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A Study of Laryngeal Variability in Three Specific Consonant-Vowel Syllable Contexts

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A STUDY OF LARYNGEAL VARIABILITY IN THREE SPECIFIC CONSONANT-VOWEL SYLLABLE CONTEXTS

by

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INTRODUCTION

Variations exist in every sphere of human life. In terms of speech, numerous variables affect each sound produced by the human articulators. A measurement of waveforms to the nearest centisecond would reveal astonishing variations between and among sounds. With recent advances in technology such measurements have been made possible.

A STUDY OF VARIATIONS OF SPEECH SOUNDS

Peterson and Lehiste (1960), claim that, "it is usually possible to determine segmental boundaries within one or two centiseconds. In some instances however, the transition between consonants and vowels involve an overlapping of cues and in such instances it does not appear meaningful to attempt to determine exact time boundaries". (pg. 694)

This paper deals with consonants being paired with vowels and how and why two distinct consonants chosen can affect vowel patterns on three specified vowels. It is a deliberate measure here to have no consonants after the vowel so as to avoid post articulatory influences. Focus is placed on the relationship of variations in periods and frequencies for 3 repetitions, with no context involved.

One of the problems in doing a study like this would be the difficulty in attempting to duplicate the study to the most accurate reliability. Although a computer has been used to measure the differential periods in each case, to isolate the acoustic parameters of interest is often a difficult problem to solve. (cf Shamo, 1988).

Contrary to Peterson and Lehiste, Haggard (cited in Allen, 1978), Wright (cited in Allen, 1978) and Kewley-Port and Preston (cited in Allen, 1978) estimate durational errors to be less than or equal to 10 ms. Abramson and Hadding-Koch (cited in Allen, 1978) and Velayudhan and Howie (cited in Allen, 1978), give their data to the nearest 5 ms. Koo and Badten (cited in Allen, 1978), however give a value of $\pm$ 50 ms for their data.

It would seem that those with 2 to 10 ms error estimates were probably not seeking statistical reliability but rather trying to intuitively gain accuracy in identifying the boundary criteria (Allen, 1978). Other investigators are more sensitive to error variability. Klatt (1975), for example, defined his boundaries between two adjacent non-nasal sonorants so as "...to maximize consistency of acoustic measurement". (pg. 132). And Umeda (1975) included aspiration portion of voiceless stops as part of the following vowel so as not just to equalize boundary criteria for voiceless stops, voiced stops and nasals, but also because "the distribution of this total duration has less variability". (pg.434)

Besides using intuitive approaches, other researchers have used actual reliability studies in their work. Menon, Jensen and Dew (1969), had two judges measure spectograms independently and had a 7.5 ms difference 96.1% of the time. Naeser (1970a, 1970b), correlated vowel durations measured 64 duplex oscillograms, with durations of the same vowels measured from 3 sets of 64 spectograms by 3 independent judges. Intercorrelations of the 4 sets came up between .97 to .99. Oller (1973) directly using error variance with 22 segments of 2 of her experimental utterrances, 4 times each came up with approximately 3 ms average standard error. From this studies it seems that a 10 ms error margin may be within today's limits. (Allen,1978)

Yet Peterson and Lehiste do warn investigators that some boundaries are different, even impossible, to determine. Differences may also come in because of different investigators and different equipment used. It should also be noted that small differences in reliability may have big effects theoretically.

Another important variable to consider when speaking of variances in production of consonant-vowel combinations is the psychobiological skills involved in the production of each phoneme or combining effects in doing so. While we often speak of articulation and phonation as single units, their interrelatedness should never be overlooked or underestimated. They are intrically intertwined so that changes of laryngeal adjustment are necessary for the coarticulation of articulatory events. (Abrahamson, Baken and Orlikoff, cited in Blache and Monroe, unpubl.).

The same muscles that function to support and position the larynx also serve in the production of articulatory gestures (Honda, cited in Blache and Monroe). Muscles that connect with the hyoid bone, originating from the mandible include the diagastric, mylohyoid, geniohyoid and stylohyoid muscles. A muscle of the tongue, the genioglossus also connects to the hyoid bone. Muscles from the larynx that make this connection include the sternohyoid and omohyoid (Zemlin, cited in Blache and Monroe).

Thus changes in the relationship among laryngeal cartilages can bring about differences in tension, mass or length of vocal folds. A rise in the tongue may be the result of a by-product of more important adjustments elsewhere. We cannot control the organs of articulation independently nor determine from sensations just what is recurring with our vocal apparatus. The fundamental frequency of vowels is often said to vary with vowel height (Peterson & Barney; House and Fairbanks; Lehiste and Peterson, cited in Blache and Monroe). High vowels are observed to have higher fundamental frequencies than low vowels.

"One way to observe the effects of articulatory postures on laryngeal stability is to examine the cycle-to-cycle variation of fundamental frequency". (Blache and Monroe, unpubl.).These variations have been the object of rather a few recent researches and many equations have been proposed to calculate the variations. Some have called it perturbation and it can be measured as mean jitter (Hillenbrand, cited in Shamo,1988); percent jitter (Lieberman; Horii; Hollein etal., cited in Shamo,1988); jitter ratio (Wolfe & Steinfall, cited in Shamo,1988) and jitter factor (Lieberman; Hollien et al., cited in Shamo,1988). It has also been noted by Baken (cited in Shamo,1988), that the standard deviation is a widely-used index of fundamental frequency variation. This can be expressed in semitones or what has been called pitch sigma.

Ryalls (1984), in his design shows how variability of fundamental frequency in words were significantly greater for aphasics than for normal speakers. It was suggested that this variability of aphasic speech was probably "due to poor laryngeal control". (pg. 108). This paper though concerned with variability of fundamental frequency as a measure of laryngeal control proposes to show such variability only between 3 normal speakers. Variabilility is seen in terms of the effect the specific consonant has on each of the specific vowel chosen.

EXPERIMENT

Three normal female speakers between the ages of 20 to 30 were taken as subjects. The vowels /u/, /i/ and /a/ were combined to follow consonants /tʃ/ and /m/.

