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ABSTRACT

This study reports various aspects of the analyses carried out on the longitudinal data reported in a previous study (PS 007 345) for determining the general growth patterns and growth velocity of mental and motor development. Preliminary analyses focused on the selection of the growth curve, its evaluation in the 208 individual cases, and the subsequent decision that it did not present an accurate description of the data. To compensate, an approach was initiated which compared each subject to a common standard and classified the subject into one of three categories: fast, normal, and slow growth. Results indicated that subjects were equally divided among categories in mental growth and that one-half of the subjects were in the normal category in motor growth with the remainder equally divided between the other two. In measuring the growth velocity of mental and motor development a curve closely approximating the velocity pattern was fitted. Curve examination showed a prominent peak for both areas in the first six months followed by a gradual decrease in velocity that was less severe than that found in the observed data. Concluding discussion focused on the limitations of the growth curve and implications of the testing conditions. (SDH)

RESEARCH REPORT No. 4

MENTAL AND MOTOR GROWTH PATTERNS AND GROWTH VELOCITY OF INDIAN BABIES

(Longitudinal Growth of Indian Children*)

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P. Phatak
(CHIEF INVESTIGATOR)

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MENTAL AND MOTOR GROWTH PATTERNS AND GROWTH VELOCITY OF INDIAN BABIES

CHAPTER I

I N T R O D U C T I O N

Generalised Growth Curves and Data:

In scientific literature many presentations of the course of human growth and development on any parameter (in specific aspect) is based upon the mean scores of cross-sectional sample of sufficiently large size and there are very few reports about the rate of growth. Generalizations of the observed sample growth leading to the knowledge of velocity of growth seems to be difficult because of a number of limitations of samples and tools specially in the field of mental and motor growth. Comparatively such studies - generalised growth patterns and velocity curves - are easier with reference to physical growth and anthropometric measurement because of constancy of measuring tools. In mental and motor growth the tools of measurement - the tests of maturity - are bound to be different and even differently standardised for various age limits to be covered under general growth curves as they are mainly the measurements of the functional aspects. The limitations of cross-sectional sample for such studies are also great. To get a generalised picture of growth curve and its velocity it seems necessary to control umpteen genetic and environmental forces which influence the growth and development of each individual in an unique manner and thus widen the individual variations within and between the subsequent age groups. The ideal sample for such studies might be the repeated observations of the same children on the same tools.

The Present Study:

The longitudinal growth study of Indian Babies provided such data with reference to mental and motor growth during the first 30 months of life. BSID (Research Form 1961) was used in collecting the mental and motor performance of the same children from the age of 1 month to 30 months. In the Final Report* of major study the longitudinal data is treated cross-sectionally and is also supplemented by cross-sectional samples to get the normative growths. The mean mental scores and mean motor scores of each month are plotted as growth curves and the differences in the means of consecutive months of related samples are plotted as speed curves.

It was felt that the longitudinal data prima-facie satisfied the conditions for evolving a generalised equation of the observed mean-growth-curves and also for studying the velocity of growth during the small but significant period of first 30 months of life. Further the longitudinal nature of data would also facilitate the comparison of growth patterns observed from individual to individual. The various aspects of the analyses carried out on the longitudinal data for determining the general growth patterns of mental and motor development and the growth velocity are described in this report.

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* Final Report - Mental and Motor Growth of Indian Babies 1-30 months - (Longitudinal growth of Indian Children) 1970 - Dept of Child Development, Maharajah Sayajirao University of Baroda, Baroda

CHAPTER II

PRELIMINARY ANALYSES

The Selection of Growth Curve:

The growth curves for both mental and motor development plotted in the Final Report* indicated that the growth curves could be approximated by one of the following families of curves viz -

$$\text{i)} \quad y = Ae^{bx} \qquad \text{ii)} \quad y = Ax^{b}$$

where y is the mental/motor performance and x the corresponding age. If we take logarithms then the above equations are transformed into -

$$\text{i)} \quad \log y = \log A + bx \text{ (exponential)}$$

$$\text{and ii)} \quad \log y = \log A + b \log x \text{ (allometric)}$$

The second set of equations are linear in log y and x or log y and log x. The linearity of the regression equations enables easy and efficient estimation of the regression parameters a(=log A) and b. Further the parameters can also be statistically compared for their significance from one curve to another.

