STATISTIC CALCULATIONS OF FORMANT DATA.

Børge Frøkjær-Jensen

1. The Statistical Treatment of Formant Data.

(Computer Programs)

During the last few months I have been working with statistic calculations on formant data. These calculations have been carried out on an IBM 7094 calculating machine at NEUCC (Northern Europe University Computing Center) placed at the Technical University of Denmark.

For simple statistic data description of formant frequencies, formant levels, and bandwidths I have used a standard BMD program (Biomedical Computer Program) no. 01D. This program has been changed a little in order to match it better to our purposes and needs. Among other things the changed program gives both a printed and a punched output (1).

For further calculations on these outputs, and for comparisons between different groups of outputs some other programs have been worked out. This paper was primarily meant as a presentation of the output from one of these programs (called TALCOM), which is intended for comparisons between two different output groups from the changed BMD-01D program. (Each group may consist of max. 999 variables with max. 999 samples).

The program has been carefully tested. The material for one of the tests has been selected from the spectrographic material employed for a paper about the spoken Danish long vowels in our last report (2).

The material for the above mentioned test consists of 10 male, 9 female subjects, and 6 children. All these subjects have spoken the Danish long vowel phonemes once. The most common variant, the /r/-influenced combinatory variant [ɑ:] of the /a:/-phoneme is included in the material.

Illustration Fig. 1 shows the statistic calculations from the changed BMD program based on 10 male speakers. The output table contains the following columns: An identification number of the variable - each vowel/formant combination has an identification number - (VAR NO), the mean value of all the samples within a given

identification number (MEAN), the standard deviation for the samples of each variable (S.D.), the standard errors of means (S.E. OF MEAN), number of samples for each mean value (SAMPLE), the maximum value of the samples (MAXIMUM), the minimum value of the samples (MINIMUM), and the dispersion range of samples (RANGE). (Reference 8.)

Fig. 2 shows the printed output based upon 9 female speakers.

Fig. 3 shows the output based upon 6 children's voices, 4 boys and 2 girls. These six children (ages between 10 and 13 years) have spoken the same text as have the adult subjects.

The output results in Fig. 1 (group A), Fig. 2 (group B), and Fig. 3 (group C) are punched by the program, and these punch cards are used as input material for the TALCOM program, the output results of which are shown in Fig. 4 and Fig. 5.

The TALCOM program calculates an output table which contains: variable numbers (I), mean values for samples in group A, which in this test equal the male formants (AMEAN), number of samples for each A-mean (K), standard errors of A-means (ASDE), standard errors of A-means in per cent (APCT), mean values for samples in group B, which in Fig. 4 equal the female formants and in Fig. 5 equal the children's formants (BMEAN), number of samples for each B-mean (L), standard errors of B-means (BSDE), standard errors of B-means in per cent (BPCT), the difference in cps between B-means and the corresponding A-means, which in Fig. 4 equals the difference between the female formants and the corresponding male formants, and in Fig. 5 equals the difference between the children's vowel formants and the corresponding male formants (DIFBA), this difference calculated in per cent (BAPCT), the absolute standard deviation of that difference (SDABS), the relative standard deviation of that difference (SDPCT), two times this standard deviation in per cent (SDPCT2), and three times this standard deviation in per cent (SDPCT3).

The job deck set-up consists of program cards and data cards. The first data card contains a text line which does not enter the computation, but is printed out as a headline immediately before the output table. The next data card contains three number codes: (a) a number (NO) indicating how many variables the computer must find in each group; (b) a number (NVAR) which tells the machine to give warnings for sample numbers which are equal to or less than this number; and (c) a code number (N) which can assume the values

BMDOID SIMPLE DATA DESCRIPTION - VERSION OF MAY 20, 1964
HEALTH SCIENCE COMPUTING FACILITY, UCLA

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VERSION OF DECEMBER, 1967.

PROBLEM CARD

PROBLEM NUMBER	SPEECH	METHOD NUMBER	1
NUMBER OF CASES	10	NUMBER OF SPECIAL VALUES	0
NUMBER OF VARIABLES	44	NUMBER OF TRANSGENERATIONS	-0
NUMBER OF VARIABLES ADDED	-0	INPUT TAPE NUMBER	5

NUMBER OF VARIABLE FORMAT CARDS 1

SPECIAL VALUES CARD
0.

VARIABLE FORMAT CARD(S)
(23X,F4.0,7X,F4.0,7X,F4.0,7X,F4.0,20X)

MALE VOICES IN SPEECH, RECORD.NO. 1,1 2,1 3,1 4,1 5,1 6,1 13,1 14,1 15,1 16,1

	VAR NO	MEAN	S.D.	S.E. OF MEAN	SAMPLE	MAXIMUM	MINIMUM	RANGE
i:	1	235.	24.66	7.80	10	280.	200.	80.
	2	2119.	180.16	56.97	10	2500.	1900.	600.
	3	3013.	188.20	59.51	10	3325.	2725.	600.
	4	3354.	187.76	62.59	9	3700.	3085.	615.
e:	5	283.	30.75	9.73	10	325.	235.	90.
	6	2091.	154.86	48.97	10	2445.	1900.	545.
	7	2709.	158.27	50.05	10	2940.	2490.	450.
	8	3389.	207.76	65.70	10	3715.	3140.	575.
ɛ:	9	367.	27.99	8.85	10	400.	310.	90.
	10	1973.	130.39	41.23	10	2200.	1775.	425.
	11	2479.	187.17	59.19	10	2710.	2150.	560.
	12	3369.	192.14	60.76	10	3720.	3150.	570.
a:	13	541.	76.95	24.33	10	700.	440.	260.
	14	1708.	186.77	59.06	10	1975.	1415.	560.
	15	2289.	198.49	62.77	10	2540.	2050.	490.
	16	3423.	206.15	65.19	10	3720.	3170.	550.
ɑ:	17	698.	83.71	26.47	10	810.	585.	225.
	18	1144.	60.05	18.99	10	1240.	1060.	180.
	19	2480.	240.34	80.11	9	2845.	2035.	810.
	20	3464.	243.63	77.04	10	3800.	3040.	760.
y:	21	242.	23.93	7.57	10	280.	215.	65.
	22	1862.	83.73	26.48	10	1990.	1710.	280.
	23	2096.	104.82	33.15	10	2265.	1975.	290.
	24	3180.	201.01	67.00	9	3570.	2855.	715.
ø:	25	308.	26.89	8.50	10	370.	265.	105.
	26	1633.	85.64	27.08	10	1775.	1480.	295.
	27	2018.	111.81	35.36	10	2200.	1875.	325.
	28	3172.	201.87	67.29	9	3480.	2815.	665.
œ:	29	380.	33.08	10.46	10	425.	340.	85.
	30	1546.	80.99	25.61	10	1700.	1400.	300.
	31	2039.	99.21	31.37	10	2250.	1935.	315.
	32	3196.	186.44	58.96	10	3420.	2885.	535.
ʉ:	33	266.	41.28	13.06	10	365.	225.	140.
	34	722.	98.90	32.97	9	875.	585.	290.
	35	2091.	122.90	50.17	6	2230.	1940.	290.
	36	3218.	266.68	119.26	5	3600.	3000.	600.
ɤ:	37	340.	28.19	8.91	10	380.	300.	80.
	38	755.	37.08	11.72	10	800.	700.	100.
	39	2224.	182.68	69.04	7	2500.	2010.	490.
	40	3094.	235.10	88.86	7	3440.	2750.	690.
ɔ:	41	426.	31.34	9.91	10	480.	380.	100.
	42	876.	63.22	19.99	10	980.	760.	220.
	43	2204.	197.20	69.72	8	2560.	2000.	560.
	44	3173.	251.83	83.94	9	3540.	2740.	800.