/tʃ/ was chosen for the experiment because it was found by Blache and Monroe (unpubl.) to have the highest variance (0.1805 ms) among consonants. They also considered /m/ to have the lowest variance (0.0072 ms). Among the vowels, the highest variance was seen in /u/ (0.0125 ms) and in descending order next came /i/ (0.0075 ms) and /a/ (0.0071 ms). In the case of /u/ and /i/ variance seemed to be slightly above /m/ while /a/ was just below. (cf. Appendix 1). The /i/, /a/ and /u/ combination of vowels also are a good representation of vowels set in the vowel quadrilateral moving from high front /i/ to low central /a/ and high back /u/. The combinations in consonant-vowel was made so that each of the consonants was paired to each of the vowels to form nonsense words. The words 'chacha','chichi', 'choochoo' , 'mama', 'mimi' and 'moomoo' were written 3 times each on 3" x 5" index cards. The cards were then randomly shuffled and presented one at a time to the subjects.

Recording was done in an anechoic chamber, on one track, using a Yamaha MT100 (multitrack cassette recorder). An external microphone was used. The 9 utterances of each subject were digitized and wave pulses displayed on the screen of the Mac Speech Lab. The wave pulses were then seen on a 95.2 ms time window. They were then cut to place each repetition of the same utterance together. Measurements were then made beginning with the vowel onset point. Naeser (1970b) reports of the possibility of determining the vowel onset point. She dealt with determining the vowel onset after initial voiceless and voiced stops and fricatives. "Fricative noise in the higher frequencies of the sound spectogram, as mentioned with the aspirated release of the stops above, showed up as a large negative dip in the duplex oscillogram. The first patterned deflection of the vowel amplitude after this negative dip marked the beginning of the vowel duration". (pg.164)

Periods were measured from one wave peak to another in two 47.6 ms frame windows. The first was considered the transition window and the second the vowel window. Differrences between periods were then used to calculate the mean of the periods, standard deviation, the variance and the mean fundamental frequency of the glottal waveform for each window.

A comparison of the two windows was then done. Statistical analysis of the transition-vowel was made by means of a T-test of unrelated mean analysis and an F-ratio.

RESULTS AND DISCUSSION

Various presuppositions can be drawn from experiments. Some of these are in agreement with past research especially in recent years but others require more indepth studies of the variables involved.

From the graphs (Appendix 2) it seems that /ʧ/ slopes have a greater slant among all 3 subjects while /m/ slopes are more horizontally aligned. Of the consonants /ʧ/ mean frequency range varies from 261 Hz to 195Hz for S.116, 204 Hz to 174 Hz for S.117 and from 221 Hz to 195 Hz for S.118. By comparison, for /m/, S.116 had a mean frequency range from 239 Hz to 210 Hz, S.117 from 211 Hz to 172 Hz and for S118 from 217 Hz to 192 Hz. One exception however seems to have occured in the case of S.117 where the highest mean frequency in /ʧ/ was less than highest mean frequency of /m/. (Appendix 3).

The consonant /ʧ/ seems to have a greater influence from the transition-vowel comparison than /m/. In all cases the vowel that precedes the consonants seem to have been affected significantly. This may be clearer because of our choice of consonants from the extreme ends of the consonant hierarchy built by Blache and Monroe. The choice of vowels however although inclusive of varied vowel formation patterns does not seem to affect the pattern of formation of the various curves from subject to subject. In all 3 cases the patterns seem to go along similar lines.

From the same figures of the mean frequency range above, it seems also that vocal behaviour can be identified individually in terms of frequency. The graphs (Appendix 2), give a clear indication of highest frequency levels in S116 of both consonants and lowest frequency level in S118 with S117 somewhere in between. Although the frequencies of /m/ seems to begin in the lower range and /ʧ/ in the upper range, the total pattern seems to show a frequency adjusted to the individual. In other words although frequency may vary from sound to sound , in general individual factors determine frequency to a greater extent. (It has already been mentioned how Ryall used variability of fundamental frequency in words and has shown it to be significantly greater for aphasics than for normal speakers.)

The other two factors that show greater significance in variation are the F-ratio and T-tests. (Appendix 3). Across the 3 subjects there seems to be a greater significant variation in the /tʃ/ sound than in the /m/ sound. Although the F-ratio showed minimal significance compared to the T-test, there is a greater significance shown in the /tʃ/ consonant than in the /m/ sound. For S116, 3 utterances /tʃ/ combination showed significance while none of the utterances showed any significance for the /m/ sound. S117 showed a similar pattern of greater significance for 7 utterances of the /tʃ/ sound measurement and only 2 utterances of the /m/ sound. For S118 however there seems to be little difference where the F-ratio of the /tʃ/ sound shows one significant utterance while that for the /m/ sound shows 3.

The significance of /tʃ/ seems more evident through results of the T-test. While S116 had all 9 utterances significant for the /tʃ/ sound there were only two for the /m/ sound. For S117 while having 7 significant utterances recorded for the /tʃ/ sound, only two utterances were noted to be significant in the /m/ sound. In utterances of S118 all 9 showed significance of the /tʃo/ sound and none were significant for the /m/ sound.

