lax vowels (II) always have a lower tongue-position than the corresponding tense vowels (I) (e.g. [ì] (bitten) lower than [i:] (bieten), [ỳ] (Hütten) lower than [y:] (hüten), etc. (3)

(iii) The lax vowels have less tension in the articulating part of the tongue than the tense ones.(This has given rise to the terminology tense/lax. But as far as I know, this difference has never been examined instrumentally for German vowels, for instance by means of electro-myography.)

(iv) The consumption of air is greater in the articulation of lax vowels than in the articulation of tense vowels, this being caused by a lesser tension in the vocal chords in the articulation of the lax ones. (4)

(v) By visual examination of spectrograms of German tense and lax vowels Fliflet (1) claims that there are general differences in the appearances of the spectrograms, such as a more equal dispersion of intensity throughout the spectrum in the lax than in the tense ones, and furthermore blurred formant contours and a less regular formant structure in the lax compared with the corresponding tense vowels, and a couple of other differences. Summarizing Fliflet claims that the lax vowels exhibit a general indistinctness or blurring of the features that normally serve to define the quality of a vowel.

(vi) According to the views of Roman Jakobson, Gunnar Fant and Morris Halle (5,6) the tense/lax difference can be described in terms of articulation as a greater tension and deviation of the vocal tract from the 'neutral position' for group I than for group II, and acoustically as a higher overall intensity throughout the spectrum and a greater deviation of the formants of group I away from the formants of a vowel pronounced with the tongue in the 'neutral position'.

My intention was to measure the exact formant frequencies of the tense and the lax vowels and on the basis of the formant values to try to find out if and how the formant frequencies differ between the two vowel groups and, furtheron, perhaps to be able to conclude something about the way of articulation. I partly used spectrograms of German vowels (in words) spoken by native speakers and made by Eli Fischer-Jørgensen (though primarily made for other purposes) and partly measured formants on spectrograms from a material especially made for this investigation. The latter material consisted of German vowels in words spoken by native male speakers from the northern part of Germany, where the tense/lax-difference is regarded as being most marked.

Six such speakers were recorded on tape each pronouncing the 15 vowel phonemes six times (in natural words). Among these six speakers I chose four, having the best voices for spectrography. My first problem was to find words in which the vowel formants were minimally influenced by the consonantal surroundings. I made two lists each pronounced twice by the speakers: A: [h]/0 + vowel + labial consonant for the back rounded vowels and [h]/0 + vowel + dental consonant for the front vowels and for [a:] and [à] , and B: [h]/0 + vowel + velar stop.

A: The dental consonants should minimally influence the second formant of front vowel, and the labials should minimally influence the second formant of back rounded vowels. B: The velar stops should not heavily influence the formants, because the place of articulation differs according to the preceding vowel. The words were thus of the types A: hiessen, hüten, hupen, hissen, Hütten, hupfen, etc. and B: Igel, Hügel, Huker, Hickel, Tücke, Hucken, etc.

The presentation of vowels in an acoustic chart raises a difficult problem for languages with both rounded and unrounded front vowels. It is not adequate just to plot F_1 versus F_2 , as F_3 seems to be of importance for the distinction between rounded and unrounded vowels. One must somehow take F_3 into account. I did so, using Gunnar Fant's formula to calculate the "effective F_2":

$$F_2' = F_2 + 1/2(F_3 + F_2)\,\frac{F_2 - F_1}{F_3 - F_1}$$

but apparently without obtaining a significant improvement in the separation of the vowels. For the back rounded vowels I preferred not to use the formula. F_1 and F_2 (respectively F_2') were plotted in a chart using the 'mel'-scale, which is nearly logarithmic above 1ooo c/s and linear below 1ooo c/s.

Fig. 1 shows the F_1 versus F_2 plotting for one person. (For the front vowels and the a-sounds the x-axis represents the F_2'-value, for the rounded back vowels the x-axis represents the F_2-value. The y-axis always represents F_1-values). Each dot stands for one vowel. In some cases the values of two samples were identical and are thus marked with a small figure (2).