FIG. 1

BMD01D SIMPLE DATA DESCRIPTION - VERSION OF MAY 20, 1964
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PROBLEM CARD

PROBLEM NUMBER	SPEECH	METHOD NUMBER	1
NUMBER OF CASES	9	NUMBER OF SPECIAL VALUES	0
NUMBER OF VARIABLES	44	NUMBER OF TRANSGENERATIONS	-0
NUMBER OF VARIABLES ADDED	-0	INPUT TAPE NUMBER	5

NUMBER OF VARIABLE FORMAT CARDS 1

SPECIAL VALUES CARD
0.

VARIABLE FORMAT CARD(S)
(23X,F4.0,7X,F4.0,7X,F4.0,7X,F4.0,20X)

FEMALE SPEECH, RECORDINGS NO. 7,1 8,1 9,1 10,1 11,1 12,1 17,1 18,1 19,1

	VAR NO	MEAN	S.D.	S.E. OF MEAN	SAMPLE	MAXIMUM	MINIMUM	RANGE
i:	1	278.	25.98	8.66	9	315.	235.	80.
	2	2588.	177.36	59.12	9	2890.	2300.	590.
	3	3397.	227.03	75.68	9	3730.	3045.	685.
	4	4014.	186.41	62.14	9	4280.	3775.	505.
e:	5	334.	32.67	10.89	9	375.	265.	110.
	6	2555.	200.06	66.69	9	2800.	2125.	675.
	7	3161.	176.80	58.93	9	3455.	2890.	565.
	8	4082.	216.65	72.22	9	4455.	3815.	640.
ɛ:	9	413.	39.21	13.07	9	475.	350.	125.
	10	2416.	223.53	74.51	9	2710.	2010.	700.
	11	2984.	146.79	48.93	9	3200.	2785.	415.
	12	4132.	236.39	78.80	9	4445.	3710.	735.
a:	13	565.	108.66	36.22	9	670.	400.	270.
	14	2146.	229.45	76.48	9	2470.	1790.	680.
	15	2889.	119.12	39.71	9	3060.	2730.	330.
	16	4118.	242.39	80.80	9	4500.	3800.	700.
ɑ:	17	808.	179.50	59.83	9	1130.	525.	605.
	18	1327.	132.71	44.24	9	1550.	1130.	420.
	19	2864.	273.62	91.21	9	3200.	2240.	960.
	20	3956.	243.37	81.12	9	4285.	3450.	835.
y:	21	247.	25.63	8.54	9	290.	215.	75.
	22	2082.	136.66	45.55	9	2310.	1940.	370.
	23	2383.	210.34	74.37	8	2615.	2145.	470.
	24	3686.	207.81	69.27	9	4000.	3370.	630.
ø:	25	342.	47.96	15.99	9	390.	275.	115.
	26	1893.	123.77	41.26	9	2090.	1660.	430.
	27	2317.	178.82	59.61	9	2625.	2120.	505.
	28	3685.	236.55	78.85	9	4045.	3270.	775.
œ:	29	413.	33.63	11.21	9	460.	345.	115.
	30	1817.	150.00	50.00	9	1970.	1515.	455.
	31	2537.	92.53	30.84	9	2680.	2375.	305.
	32	3781.	160.61	56.78	8	4080.	3570.	510.
u:	33	283.	32.60	10.87	9	350.	230.	120.
	34	798.	112.62	42.56	7	970.	650.	320.
	35	3810.	0.	0.	1	3810.	3810.	0.
	36	3988.	406.59	287.50	2	4275.	3700.	575.
o:	37	360.	32.79	10.93	9	400.	320.	80.
	38	778.	31.73	11.22	8	815.	710.	105.
	39	2770.	0.	0.	1	2770.	2770.	0.
	40	3677.	377.68	168.91	5	4180.	3220.	960.
ɔ:	41	432.	49.12	16.37	9	500.	365.	135.
	42	968.	99.28	33.09	9	1135.	810.	325.
	43	2613.	3.54	2.50	2	2615.	2610.	5.
	44	3757.	281.65	114.98	6	4125.	3400.	725.

FIG. 2

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NUMBER OF CASES	6	NUMBER OF SPECIAL VALUES	0
NUMBER OF VARIABLES	44	NUMBER OF TRANSGENERATIONS	-0
NUMBER OF VARIABLES ADDED	-0	INPUT TAPE NUMBER	5

NUMBER OF VARIABLE FORMAT CARDS 1

SPECIAL VALUES CARD
0.