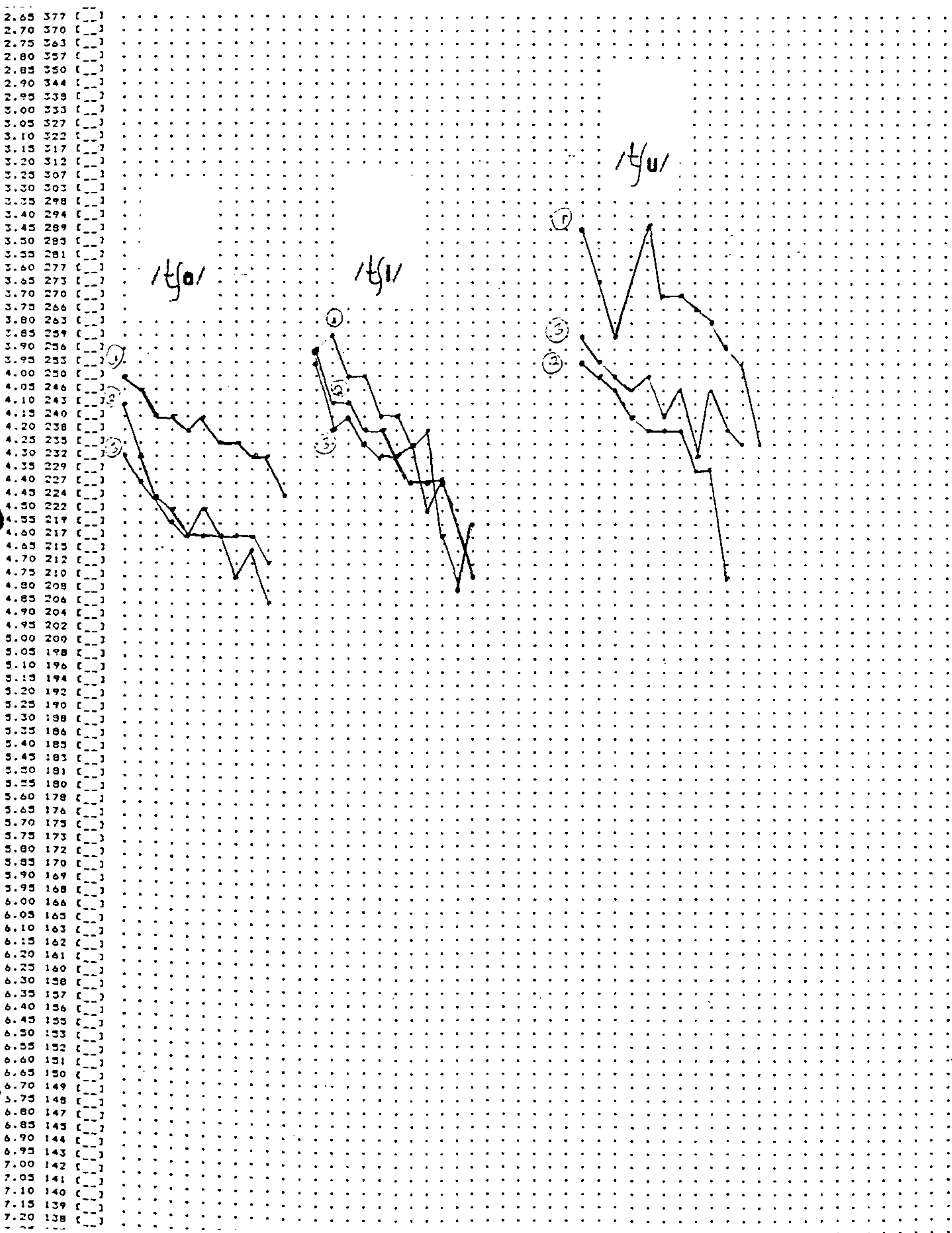
Appendix 1

Table 1

Sound	Variance	Std. Dev.	mean	Hz
/ch/	0.1805	0.4249	4.905 ms	204
/u/	0.1246	0.1116	4.563 ms	219
/i/	0.0075	0.0868	3.517 ms	284
/m/	0.0072	0.0851	4.725 ms	212
/a/	0.0071	0.0840	4.700 ms	212