It was decided that to choose the best both the above forms should be tried out on some sample subjects. Accordingly test results for 5 subjects chosen at random were first analysed and the regression equations under both models was obtained. A comparative picture of the two regression models is presented in Tables 1a and 1b for the mental and motor growth respectively, wherein the values of the intercept 'a', and the slope 'b' are given for each case alongwith the value of r^2, the square of correlation coefficient which signifies the proportion of the variation in the dependent variable (log y) explained by the regression equation.

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* Vide Footnote - Page 2

Table-1a: COMPARISON OF REGRESSION EQUATIONS (MENTAL GROWTH)

Case No	Number of Testings	EXPONENTIAL log y = a+bx			ALLOMETRIC log y = a+b log x		
		a	b	r^2	a	b	r^2
105	21	1.7883	.0157	.84	1.4246	.5377	.98
165	23	1.6137	.0249	.78	1.3198	.6293	.98
180	20	1.6942	.0197	.80	1.3154	.6308	.96
235	20	1.7797	.0164	.89	1.5923	.5696	.98
258	24	1.6659	.0213	.79	1.2976	.6386	.98

Table-1b: COMPARISON OF REGRESSION EQUATIONS (MOTOR GROWTH)

Case No	Number of Testings	EXPONENTIAL log y = a+bx			ALLOMETRIC log y = a+b log x		
		a	b	r^2	a	b	r^2
105	21	1.3888	.0158	.46	1.1332	.4971	.96
165	23	1.2625	.0240	.70	0.9557	.6369	.96
180	20	1.3863	.0154	.75	1.0496	.5213	.90
235	20	1.4039	.0154	.77	1.0102	.5598	.94
258	24	1.3013	.0192	.65	0.9354	.6052	.93

It is evident from Tables 1a and 1b that the second family of curves viz. log y = a+b log x (or $y = Ax^b$) is better approximation to the growth phenomena than the first family of curves because the value of r^2 is significantly higher in all cases.

Verification of Selected Curve:

For the second equation the data were transferred back to the original scale and the errors (observed - calculated) in the prediction were examined. The measure of the relative error in prediction defined as the ratio of the Error Sum of Squares (ESS) to the corrected Total Sum of Squares (TSS) of the mental and motor scores was calculated for each case. These are shown in Table-1c.

Table-1c: RELATIVE ERRORS IN PREDICTION

Case No	Number of Testings	Ratio (%) = Error Sum of Squares / Total Sum of Squares	
		Mental Growth	Motor Growth
105	21	2.83	12.30
165	23	3.74	9.48
190	20	3.8[illegible]	5.25
235	20	1.93	7.26
253	24	2.92	12.73

It was noted that the relative errors in prediction are not very high when the variables are transformed into original scales. Especially in respect of mental growth the corresponding curve in the original scale was almost as efficient as the line fitted using logarithms because the relative errors were below 5.0%. Only in respect of motor growth the relative error in the original scale was noted to be higher than 10.0% for two cases.

The equality of regression lines worked out for the five cases was also examined. The results revealed that the five lines are significantly different for both mental and motor growth. Next the parallelism of the lines was examined by testing the significance only of the 'b' values. The results again indicated the lines are not parallel either for mental or for motor growths.

Conclusion:

Thus preliminary analyses carried out have indicated that the test results are amenable to scientific analysis. On the basis of the preliminary analyses it was decided that the growth curves should be worked out individually for each subject and examined for evolving some general growth patterns.

CHAPTER III

INDIVIDUAL GROWTH CURVES - EVALUATION AND COMPARISON

Sample individuals with Longitudinal Testings

For the purpose of study the test results of any individual case was defined to be longitudinal if the following conditions were satisfied :

i There existed a minimum of 4 testings between 1 and 30 months.

ii At least one testing has been carried out in any two of the periods 1 to 10, 11 to 20 and 21 to 30 months.

iii The maximum interval between any two successive testings was less than 12 months.

A total of 208 cases satisfying the above conditions constituted the sample for the present study.

Individual Growth Curves

On the basis of the longitudinal test results regression equations of of the form $\log y = a + b \log x$ for the mental and motor growths were evaluated for all the 208 individual cases. The variation between the individual lines was found to be extremely wide for both mental and motor growths. A fair idea about the variation can be had from the frequency distribution of the regression parameters viz the slope 'b' and the intercept 'a' (Tables 2a and 2b).