VARIABLE FORMAT CARD(S)
(23X,F4.0,7X,F4.0,7X,F4.0,7X,F4.0,20X)

VOWELS SPOKEN BY CHILDREN. REC. NO. 20.1 21.1 22.1 23.1 24.1 25.1

	VAR NO	MEAN	S.D.	S.E. OF MEAN	SAMPLE	MAXIMUM	MINIMUM	RANGE
i:	1	304.	35.97	14.69	6	375.	275.	100.
	2	2921.	226.90	92.63	6	3150.	2690.	460.
	3	3522.	235.21	96.02	6	3710.	3120.	590.
	4	4427.	200.22	81.74	6	4760.	4175.	585.
e:	5	407.	50.46	20.60	6	465.	350.	115.
	6	2581.	447.35	182.63	6	3025.	1985.	1040.
	7	3287.	321.80	131.38	6	3555.	2720.	835.
	8	4383.	207.50	84.71	6	4685.	4115.	570.
ɛ:	9	490.	33.17	13.54	6	540.	455.	85.
	10	2554.	196.45	80.20	6	2735.	2250.	535.
	11	3291.	243.20	99.28	6	3585.	2890.	695.
	12	4339.	253.80	103.61	6	4825.	4150.	675.
a:	13	537.	81.71	33.36	6	625.	400.	225.
	14	2380.	190.32	77.70	6	2660.	2165.	495.
	15	3213.	251.83	102.81	6	3520.	2795.	725.
	16	4314.	232.22	94.80	6	4780.	4160.	620.
ɑ:	17	985.	123.09	50.25	6	1165.	825.	340.
	18	1543.	77.77	31.75	6	1650.	1435.	215.
	19	2888.	265.76	108.50	6	3195.	2540.	655.
	20	3998.	211.30	86.26	6	4365.	3765.	600.
y:	21	284.	23.33	9.52	6	330.	265.	65.
	22	2181.	209.68	93.77	5	2395.	1925.	470.
	23	2568.	301.63	134.89	5	2810.	2075.	735.
	24	3863.	261.55	106.78	6	4290.	3520.	770.
ø:	25	413.	60.47	24.69	6	490.	345.	145.
	26	1873.	175.16	78.34	5	2035.	1575.	460.
	27	2599.	325.78	145.69	5	2900.	2085.	815.
	28	3932.	225.54	100.87	5	4230.	3640.	590.
œ:	29	478.	67.36	27.50	6	575.	400.	175.
	30	1815.	148.19	60.50	6	2000.	1600.	400.
	31	2849.	175.82	71.78	6	3045.	2570.	475.
	32	4018.	214.87	96.09	5	4250.	3790.	460.
u:	33	305.	31.22	13.96	5	350.	270.	80.
	34	794.	64.08	32.04	4	885.	735.	150.
	35	3553.	562.15	397.50	2	3950.	3155.	795.
	36	4270.	0.	0.	1	4270.	4270.	0.
ʊ:	37	414.	54.17	22.11	6	485.	350.	135.
	38	876.	76.32	38.16	4	945.	782.	163.
	39	3810.	193.13	111.50	3	3980.	3600.	380.
	40	4630.	311.13	220.00	2	4850.	4410.	440.
ɔ:	41	461.	52.77	21.54	6	515.	380.	135.
	42	981.	97.49	39.80	6	1150.	875.	275.
	43	3678.	450.45	260.07	3	3975.	3160.	815.
	44	4503.	508.46	293.56	3	4950.	3950.	1000.

FIG. 3

INSTITUTE OF PHONETICS, UNIVERSITY OF COPENHAGEN, DENMARK

PROGRAM FOR COMPARISONS BETWEEN VOWEL SPECTRA GROUP A AND VOWEL SPECTRA GROUP B WITH STATISTIC CALCULATIONS.
VERSION OF DECEMBER 1967, (BFJ).

INPUT GROUP A AND INPUT GROUP B ARE TWO SETS OF VARIABLE NUMBERS,
MEAN VALUES,
STANDARD ERRORS OF MEANS, AND
NUMBER OF SAMPLES FOR EACH VARIABLE.
NUMBER OF VARIABLES MUST BE THE SAME IN GROUP A AND GROUP B.
THE MAXIMUM NUMBER OF VARIABLES IS 999.
THE MAXIMUM NUMBER OF SAMPLES IN A VARIABLE IS 999.

I = NUMBER OF A VARIABLE IN GROUP A.
AMEAN = MEANS OF SAMPLES IN GROUP A.
K = NUMBER OF SAMPLES FOR AMEAN.
ASDE = STANDARD ERRORS OF MEANS IN GROUP A.
APCT = ASDE IN PER CENT OF MEANS.
J = NUMBER OF A VARIABLE IN GROUP B.
BMEAN = MEANS OF SAMPLES IN GROUP B.
L = NUMBER OF SAMPLES FOR BMEAN.
BSDE = STANDARD ERRORS OF MEANS IN GROUP B.
BPCT = BSDE IN PER CENT OF MEANS.
DIFBA = THE DIFFERENCE BMEAN - AMEAN.
BAPCT = DIFBA IN PER CENT OF AMEAN.
SDABS = STANDARD DEVIATION FOR THE DIFFERENCE DIFBA.
SDPCT = THE RELATIVE STANDARD DEVIATION FOR DIFBA CALCULATED IN PER CENT.
SDPCT2 = TWO TIMES SDPCT.
SDPCT3 = THREE TIMES SDPCT.
NO = THE TOTAL NUMBER OF VARIABLES IN A GROUP.

COMPARISON BETWEEN FEMALE AND MALE SPOKEN VOWELS.