Only for [ỳ]/[ø:] and [a:]/[à] you find true overlapping, and only in the case of [a:]/[à] the overlapping concerns corresponding vowels from different groups. (The position of [ε:] quite close to [e:] reflects the frequent merging of [ε:] and [e:] in the northern part of Germany).

In a vowel-chart like this, F_1 seems to represent in articulatory terms the degree of opening (the higher F_1, the larger the opening), and F_2 to a certain extent represents the place of articulation, front vowels having a rather high F_2 (F_2') and back vowels having a low F_2. The vowels of group II are all placed lower than the corresponding vowels of I, which is without doubt caused by a lower tongue-position. For instance [ì], [ỳ] and [ù] are not only lower than [i:], [y:] and [u:]; they are in fact found on the same F_1-level as [e:], [ø:] and [o:], or even lower (cf. Fig. 3).

Another obvious difference between the two groups of vowels is the centralization of the lax vowels in proportion to the tense ones, [ì] and [è] being to the right of [i:], [e:] and [ε:] and [ù], [ò] being to the left of [u:] and [o:]. Because of the placing of the rounded front vowels in between the other groups on the x-axis you cannot speak of a centralization (in that sense) of the lax [ỳ] and [ø̀] in proportion to the tense [y:] and [ø:].

What could this general centralization (see also Figs. 2 and 3) be referred to in articulation? It is clear that it might be possible to regard it as an expression of less accurate articulation. The lax vowels do not reach the extremes of articulation as the tense