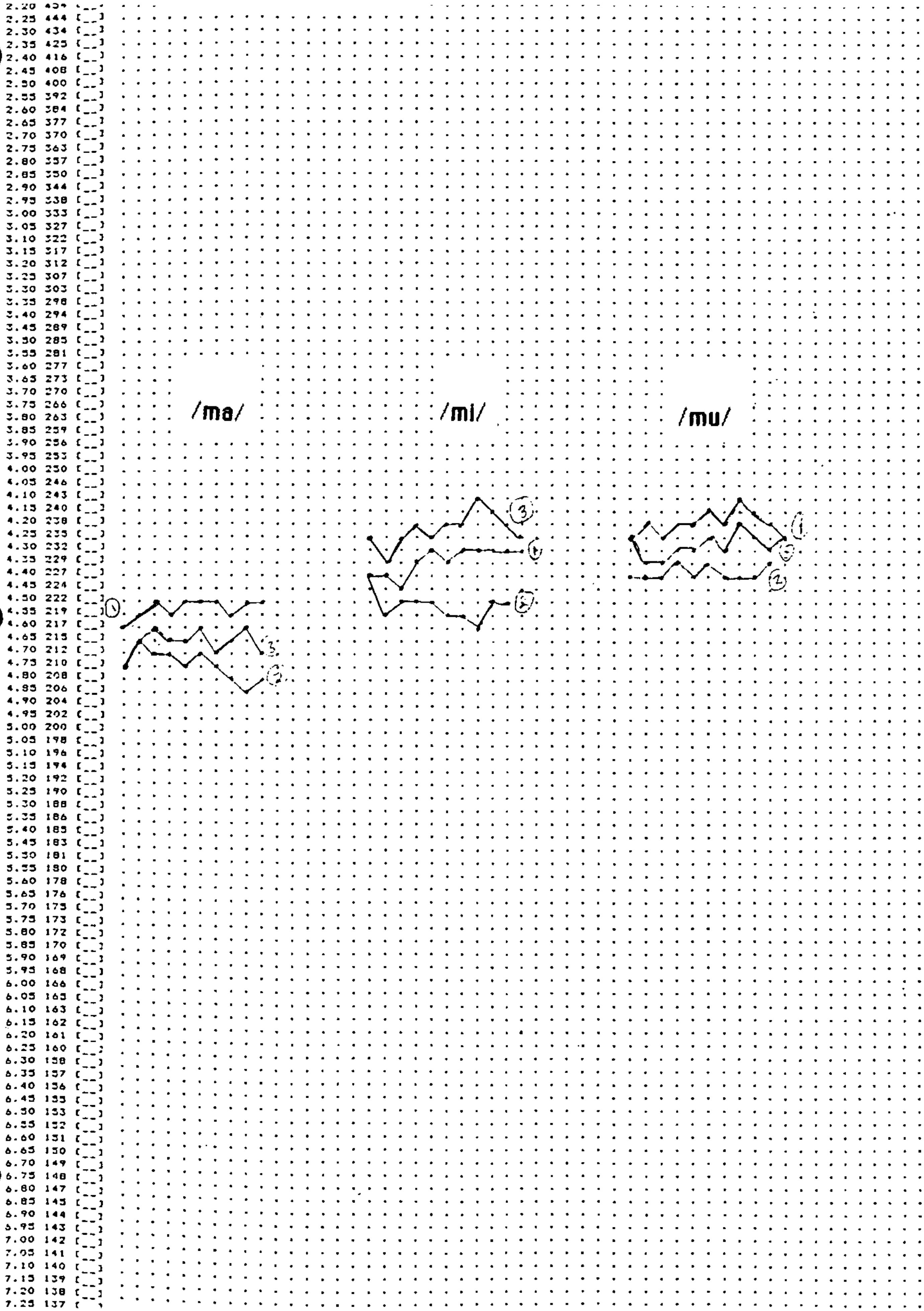
Appendix 2
Graph 1

SUBJECT 116



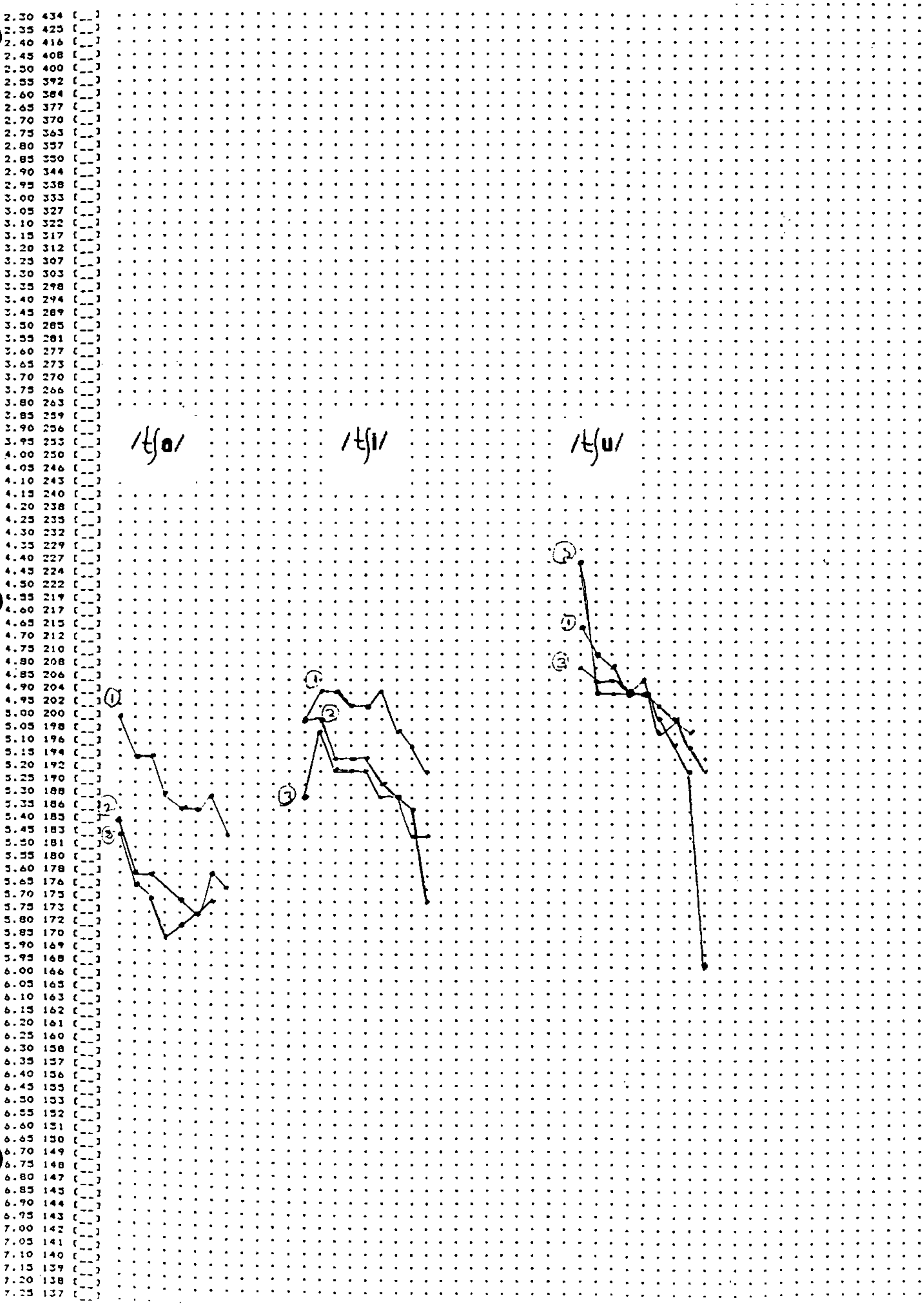
Graph 2

SUBJECT 116



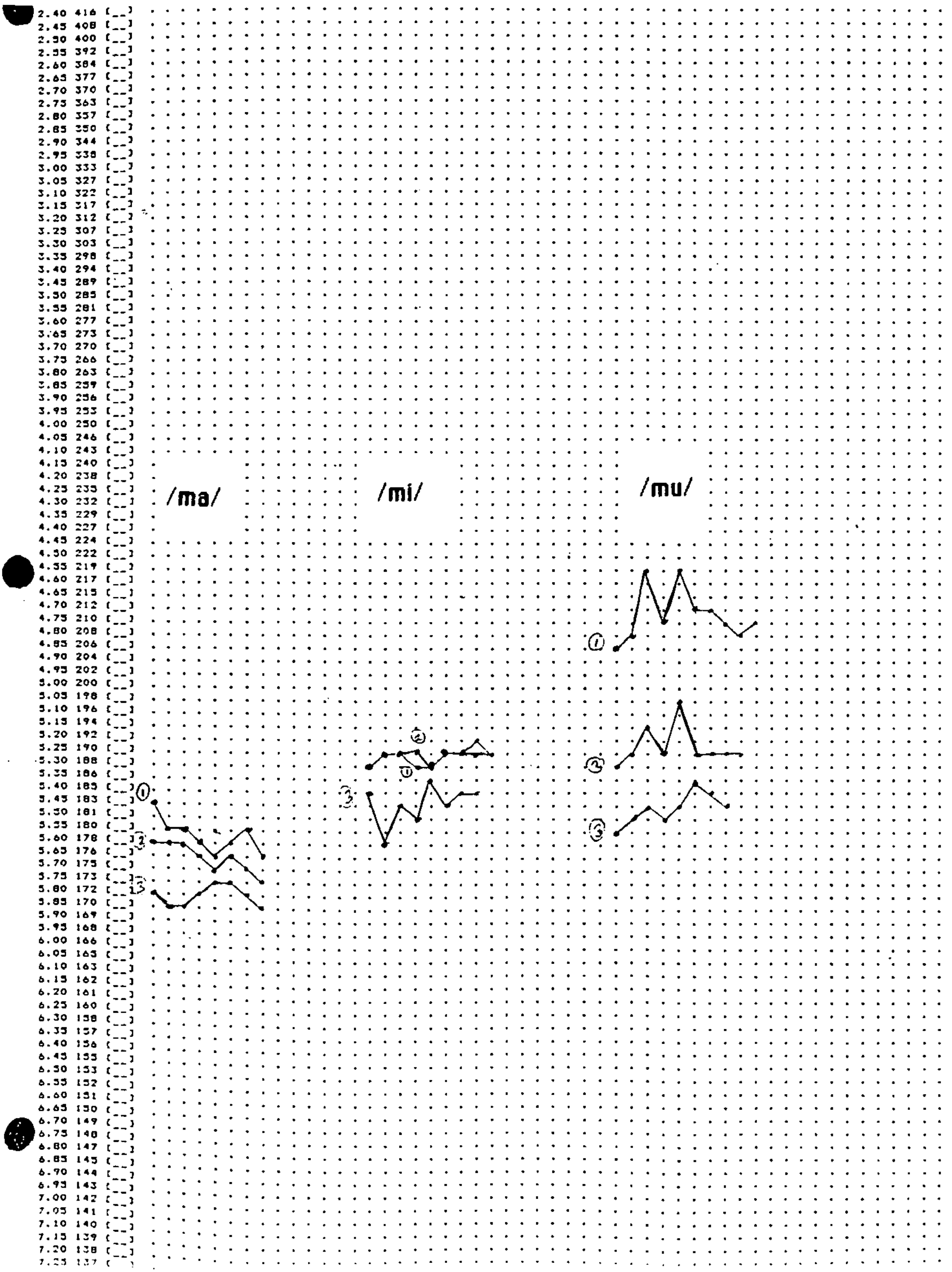
Graph 3

SUBJECT 117



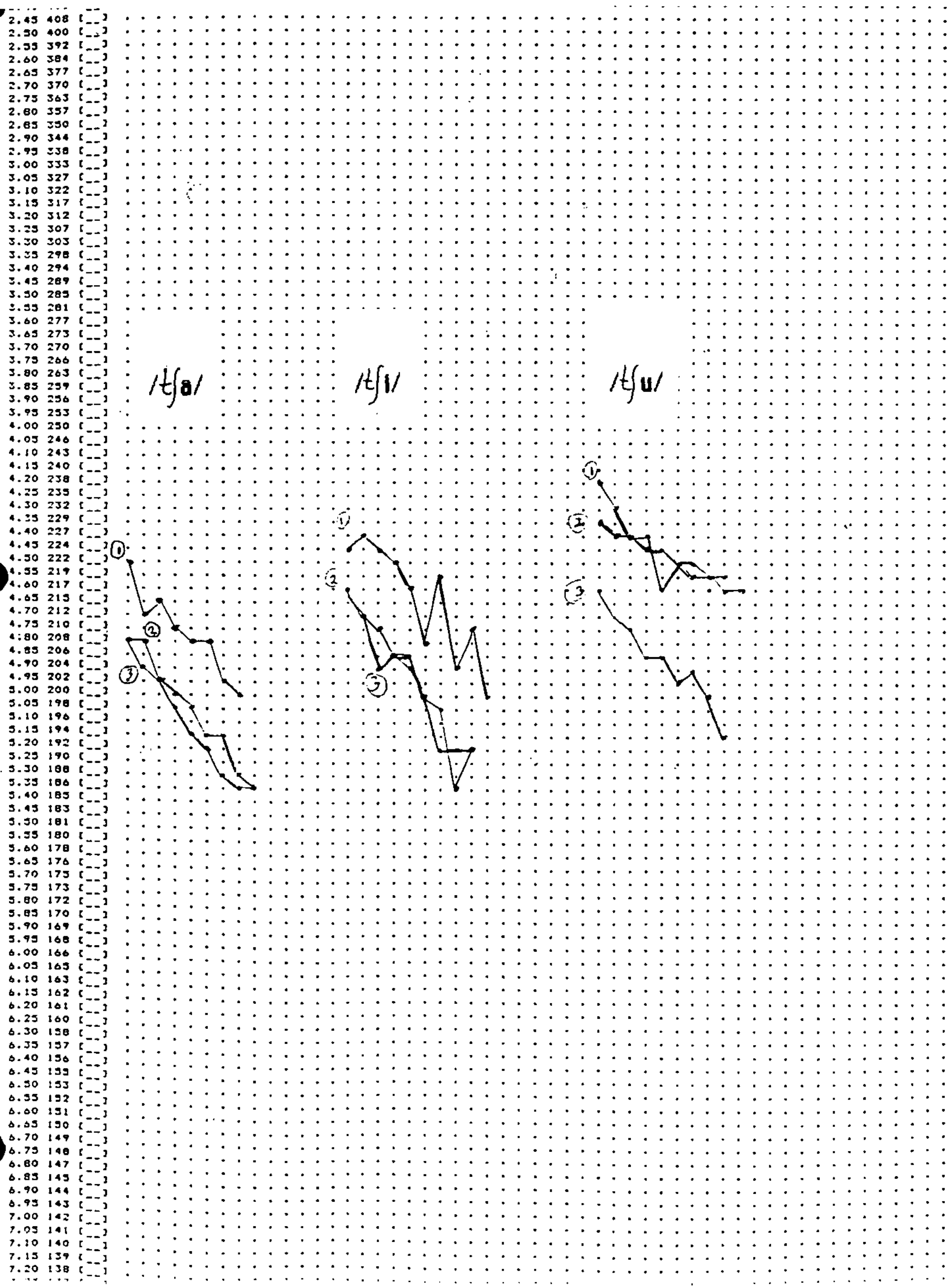
Graph 4

SUBJECT 117



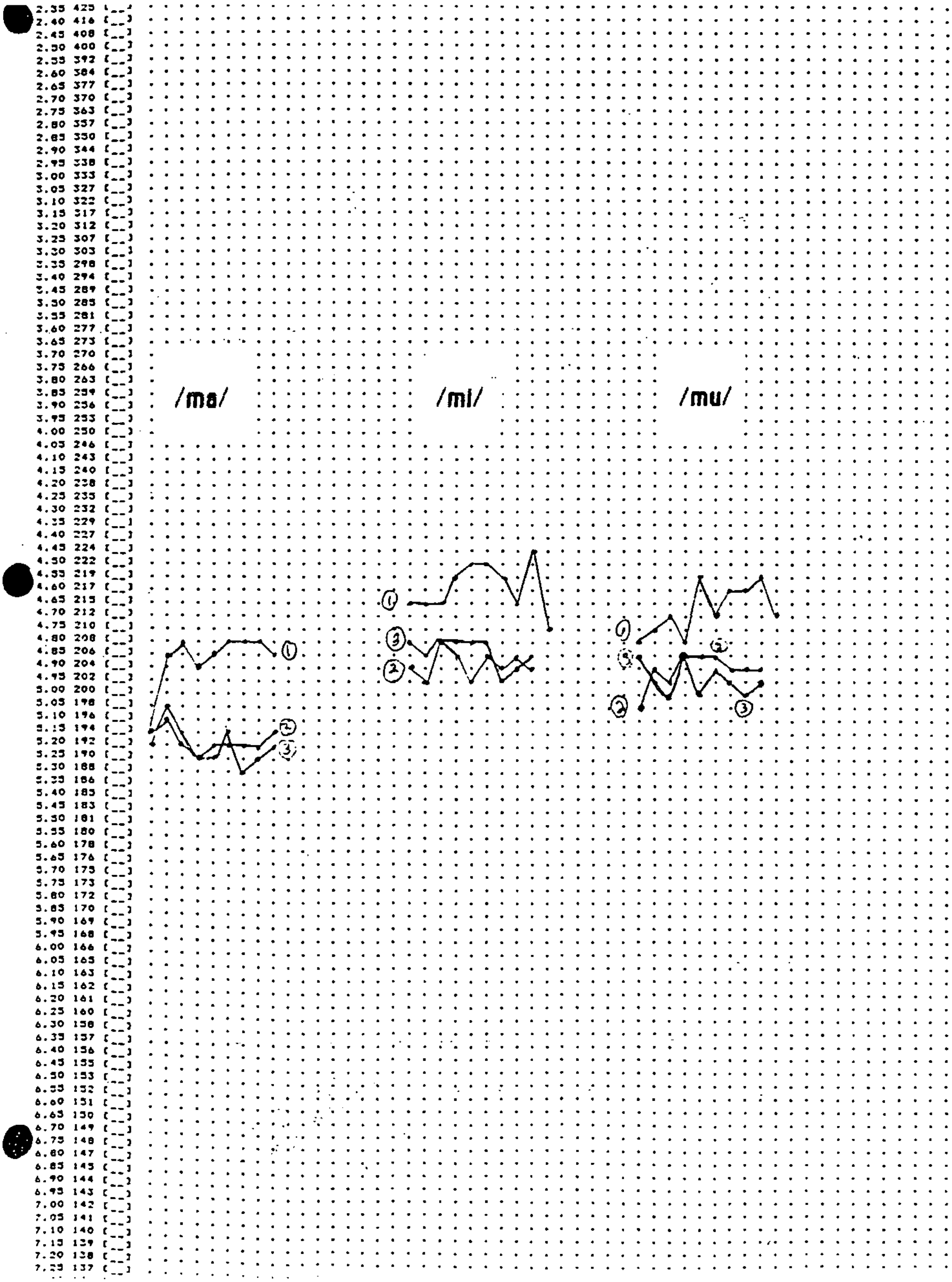
Graph 5

SUBJECT 118



Graph 6

SUBJECT 118



Appendix 3
Table 1

SUBJECT 116

Word	Var(x)	Sum (x)	Sum-x2	N-1	Var(y)	Sum(y)
Cha.1 (vow)	.01	47.3	203.49	11	8.909E-03	45.2
Cha.2 (vow)	.0449	48.5	214.29	11	.0244	47
Cha.3 (tra)	.0126	44.6	199.06	10	4.444E-03	46
Chi.1 (vow)	.0795	44.8	201.42	10	.0227	48.1
Chi.2 (vow)	.0196	44.2	195.54	10	.0149	45.2
Chi.3 (vow)	.0484	45.2	204.74	10	.0201	45.9
Choo.1 (vow)	.0924	48.2	194.62	12	.0410	47.4
Choo.2 (vow)	.0505	44.2	195.9	10	.0116	44.9