VAR NO	AMEAN	K	ASDE	APCT	BMEAN	L	BSDE	BPCT	DIFBA	BAPCT	SDABS	SDPCT	SDPCT2	SDPCT3	
1	235.	10	7.80	3.32	278.	9	8.66	3.12	43.	18.30	11.65	4.55	9.10	13.66	
2	2119.	10	56.97	2.69	2588.	9	59.12	2.28	469.	22.13	82.10	3.53	7.06	10.58	i:
3	3013.	10	59.51	1.98	3397.	9	75.68	2.23	384.	12.74	96.28	2.98	5.95	8.93	
4	3354.	9	62.59	1.87	4014.	9	62.14	1.55	660.	19.68	88.20	2.42	4.85	7.27	
5	283.	10	9.73	3.44	334.	9	10.89	3.26	51.	18.02	14.60	4.74	9.48	14.21	
6	2091.	10	48.97	2.34	2555.	9	66.69	2.61	464.	22.19	82.74	3.51	7.01	10.52	e:
7	2709.	10	50.05	1.85	3161.	9	58.93	1.86	452.	16.69	77.32	2.62	5.25	7.87	
8	3389.	10	65.70	1.94	4082.	9	72.22	1.77	693.	20.45	97.63	2.62	5.25	7.87	
9	367.	10	8.85	2.41	413.	9	13.07	3.16	46.	12.53	15.78	3.98	7.96	11.94	
10	1973.	10	41.23	2.09	2416.	9	74.51	3.08	443.	22.45	85.16	3.73	7.45	11.18	ɛ:
11	2479.	10	59.19	2.39	2984.	9	48.93	1.64	505.	20.37	76.80	2.90	5.79	8.69	
12	3369.	10	60.76	1.80	4132.	9	78.80	1.91	763.	22.65	99.50	2.62	5.25	7.87	
13	541.	10	24.33	4.50	565.	9	36.22	6.41	24.	4.44	43.63	7.83	15.66	23.49	
14	1708.	10	59.06	3.46	2146.	9	76.48	3.56	438.	25.64	96.63	4.97	9.93	14.90	a:
15	2289.	10	62.77	2.74	2889.	9	39.71	1.37	600.	26.21	74.28	3.07	6.13	9.20	
16	3423.	10	65.19	1.90	4118.	9	80.80	1.96	695.	20.30	103.82	2.73	5.47	8.20	
17	698.	10	26.47	3.79	808.	9	59.83	7.40	110.	15.76	65.42	8.32	16.64	24.96	
18	1144.	10	18.99	1.66	1327.	9	44.24	3.33	183.	16.00	48.14	3.72	7.45	11.17	a:
19	2480.	9	80.11	3.23	2864.	9	91.21	3.18	384.	15.48	121.40	4.54	9.07	13.61	
20	3464.	10	77.04	2.22	3956.	9	81.12	2.05	492.	14.20	111.87	3.03	6.05	9.08	
21	242.	10	7.57	3.13	247.	9	8.54	3.46	5.	2.07	11.41	4.66	9.33	13.99	
22	1862.	10	26.48	1.42	2082.	9	45.55	2.19	220.	11.82	52.69	2.61	5.22	7.83	y:
23	2096.	10	33.15	1.58	2383.	8	74.37	3.12	287.	13.69	81.42	3.50	7.00	10.50	
24	3180.	9	67.00	2.11	3686.	9	69.27	1.88	506.	15.91	96.37	2.82	5.65	8.47	
25	308.	10	8.50	2.76	342.	9	15.99	4.68	34.	11.04	18.11	5.43	10.86	16.29	
26	1633.	10	27.08	1.66	1893.	9	41.26	2.18	260.	15.92	49.35	2.74	5.48	8.22	ø:
27	2018.	10	35.36	1.75	2317.	9	59.61	2.57	299.	14.82	69.31	3.11	6.23	9.34	
28	3172.	9	67.29	2.12	3685.	9	78.85	2.14	513.	16.17	103.66	3.01	6.03	9.04	
29	380.	10	10.46	2.75	413.	9	11.21	2.71	33.	8.68	15.33	3.87	7.73	11.60	
30	1546.	10	25.61	1.66	1817.	9	50.00	2.75	271.	17.53	56.18	3.21	6.42	9.64	œ:
31	2039.	10	31.37	1.54	2537.	9	30.84	1.22	498.	24.42	43.99	1.96	3.92	5.88	
32	3196.	10	58.96	1.84	3781.	8	56.78	1.50	585.	18.30	81.86	2.38	4.76	7.14	
33	266.	10	13.06	4.91	283.	9	10.87	3.84	17.	6.39	16.99	6.23	12.47	18.70	
34	722.	9	32.97	4.57	798.	7	42.56	5.33	76.	10.53	53.84	7.02	14.04	21.06	u:
35	2091.	6	50.17	2.40	3810.	1	0.	0.	1719.	82.21	50.17	2.40	4.80	7.20	
	WARNING ONLY, - NUMBER OF SAMPLES (L) FOR BMEAN IS LESS THAN OR EQUALS 3														
36	3218.	5	119.26	3.71	3988.	2	287.50	7.21	770.	23.93	311.25	8.11	16.21	24.32	
	WARNING ONLY, - NUMBER OF SAMPLES (L) FOR BMEAN IS LESS THAN OR EQUALS 3														
37	340.	10	8.91	2.62	360.	9	10.93	3.04	20.	5.88	14.10	4.01	8.02	12.03	
38	755.	10	11.72	1.55	778.	8	11.22	1.44	23.	3.05	16.22	2.12	4.24	6.36	o:
39	2224.	7	69.04	3.10	2770.	1	0.	0.	546.	24.55	69.04	3.10	6.21	9.31	
	WARNING ONLY, - NUMBER OF SAMPLES (L) FOR BMEAN IS LESS THAN OR EQUALS 3														
40	3094.	7	88.86	2.87	3677.	5	168.91	4.59	583.	18.84	190.86	5.42	10.84	16.25	
41	426.	10	9.91	2.33	432.	9	16.37	3.79	6.	1.41	19.14	4.45	8.89	13.34	
42	876.	10	19.99	2.28	968.	9	33.09	3.42	92.	10.50	38.66	4.11	8.22	12.33	ɔ:
43	2204.	8	69.72	3.16	2613.	2	2.50	0.10	409.	18.56	69.76	3.16	6.33	9.49	
	WARNING ONLY, - NUMBER OF SAMPLES (L) FOR BMEAN IS LESS THAN OR EQUALS 3														
44	3173.	9	83.94	2.65	3757.	6	114.98	3.06	584.	18.41	142.36	4.05	8.09	12.14	

THE AVERAGE PERCENTAGE OF FORMANT 1 IN GROUP B IN RELATION TO GROUP A IS 9.50 PER CENT,

THE AVERAGE PERCENTAGE OF FORMANT 2 IN GROUP B IN RELATION TO GROUP A IS 16.16 PER CENT,

THE AVERAGE PERCENTAGE OF FORMANT 3 IN GROUP B IN RELATION TO GROUP A IS 24.52 PER CENT,

THE AVERAGE PERCENTAGE OF FORMANT 4 IN GROUP B IN RELATION TO GROUP A IS 18.99 PER CENT.