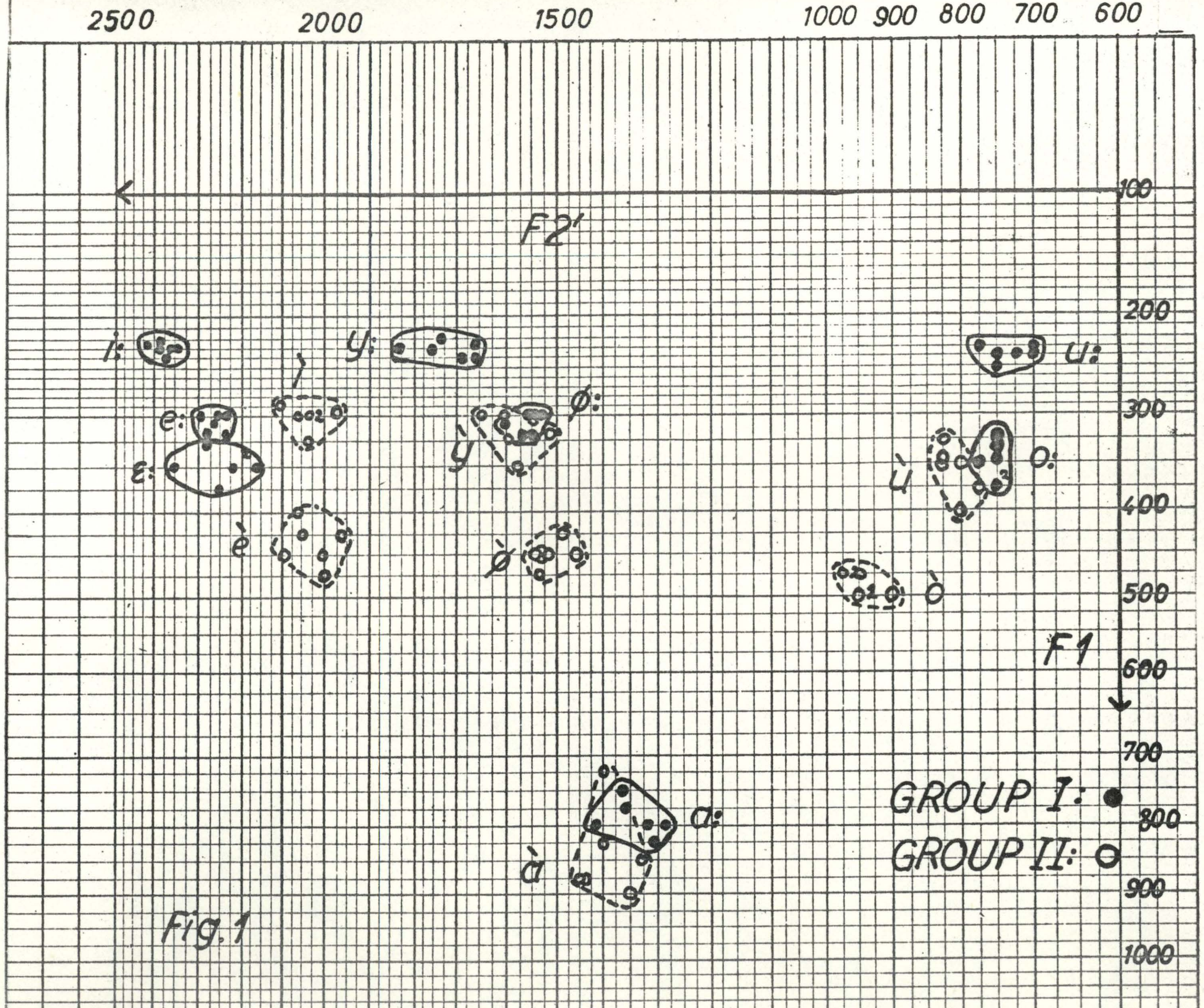

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Fig.1

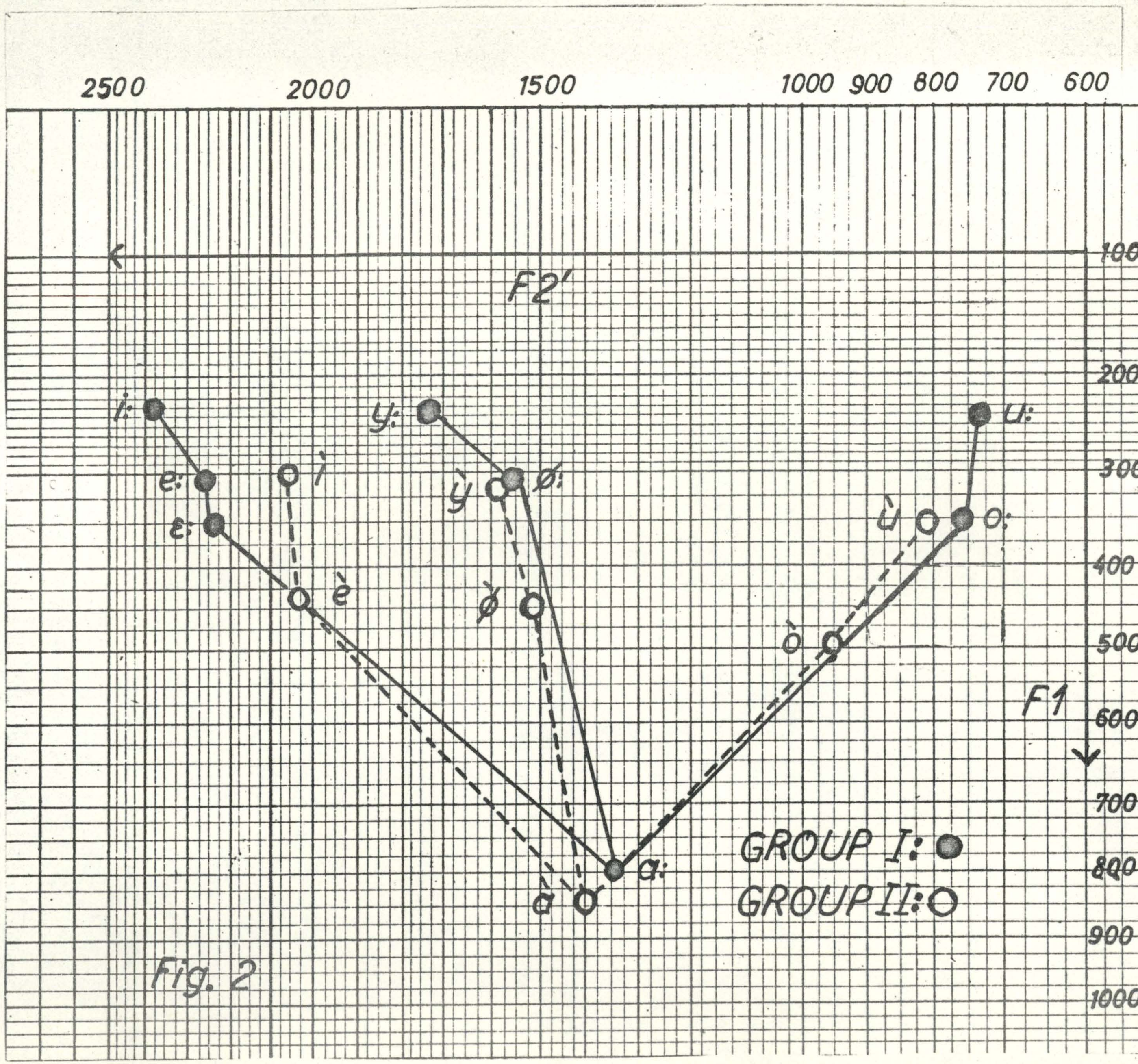
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Fig. 2