Choo.3 (vow)	.0429	46.1	193.63	11	.0127	48

Sum-y2	N-(2)	F-Ratio	T-Test
185.82	11	1.1225 (ns)	4.6046 (sig .01)
221.12	10	1.8372 (ns)	3.5480 (sig .01)
211.64	10	2.8463 (ns)	3.0963 (sig .01)
193.05	12	3.5121 (sig .05)	5.0145 (sig .01)
185.88	11	1.3117 (ns)	5.4399 (sig .01)
191.73	11	2.4004 (ns)	4.3380 (sig .01)
173.32	13	2.2528 (ns)	3.6134 (sig .01)
183.39	11	4.3448 (sig .05)	4.1770 (sig .01)
192.14	12	3.3715 (sig .05)	2.7782 (sig .05)

TRANSITION & VOWEL

Word	Number	Mean	Vari	Std.dev.	Fund.freq	ms
Cha.1	22	4.2045	0.0186	0.1361	237 Hz	4.2 ms
Cha.2	21	4.5476	0.0556	0.2358	219 Hz	4.5 ms
Cha.3	20	4.5300	0.0148	0.1218	220 Hz	4.5 ms
Chi.1	22	4.2227	0.1037	0.3221	236 Hz	4.2 ms
Chi.2	21	4.2571	0.0416	0.2039	234 Hz	4.3 ms
Chi.3	21	4.3381	0.0634	0.2519	230 Hz	4.3 ms
Choo.1	25	3.8240	0.0985	0.3139	261 Hz	3.8 ms