THE TOTAL AVERAGE PERCENTAGE OF FORMANTS IN GROUP A IN RELATION TO FORMANTS IN GROUP B IS 17.29 PER CENT.

CALCULATIONS HAVE BEEN COMPLETED.

STOP

FIG. 4

INSTITUTE OF PHONETICS, UNIVERSITY OF COPENHAGEN, DENMARK

PROGRAM FOR COMPARISONS BETWEEN VOWEL SPECTRA GROUP A AND VOWEL SPECTRA GROUP B WITH STATISTIC CALCULATIONS.
VERSION OF DECEMBER 1967, (BFJ).

INPUT GROUP A AND INPUT GROUP B ARE TWO SETS OF VARIABLE NUMBERS,
MEAN VALUES,
STANDARD ERRORS OF MEANS, AND
NUMBER OF SAMPLES FOR EACH VARIABLE.
NUMBER OF VARIABLES MUST BE THE SAME IN GROUP A AND GROUP B.
THE MAXIMUM NUMBER OF VARIABLES IS 999.
THE MAXIMUM NUMBER OF SAMPLES IN A VARIABLE IS 999.

I = NUMBER OF A VARIABLE IN GROUP A.
AMEAN = MEANS OF SAMPLES IN GROUP A.
K = NUMBER OF SAMPLES FOR AMEAN.
ASDE = STANDARD ERRORS OF MEANS IN GROUP A.
APCT = ASDE IN PER CENT OF MEANS.
J = NUMBER OF A VARIABLE IN GROUP B.
BMEAN = MEANS OF SAMPLES IN GROUP B.
L = NUMBER OF SAMPLES FOR BMEAN.
BSDE = STANDARD ERRORS OF MEANS IN GROUP B.
BPCT = BSDE IN PER CENT OF MEANS.
DIFBA = THE DIFFERENCE BMEAN - AMEAN.
BAPCT = DIFBA IN PER CENT OF AMEAN.
SDABS = STANDARD DEVIATION FOR THE DIFFERENCE DIFBA.
SDPCT = THE RELATIVE STANDARD DEVIATION FOR DIFBA CALCULATED IN PER CENT.
SDPCT2 = TWO TIMES SDPCT.
SDPCT3 = THREE TIMES SDPCT.
NO = THE TOTAL NUMBER OF VARIABLES IN A GROUP.

COMPARISON BETWEEN SPOKEN MALE VOWELS AND SPOKEN CHILDREN'S VOWELS.

VAR NO	AMEAN	K	ASDE	APCT	BMEAN	L	BSDE	BPCT	DIFBA	BAPCT	SDABS	SDPCT	SDPCT2	SDPCT3	
1	235.	10	7.80	3.32	304.	6	14.69	4.83	69.	29.36	16.63	5.86	11.72	17.59	i:
2	2119.	10	56.97	2.69	2921.	6	92.63	3.17	802.	37.85	108.75	4.16	8.31	12.47	
3	3013.	10	59.51	1.98	3522.	6	96.02	2.73	509.	16.89	112.97	3.37	6.73	10.10	
4	3354.	9	62.59	1.87	4427.	6	81.74	1.85	1073.	31.99	102.95	2.63	5.25	7.88	
5	283.	10	9.70	3.43	407.	6	20.60	5.06	124.	43.82	22.77	6.11	12.23	18.34	e:
6	2091.	10	48.97	2.34	2581.	6	182.63	7.08	490.	23.43	189.08	7.45	14.91	22.36	
7	2709.	10	50.05	1.85	3287.	6	131.38	4.00	578.	21.34	140.59	4.40	8.81	13.21	
8	3389.	10	65.70	1.94	4383.	6	84.71	1.93	994.	29.33	107.20	2.74	5.47	8.21	
9	367.	10	8.85	2.41	490.	6	13.54	2.76	123.	33.51	16.18	3.67	7.34	11.00	ɛ:
10	1973.	10	41.03	2.08	2554.	6	80.20	3.14	581.	29.45	90.09	3.77	7.53	11.30	
11	2479.	10	59.19	2.39	3291.	6	99.28	3.02	812.	32.76	115.59	3.85	7.69	11.54	
12	3369.	10	60.76	1.80	4339.	6	103.61	2.39	970.	28.79	120.11	2.99	5.98	8.98	
13	541.	10	24.33	4.50	537.	6	33.36	6.21	-4.	-0.74	41.29	7.67	15.34	23.01	a:
14	1708.	10	59.06	3.46	2380.	6	77.70	3.26	672.	39.34	97.60	4.76	9.51	14.27	
15	2289.	10	62.77	2.74	3213.	6	102.81	3.20	924.	40.37	120.46	4.21	8.43	12.64	
16	3423.	10	65.19	1.90	4314.	6	94.80	2.20	891.	26.03	115.05	2.91	5.82	8.72	
17	698.	10	26.47	3.79	985.	6	50.25	5.10	287.	41.12	56.80	6.36	12.71	19.07	ɑ:
18	1144.	10	18.99	1.66	1543.	6	31.75	2.06	399.	34.88	37.00	2.64	5.29	7.93	
19	2480.	9	80.11	3.23	2888.	6	108.50	3.76	408.	16.45	134.87	4.95	9.91	14.86	
20	3464.	10	77.04	2.22	3998.	6	86.26	2.16	534.	15.42	115.65	3.10	6.20	9.30	
21	242.	10	7.57	3.13	284.	6	9.52	3.35	42.	17.36	12.16	4.58	9.17	13.75	y:
22	1862.	10	26.48	1.42	2181.	5	93.77	4.30	319.	17.13	97.44	4.53	9.06	13.59	
23	2096.	10	33.15	1.58	2568.	5	134.89	5.26	472.	22.52	138.90	5.49	10.97	16.46	
24	3180.	9	67.00	2.11	3863.	6	106.78	2.76	683.	21.48	126.06	3.48	6.95	10.43	
25	308.	10	8.50	2.76	413.	6	24.69	5.98	105.	34.09	26.11	6.58	13.17	19.75	ø:
26	1633.	10	27.08	1.66	1873.	5	78.34	4.18	240.	14.70	82.89	4.50	9.00	13.50	
27	2018.	10	35.36	1.75	2599.	5	145.69	5.61	581.	28.79	149.92	5.87	11.75	17.62	
28	3172.	9	67.29	2.12	3932.	5	100.87	2.57	760.	23.96	121.25	3.33	6.66	9.99	
29	380.	10	10.46	2.75	478.	6	27.50	5.75	98.	25.79	29.42	6.38	12.76	19.13	œ:
30	1546.	10	25.61	1.66	1815.	6	60.50	3.33	269.	17.40	65.70	3.72	7.44	11.17	
31	2039.	10	31.37	1.54	2849.	6	71.78	2.52	810.	39.73	78.34	2.95	5.90	8.86	
32	3196.	10	58.96	1.84	4018.	5	96.09	2.39	822.	25.72	112.74	3.02	6.04	9.06	
33	266.	10	13.06	4.91	305.	5	13.96	4.58	39.	14.66	19.12	6.71	13.42	20.14	u:
34	722.	9	32.97	4.57	794.	4	32.04	4.04	72.	9.97	45.97	6.09	12.19	18.28	
35	2091.	6	50.17	2.40	3553.	2	397.50	11.19	1462.	69.92	400.65	11.44	22.88	34.33	
	WARNING ONLY, - NUMBER OF SAMPLES (L) FOR BMEAN IS LESS THAN OR EQUALS 3														
36	3218.	5	119.26	3.71	4270.	1	0.	0.	1052.	32.69	119.26	3.71	7.41	11.12	
	WARNING ONLY, - NUMBER OF SAMPLES (L) FOR BMEAN IS LESS THAN OR EQUALS 3														
37	340.	10	8.91	2.62	414.	6	22.11	5.34	74.	21.76	23.84	5.95	11.90	17.85	ʊ:
38	755.	10	11.72	1.55	876.	4	38.16	4.36	121.	16.03	39.92	4.62	9.25	13.87	
39	2224.	7	69.04	3.10	3810.	3	111.50	2.93	1586.	71.31	131.14	4.27	8.53	12.80	
	WARNING ONLY, - NUMBER OF SAMPLES (L) FOR BMEAN IS LESS THAN OR EQUALS 3														
40	3094.	7	88.86	2.87	4630.	2	220.00	4.75	1536.	49.64	237.27	5.55	11.10	16.66	
	WARNING ONLY, - NUMBER OF SAMPLES (L) FOR BMEAN IS LESS THAN OR EQUALS 3														
41	426.	10	9.91	2.33	461.	6	21.54	4.67	35.	8.22	23.71	5.22	10.44	15.66	ɔ:
42	876.	10	19.99	2.28	981.	6	39.80	4.06	105.	11.99	44.54	4.65	9.31	13.96	
43	2204.	8	69.72	3.16	3678.	3	260.07	7.07	1474.	66.88	269.25	7.75	15.49	23.24	
	WARNING ONLY, - NUMBER OF SAMPLES (L) FOR BMEAN IS LESS THAN OR EQUALS 3														
44	3173.	9	83.94	2.65	4503.	3	293.56	6.52	1330.	41.92	305.33	7.04	14.07	21.11	
	WARNING ONLY, - NUMBER OF SAMPLES (L) FOR BMEAN IS LESS THAN OR EQUALS 3														