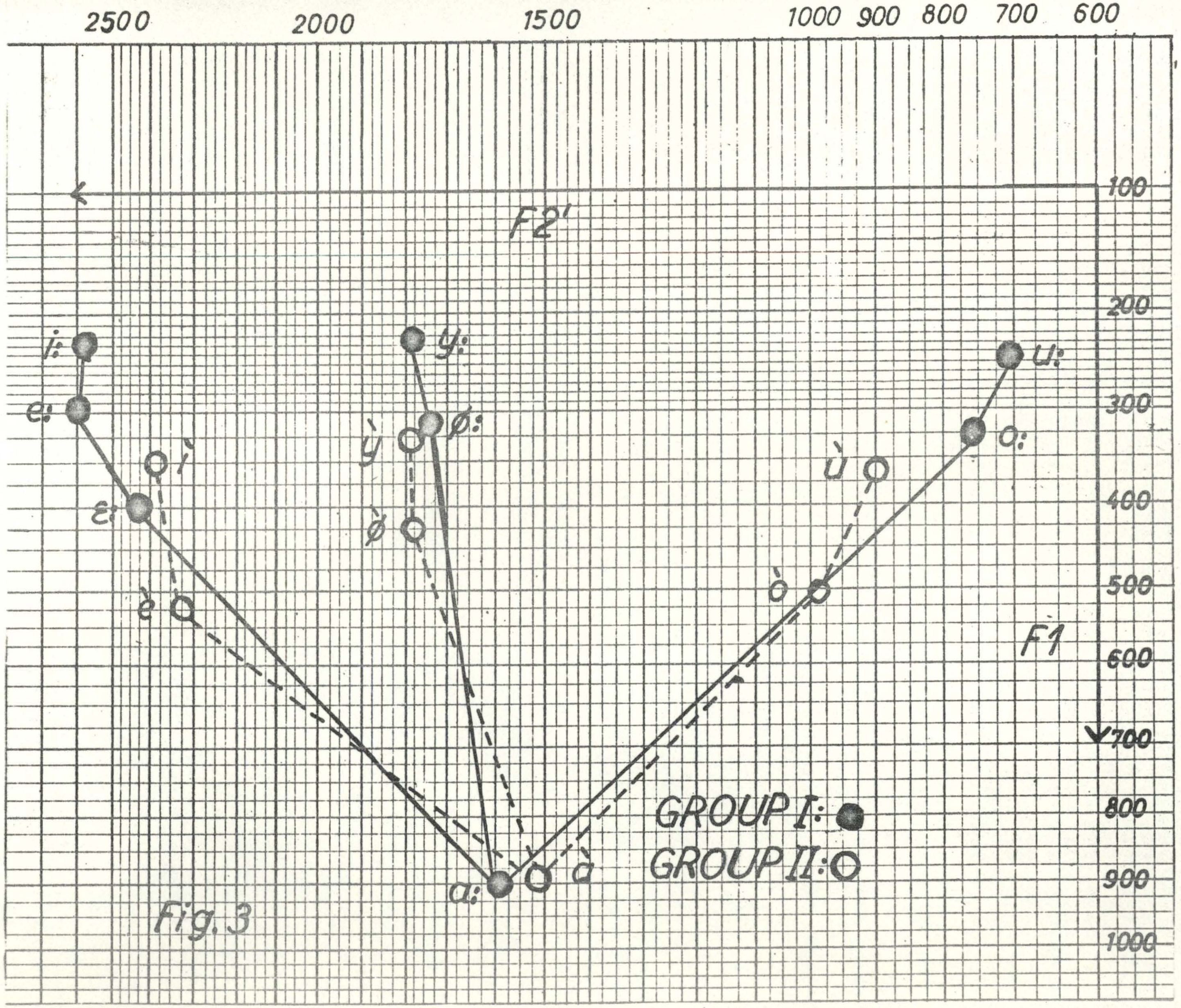
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Fig. 3