Choo.2	21	4.2429	0.0625	0.2501	235 Hz	4.2 ms
Choo.3	23	4.0913	0.0354	0.1880	244 Hz	4.1 ms

A/A	Sum x	x2
3.2%	92.5	389.31
5.2%	95.5	435.41
2.7%	90.6	410.7
7.6%	92.9	394.47
4.8%	89.4	381.42
5.8%	91.1	396.47
8.2%	95.6	367.94
5.9%	89.1	379.29
4.6%	94.1	385.77

Table 2

SUBJECT 116

Word	Var(x)	Sum (x)	Sum-x2	N-1	Var(y)	Sum(y)
Ma.1 (tra)	4.889E-03	45.4	206.16	10	3.222E-03	45.1
Ma.2 (vow)	4E-03	47.8	228.52	10	3.222E-03	47.1
Ma.3 (tra)	9.333E-03	46.6	217.24	10	5E-03	46.5
Me.1 (vow)	6.727E-03	47.9	208.65	11	5.636E-03	48.2
Me.2 (tra)	7.667E-03	44.9	201.67	10	2.778E-03	45.5
Me.3 (vow)	0.0149	46.1	193.35	11	0.0107	46.7
Moo.1 (vow)	2.727E-03	45.6	189.06	11	1.636E-03	46.4
Moo.2 (tra)	2.909E-03	48.3	212.11	11	2.909E-03	48.3
Moo.3 (vow)	4.545E-03	46.9	200.01	11	4.E-03	47.3