THE AVERAGE PERCENTAGE OF FORMANT 1 IN GROUP B IN RELATION TO GROUP A IS 24.45 PER CENT,

THE AVERAGE PERCENTAGE OF FORMANT 2 IN GROUP B IN RELATION TO GROUP A IS 22.92 PER CENT,

THE AVERAGE PERCENTAGE OF FORMANT 3 IN GROUP B IN RELATION TO GROUP A IS 38.81 PER CENT,

THE AVERAGE PERCENTAGE OF FORMANT 4 IN GROUP B IN RELATION TO GROUP A IS 29.72 PER CENT.

THE TOTAL AVERAGE PERCENTAGE OF FORMANTS IN GROUP A IN RELATION TO FORMANTS IN GROUP B IS 28.98 PER CENT.

CALCULATIONS HAVE BEEN COMPLETED.

STOP

FIG. 5

0, 1, and 2. If the code is "0" only the above mentioned output table will be calculated and printed out. If the code number is "1", the computer will add a table of the formant frequency ratios between group B and group A, as shown in Figs. 4 and 5. If the code number is "2", the output will consist of the output table with means and standard deviations, formant frequency ratios, and finally a table of formant level ratios. (Reference 9.)

In order to avoid mistakes some typical defects or errors in the input material will cause error messages in the output. These error messages have been tested by means of deliberately incorrectly punched input cards.

2. The Relation between Female and Male Formant Frequencies.

As a preliminary example of the phonetic application of the two statistic programs described above I shall now proceed to discuss the output tables given in Figs. 4 and 5.

Illustration Fig. 6 shows a diagram based on the female/male formant frequency calculations in Fig. 4, and Fig. 7 shows a diagram based on the children/male formant frequency calculations presented in Fig. 5.

The scale factor k (called BAPCT in the TALCOM program), which equals the differences in per cent between the female and the corresponding male formant frequencies for each formant in the 11 vowels, is indicated by means of small circles.

The vertical lines extending from each k-circle indicate an interval of $\pm$ twice the standard deviation of k. Provided that the distribution is normal more than 95 % of all possible female/male formant ratios must fall inside this interval.

k_1, k_2, k_3, and k_4 are placed over each other in the diagram. In this way it is possible to compare the k scale factor variations directly in the four formant regions. The vowels are plotted along the horizontal axis, and the variations of k in per cent along the vertical axis.

How do these Data correlate with Investigations from other Authors?