ones do. Compared to this they approach the 'neutral tongue position', perhaps because of a certain laxness in the tongue-muscles involved.

Fig. 2 shows the average formant-values for one person. They naturally show the same tendencies as described above, maybe even clearer.

Fig. 3 is an illustration of the average formant-values for another person. The same tendency of lowering and centralization of the lax vowels compared with the corresponding tense ones is obvious. [ì] and [ù] even lie somewhat lower than [e:] and [o:]! This fact seems in a way to prove E.A. Meyers results based on his method of plastrography (3). The degree of centralization is almost the same as in Fig. 2 (less for [ì] and more for [ù]). It is of importance to mention, comparing Fig. 2 with Fig. 3, that it is not the exact placement of each vowel in the chart, but rather the relations between the vowels that seem to be important: Fig. 3 has, for instance, [ì] and [è] almost in the same F_2'-area where Fig. 2 has [i:], [e:] and [ɛ:], but Fig. 3 has still higher F_2'-values for [i:], [e:] and [ɛ:], and thus the relations between the vowels look almost the same.

To sum up: the acoustic data plotted in the charts presented here seem to be the acoustic result of an articulation, by which the group II-vowels approach the 'neutral tongue position' (i.e., are centralized). This is perhaps due to a certain laxness of the tongue-muscles. But to <u>prove</u> a connexion of this kind more detailed investigations both of the articulatory and the acoustic phenomena are obviously necessary.

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References:

(1) A.L. Fliflet, "Gespannte und ungespannte Vokale", <u>Studia Lingustica</u> 1963.

(2) H. Sweet, <u>A Primer of Phonetics</u> (1892), p. 18.

(3) among others: E.A. Meyer, "Untersuchungen über Lautbildung", <u>Die neueren Sprachen</u> 191o.

(4) E.A. Meyer, "Das Problem der Vokalspannung", <u>Die neueren Sprachen</u> 1913.

(5) Roman Jakobson, Gunnar Fant and Morris Halle, <u>Preliminaries to Speech Analysis</u> (1952).

(6) Roman Jakobson and Morris Halle, <u>Fundamentals of Language</u> (1956).