Sum-y2	N-(2)	F-Ratio	T-Test
203.43	10	1.5174 (ns)	1.0534 (ns)
221.87	10	1.2415 (ns)	2.6047 (sig .05)
216.27	10	1.8666 (ns)	0.2641 (ns)
211.26	11	1.1936 (ns)	0.8135 (ns)
207.05	10	2.7599 (ns)	1.8566 (ns)
198.37	11	1.3899 (ns)	1.1299 (ns)
195.74	11	1.6669 (ns)	3.6515 (sig .01)
212.11	11	1.0000 (ns)	0.0000 (ns)
203.43	11	1.1363 (ns)	1.3047 (ns)

TRANSITION & VOWEL

Word	Number	Mean	Vari	Std.dev.	Fund.freq	ms
Ma.1	20	4.5250	0.0040	0.0638	220 Hz	4.5 ms
Ma.2	20	4.7450	0.0047	0.0686	210 Hz	4.7 ms
Ma.3	20	4.6550	0.0068	0.0825	214 Hz	4.7 ms
Me.1	22	4.3681	0.0060	0.0779	228 Hz	4.4 ms
Me.2	20	4.5200	0.0059	0.0767	221 Hz	4.5 ms
Me.3	22	4.2181	0.0129	0.1139	237 Hz	4.2 ms
Moo.1	22	4.1818	0.0034	0.0588	239 Hz	4.2 ms
Moo.2	22	4.3909	0.0027	0.0526	227 Hz	4.4 ms
Moo.3	22	4.2818	0.0044	0.0664	233 Hz	4.3 ms

A/A	Sum x	x2
1.4%	90.5	409.59
1.4%	94.9	450.39
1.8%	93.1	433.51
1.8%	96.1	419.19
1.7%	90.4	408.72
2.7%	92.8	391.72
1.4%	92	384.80
1.2%	96.6	424.22
1.6%	94.2	403.44

Table 3

SUBJECT 117

Word	Var(x)	Sum (x)	Sum-x2	N-1	Var(y)	Sum(y)
Cha.1 (tra)	.0294	46.6	241.52	9	7.778E-03	48.1
Cha.2 (tra)	.0212	44.7	249.91	8	5.E-03	45.4
Cha.3 (tra)	.0336	45.4	257.88	8	7.857E-03	46.2
Chi.1 (vow)	.0127	45.5	230.13	9	2.5E-03	44.4
Chi.2 (vow)	.0525	48.3	259.63	9	.0111	45.8
Chi.3 (tra)	.0161	46.7	242.45	9	.0127	48.2
Choo.1 (vow)	.1036	46.7	243.15	9	.0232	47.9
Choo.2 (tra)	.0582	47.6	227.1	10	.0502	45.5
Choo.3 (vow)	.1825	47.4	251.1	9	.0127	43.7

Sum-y2	N-(2)	F-Ratio	T-Test
257.13	9	3.7855 (sig .05)	2.5916 (sig .05)
257.68	8	4.2500 (sig .05)	1.5275 (ns)
266.86	8	4.2728 (sig .05)	1.3896 (ns)
219.06	9	5.1112 (sig .05)	2.9665 (sig .05)
233.16	9	4.7250 (sig.05)	3.3041 (sig .01)
258.24	9	1.2608 (ns)	2.9417 (sig .01)
229.65	10	4.4618 (sig .05)	3.5135 (sig .01)
230.43	9	1.1580 (ns)	2.7558 (sig .05)
212.29	9	14.2824 (sig .01)	2.7910 (sig .05)

TRANSITION & VOWEL

Word	Number	Mean	Vari	Std.dev.	Fund.freq	ms
Cha.1	18	5.2611	0.0248	0.1577	190 Hz	5.3 ms
Cha.2	16	5.6312	0.0143	0.1195	177 Hz	5.6 ms
Cha.3	16	5.7250	0.0220	0.1483	174 Hz	5.7 ms
Chi.1	18	4.9944	0.0111	0.1055	200 Hz	5.0 ms
Chi.2	18	5.2277	0.0503	0.2244	191 Hz	5.2 ms
Chi.3	18	5.2722	0.0209	0.1447	189 Hz	5.3 ms
Choo.1	19	4.9789	0.0995	0.3154	200 Hz	5.0 ms
Choo.2	19	4.9000	0.0744	0.2728	204 Hz	4.9 ms
Choo.3	18	5.0611	0.1366	0.3696	197 Hz	5.1 ms

A/A	Sum x	x2
3.0%	94.7	498.65
2.1%	90.1	507.59
2.6%	91.6	524.74
2.1%	89.9	449.19
4.3%	94.1	492.79
2.7%	94.9	500.69
6.3%	94.6	472.80
5.6%	93.1	457.53
7.3%	91.1	463.39

Table 4

SUBJECT 117

Word	Var(x)	Sum (x)	Sum-x2	N-1	Var(y)	Sum(y)
Ma.1 (tra)	8.393E-03	44.3	245.37	8	6.964E-03	44.9
Ma.2 (tra)	6.964E-03	44.9	252.05	8	2.857E-03	45.6
Ma.3 (vow)	9.821E-03	46.3	268.03	8	5.E-03	46.6
Me.1 (vow)	5.278E-03	47.2	247.58	9	4.444E-03	47.5
Me.2 (tra)	.0394	47.5	251.01	9	2.778E-03	47.3
Me.3 (tra)	.0126	43.9	240.99	8	8.571E-03	43.2
Moo.1(tra)	.0311	47	221.18	10	2.667E-03	47.4
Moo.2 (tra)	.0111	46.9	244.49	9	6.944E-03	46.6
Moo.3 (vow)	6.111E-03	48.7	263.57	9	2.857E-03	44

Sum-y2	N-(2)	F-Ratio	T-Test
252.05	8	1.2052 (ns)	1.7118 (ns)
259.94	8	2.4375 (ns)	2.4973 (sig .05)
271.48	8	1.9642 (ns)	0.8712 (ns)
250.73	9	1.1877 (ns)	1.0142 (ns)
248.61	9	14.1987 (sig .01)	0.0324 (ns)
233.34	8	1.4793 (ns)	1.6977 (ns)
224.7	10	11.6652 (sig .01)	0.6882 (ns)
241.34	9	1.6001 (ns)	0.7442 (ns)
242.02	8	2.1390 (ns)	2.6994 (sig .05)