As for the female/male and children/male formant ratios the first investigation on this subject was carried out in Japan in

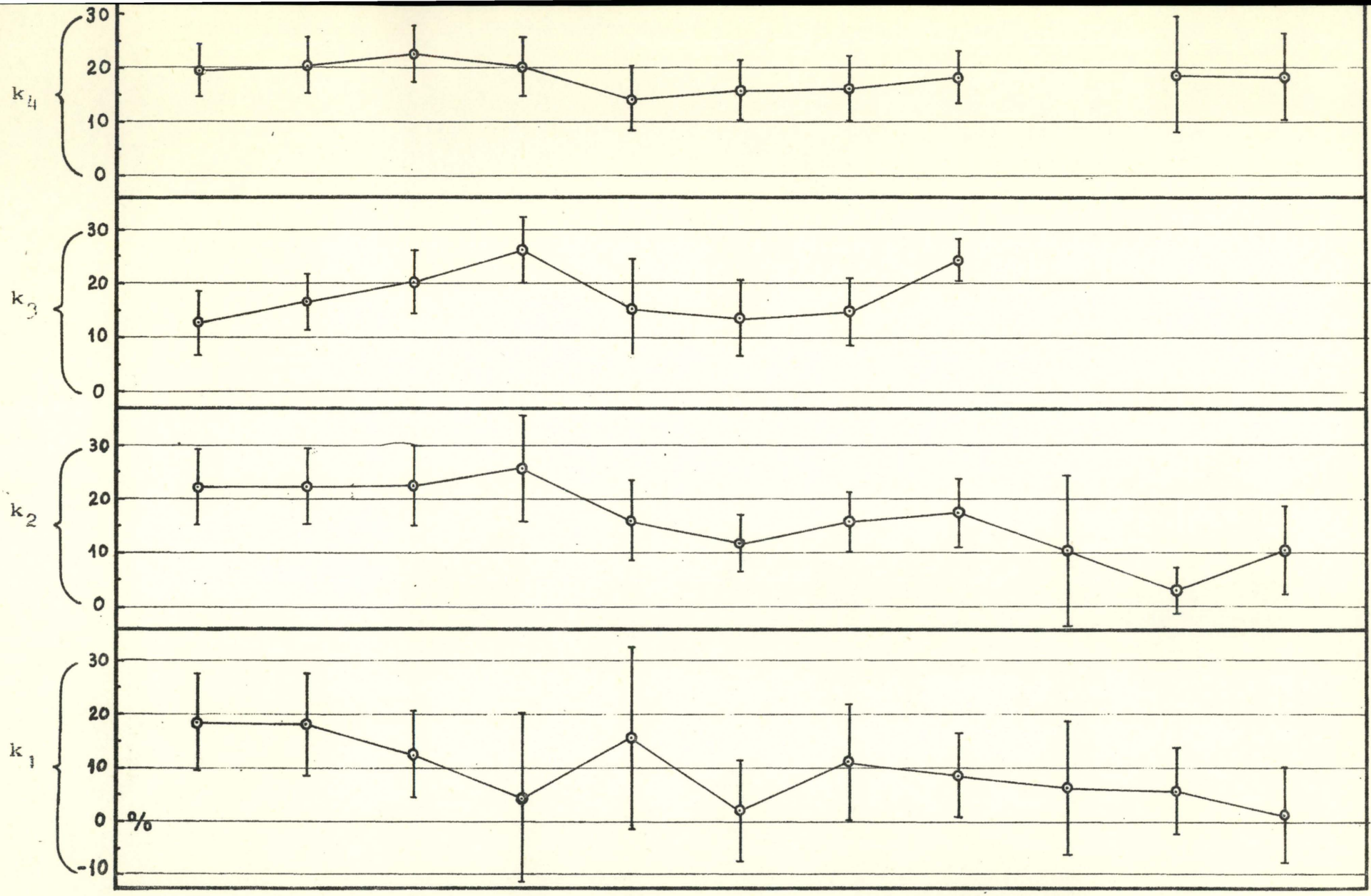

Fig. 6 The average female/male formant frequency ratio. $k_n = \left(\frac{F_n(\text{female})}{F_n(\text{male})} - 1 \right) \cdot 100\ \%$

The statistic error on each k_n-value is shown by means of vertical lines indicating ± 2 times the standard deviation of k_n.

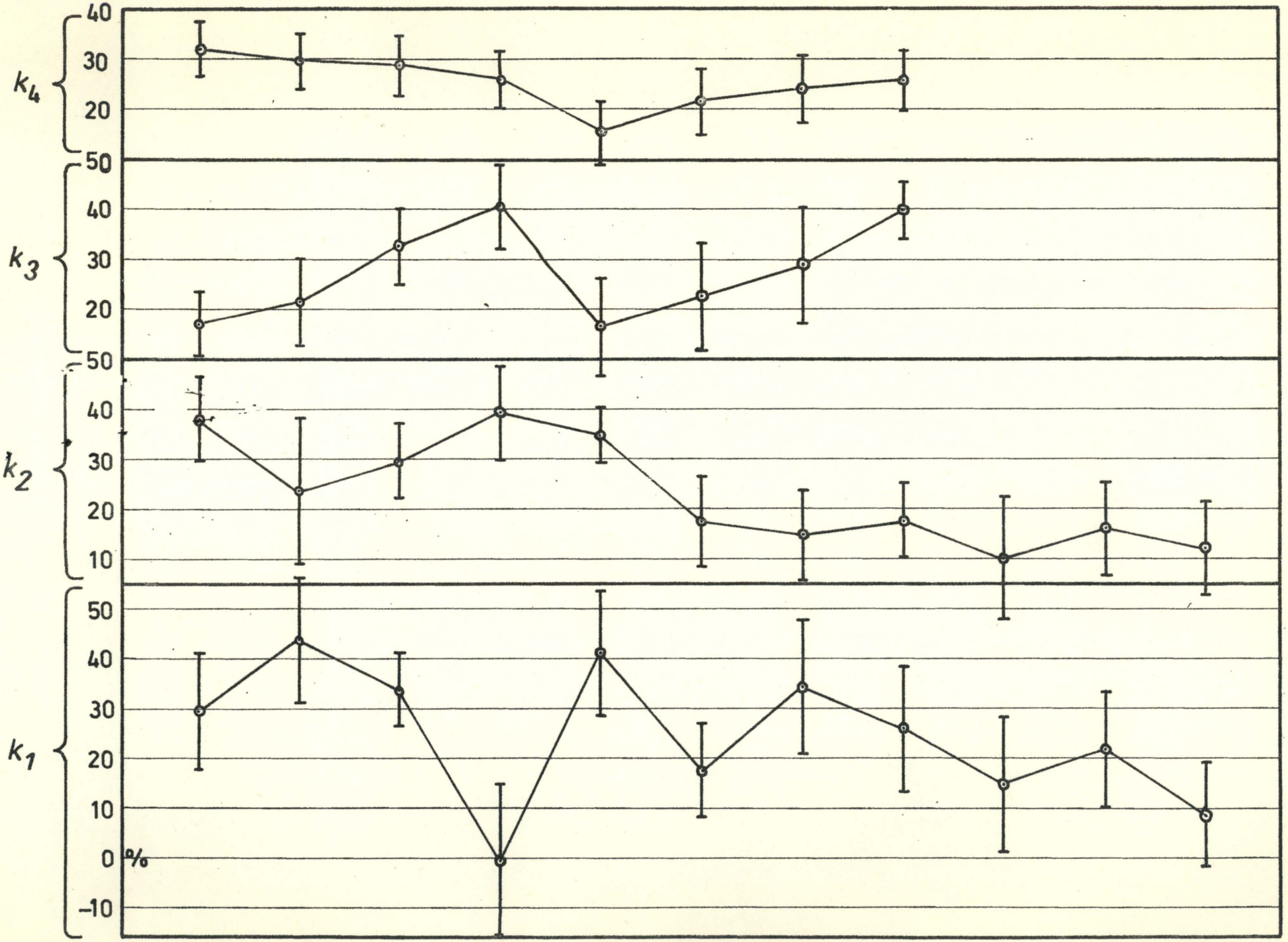
k_4
40
30
20
k_3
50
40
30
20
k_2
50
40
30
20
10
k_1
50
40
30
20
10
0 %
-10
i: e: ɛ: ə: a: y: ø: œ: u: o: ɔ:

FIG. 7

1940 by Chiba and Kajiyama (3). In 1959 - 1966 some data were published by G. Fant ((4), (5), and (6)) based on 7 male and 7 female subjects. These data included measurements of the formant levels, and so did the published data by G.E. Peterson and Barney in 1952 (7). The material of these authors was based upon 33 male subjects, 28 female subjects, and 15 children, and it is thus a rather extensive collection of data. As pointed out by the authors, too, this material shows statistically significant differences between the speakers with a 99 % confidence limit for the averages of formant frequencies and levels.

The Swedish, English, and Danish data correlate fairly well for most of the vowels. In all three sets of data we find that k_1 is high in the open back vowel [ɑ:] and low in the rounded back vowels [o:] and [ɔ:]. Also the close rounded front vowel [y:] has a low k_1. In contradistinction to the data of Fant and Peterson/Barney my material shows a high k_1 in the unrounded front vowels [i:], [e:], and[ɛ:]. All authors have found that k_2 is lowest in back vowels and highest in the unrounded front vowels. Notice the k scale factor in [a:] and [ɑ:] especially in Fig. 7 (comparison between children's and male vowel formants): [a:] and [ɑ:] have significantly different k_1 and k_3 scale factors, where k_1 for [a:] is slightly below 0 % and k_1 for [ɑ:] is higher than 40 %, whereas k_3 for [a:] is higher than 40 % and k_3 for [ɑ:] is only 16.5 %. Finally, my data suggest that k_4 is of a rather constant nature.

3. Discussion concerning Requirements on Confidence Limits:

It is clearly shown in Fig. 6 and Fig. 7 that there is in general a significant difference between male formant frequencies and female or children's formant frequencies. All the average formants in female or children's speech are higher than the corresponding male average formants, which may be seen from the formant ratio tables below the main tables of statistic calculations, Fig. 4 and Fig. 5. We do not need any statistic calculations in order to observe this. Quite another problem appears when we oberve the differences between the vowels, i.e. the k scale factors for different vowels. Is the difference between the k scale factors significant ?

Because of the overlapping in Fig. 6 we must conclude that a request for 95 % confidence limits (which is satisfied by k_n ± twice the standard deviation of k_n) is too hard a request for a comparison of the female/male formant ratio if it is based on 10 male and 9 female recordings only as is the case in my test material for this paper. Especially in the k_1 range we have a strong overlapping (it is virtually possible to draw a straight line through all the k_1 dispersion ranges indicating a common 7 % k_1 scale factor). A 68 % significance level (which is satisfied for k_n ± the standard deviation of k_n) would be more realistic because of the reduced overlapping ranges, but it has on the other hand very little meaning to speak of a significance level which excludes about one third of the cases.

If we compare the 6 children's vowels with the male vowels, Fig. 7, we can observe greater differences between the various children/male formant ratios than between the female/male formant ratios. This has been pointed out earlier by several investigators.

In spite of the greater standard deviations in Fig. 7 caused by the smaller number of samples in the children's group, we may probably expect a better significance level because of the greater differences between the k scale factors. This is seen in the diagram where the k scale factor variations are greater and the overlappings between the vowels therefore fewer than in Fig. 6.

These rough statistic calculations may give rise to the essential question whether or not the phoneticians normally operate with a too restricted material for phonetic investigations. If we want a reliable significance in a certain material we ought to operate with a probability level which equals or is better than 0.05 as a criterion of significance. This presupposes a sample number which must be so great that the range constituted of at least ± twice the standard deviation is small in relation to the differences between the phenomena under consideration.

Acknowledgement:

We want to thank the Northern Europe University Computing Center for ready help with the program tests and run of programs.

References:

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(3) Chiba and Kajiyama, The Vowel (Tokio, 1941).

(4) Gunnar Fant, "Acoustic Analysis and Synthesis of Speech with Application to Swedish", Ericsson Technics 15 (1959), pp. 6o-86.

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(6) Gunnar Fant, "A Note on Vocal Tract Size Factors and Non-Uniform F-Pattern Scalings", Quarterly Progress and Status Report 4/1966, Speech Transmission Laboratory, RIT, Stockholm.

(7) G.E.Peterson and H.L.Barney, "Control Methods Used in a Study of the Vowels", Journal of the Acoustic Society of America 24 (1952), pp. 175-184.

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(8) On request the changed BMD-01D program can be obtained from our Institute as Fortran II source deck.

(9) On request the TALCOM program can be obtained from our Institute as Fortran IV source deck.