TRANSITION & VOWEL

Word	Number	Mean	Vari	Std.dev.	Fund.freq	ms
Ma.1	16	5.5750	0.0086	0.0930	179 Hz	5.6 ms
Ma.2	16	5.6562	0.0066	0.0814	176 Hz	5.7 ms
Ma.3	16	5.8062	0.0072	0.0853	172 Hz	5.8 ms
Me.1	18	5.2611	0.0049	0.0698	190 Hz	5.3 ms
Me.2	18	5.2666	0.0200	0.1414	189 Hz	5.3 ms
Me.3	16	5.4437	0.0119	0.1094	183 Hz	5.4 ms
Moo.1	20	4.7200	0.0164	0.1281	211 Hz	4.7 ms
Moo.2	18	5.1944	0.0088	0.0938	192 Hz	5.2 ms
Moo.3	17	5.4529	0.0063	0.0800	183 Hz	5.5 ms

A/A	Sum x	x2
1.7%	89.2	497.42
1.4%	90.5	511.99
1.5%	92.9	539.51
1.3%	94.7	498.31
2.7%	94.8	499.62
2.0%	87.1	474.33
2.7%	94.4	445.88
1.8%	93.5	485.83
1.5%	92.7	505.59

Table 5

SUBJECT 118

Word	Var(x)	Sum (x)	Sum-x2	N-1	Var(y)	Sum(y)
Cha.1(tra)	.0173	46.8	219.18	10	.01	44.1
Cha.2 (tra)	.0125	44.1	216.19	9	.0119	47
Cha.3 (tra)	.0253	44.6	221.22	9	9.444E-03	47.5
Chi.1 (tra)	.0410	47.9	229.81	10	.0107	44.
Chi.2 (vow)	.0275	46.5	240.47	9	.016	47.6
Chi.3 (vow)	.0375	46.5	240.55	9	.0196	47.8
Choo.1(tra)	5.636E-03	48.6	214.78	11	4.E-03	46.2
Choo.2(tra)	.0289	48.3	212.37	11	.016	46.4
Choo.3 (tra)	.0116	47.5	225.73	10	.01	45

Sum-y2	N-(2)	F-Ratio	T-Test
216.17	9	1.7333 (ns)	4.0638 (sig .01)
245.54	9	1.0466 (ns)	6.1828 (sig .01)
250.77	9	2.6766 (ns)	5.1877 (sig .01)
200.8	10	3.8436 (sig .05)	4.3128 (sig .01)
226.72	10	1.7188 (ns)	6.0486 (sig .01)
228.66	10	1.9176 (ns)	5.0292 (sig .01)
213.48	10	1.4090 (ns)	6.6248 (sig .01)
215.44	10	1.8068 (ns)	3.7760 (sig .01)
225.08	9	1.1667 (ns)	5.2158 (sig .01)

TRANSITION & VOWEL

Word	Number	Mean	Vari	Std.dev.	Fund.freq	ms
Cha.1	19	4.7842	0.0258	0.1608	209 Hz	4.8 ms
Cha.2	18	5.0611	0.0390	0.1975	197 Hz	5.1 ms
Cha.3	18	5.1166	0.0438	0.2093	195 Hz	5.1 ms
Chi.1	20	4.635	0.0497	0.2230	215 Hz	4.6 ms
Chi.2	19	4.9526	0.0637	0.2524	201 Hz	5.0 ms
Chi.3	19	4.9631	0.0658	0.2565	201 Hz	5.0 ms
Choo.1	21	4.5143	0.0152	0.1236	221 Hz	4.5 ms
Choo.2	21	4.5095	0.0379	0.1947	221 Hz	4.5 ms
Choo.3	19	4.8684	0.0267	0.1634	205 Hz	4.9 ms

A/R	Sum x	x2
3.4%	90.9	435.35
3.9%	91.1	461.73
4.1%	92.1	471.99
4.8%	92.7	430.61
5.1%	94.1	467.19
5.2%	94.3	469.21
2.7%	94.8	428.26
4.3%	94.7	427.81
3.4%	92.5	450.81

Table 6

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Word	Var(x)	Sum (x)	Sum-x2	N-1	Var(y)	Sum(y)
Ma.1 (tra)	.0511	44.2	217.48	9	2.333E-03	48.3
Ma.2 (vow)	1.111E-03	46.7	242.33	9	.01	46.5
Ma.3 (tra)	6.944E-03	46.6	241.34	9	5.E-03	47.1
Me.1 (vow)	.0284	45.8	210.02	10	6.667E-03	46
Me.2 (vow)	.0225	44.1	216.27	9	.0175	43.8
Me.3 (vow)	9.444E-03	43.9	214.21	9	5.444E-03	48.1
Moo.1 (tra)	.0178	47.2	222.94	10	9.E-03	46.3
Moo.2 (tra)	9.444E-03	44.3	218.13	9	3.611E-03	44
Moo.3 (tra)	0.01	44.5	219.12	9	2.778E-03	44.5

Sum-y2	N-(2)	F-Ratio	T-Test
233.31	10	21.9078 (sig .01)	1.1101 (ns)
240.33	9	0.1111 (ns)	.6325 (ns)
246.53	9	1.3888 (ns)	1.5250 (ns)
211.66	10	4.2664 (sig .05)	.0337 (ns)
213.3	9	1.2857 (ns)	0.5000 (ns)
231.14	10	1.7348 (ns)	1.7324 (ns)
214.45	10	1.9126 (ns)	1.7538 (ns)
215.14	9	2.6153 (ns)	.8752 (ns)
220.05	9	3.5997 (sig .05)	.2949 (ns)

TRANSITION & VOWEL

Word	Number	Mean	Vari	Std.dev.	Fund.freq	ms
Ma.1	19	4.8684	0.0256	0.1600	205 Hz	4.9 ms
Ma.2	18	5.1777	0.0053	0.0073	198 Hz	5.2 ms
Ma.3	18	5.2056	0.0064	0.0802	192 Hz	5.2 ms
Me.1	20	4.5900	0.0167	0.1293	217 Hz	4.6 ms
Me.2	18	4.8833	0.0191	0.1382	204 Hz	4.9 ms
Me.3	19	4.8421	0.0081	0.0901	206 Hz	4.9 ms
Moo.1	20	4.6750	0.0146	0.1209	213 Hz	4.7 ms
Moo.2	18	4.9056	0.0064	0.0802	203 Hz	4.9 ms
Moo.3	18	4.9389	0.0060	0.0778	202 Hz	4.9 ms

A/A	Sum x	x2
3.3%	92.5	450.79
1.4%	93.2	482.66
1.5%	93.7	487.87
2.8%	91.8	421.68
2.8%	87.9	429.57
1.9%	92	445.62
2.6%	98.5	497.39
1.6%	88.3	433.27
1.6%	88.9	439.17

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