Table-2a: FREQUENCY DISTRIBUTION OF THE REGRESSION PARAMETERS (MENTAL GROWTH)

Slope 'b'			Intercept 'a'		
Class Interval	Frequency	%	Class Interval	Frequency	%
0.35 - 0.40	1	0.48	1.05 - 1.10	2	0.96
0.40 - 0.45	10	4.80	1.10 - 1.15	0	0.00
0.45 - 0.50	24	11.85	1.15 - 1.20	7	3.37
0.50 - 0.55	43	20.67	1.20 - 1.25	15	7.21
0.55 - 0.60	27	12.98	1.25 - 1.30	39	18.75
0.60 - 0.65	55	26.45	1.30 - 1.35	41	19.71
0.65 - 0.70	27	12.98	1.35 - 1.40	22	10.58
0.70 - 0.75	16	7.69	1.40 - 1.45	31	14.90
0.75 - 0.80	2	0.96	1.45 - 1.50	28	13.46
0.80 - 0.85	1	0.48	1.50 - 1.55	17	8.17
0.85 - 0.90	1	0.48	1.55 - 1.60	6	2.89
0.90 - 0.95	1	0.48			
Total	208	100.00	Total	208	100.00

Table-2b: FREQUENCY DISTRIBUTION OF THE REGRESSION PARAMETERS (MOTOR GROWTH)

Slope 'b'			Intercept 'a'		
Class Interval	Frequency	%	Class Interval	Frequency	%
0.15 - 0.20	1	0.48	0.75 - 0.80	2	0.96
0.20 - 0.25	2	0.96	0.80 - 0.85	5	2.40
0.25 - 0.30	5	2.40	0.85 - 0.90	13	6.25
0.30 - 0.35	9	4.33	0.90 - 0.95	26	12.50
0.35 - 0.40	11	5.29	0.95 - 1.00	34	16.35
0.40 - 0.45	16	7.69	1.00 - 1.05	47	22.60
0.45 - 0.50	20	9.62	1.05 - 1.10	17	8.18
0.50 - 0.55	32	15.39	1.10 - 1.15	19	9.14
0.55 - 0.60	55	26.44	1.15 - 1.20	10	4.80
0.60 - 0.65	30	14.42	1.20 - 1.25	14	6.74
0.65 - 0.70	17	8.18	1.25 - 1.30	6	2.88
0.70 - 0.75	5	2.40	1.30 - 1.35	6	2.88
0.75 - 0.80	4	1.92	1.35 - 1.40	5	2.40
0.80 - 0.85	1	0.48	1.40 - 1.45	2	0.96
			1.45 - 1.50	2	0.96
Total	208	100.00	Total	208	100.00

From the data given in Tables 2a and 2b the averages and standard deviations were calculated. The values were as follows :

	Average	s.d
Slope of mental growth	0.5889	0.0905
Slope of motor growth	0.5363	0.1158
Intercept of mental growth	1.3649	0.1044
Intercept of motor growth	1.0541	0.1400

The higher value of standard deviation in case of motor growth indicated that the subject to subject variability was higher for motor growth than the mental growth.

Further examination of the frequency distributions given in tables 2a and 2b also revealed that no known theoretical distribution could be fitted to the data. This was mainly due to the bimodal nature of the frequency distributions.

For each case the value of r^2 which measures the closeness of the line fitted to the observed data was also calculated. The cases were next classified as per the values of r^2 and a short summary is given below :

Table-2c: FREQUENCY DISTRIBUTION OF SQUARE OF CORRELATION COEFFICIENCY (r^2)

Range of r^2 value	Mental Scale Frequency	%	Motor Scale Frequency	%
Above .99	7	3.4	3	1.4
Between .99 and .95	172	82.7	77	37.0
Between .949 and .900	27	13.0	93	44.7
Below .900	2	0.9	35	16.9
Total	208	100.0	208	100.0

It may be noted from Table-2c that the regression equation very closely approximates the pattern of growth especially for mental growth for which the value of 'r^2' was above 0.95 for nearly 86% of the cases. However

in respect of motor growth the approximation by the regression equation was not as close and for about 17% of cases the value of r^2 was below 0.90.

Study of variation of slope of Individual Growth Curves

The causes for large variation in the slope and intercept values were next examined. It was observed that for lines with high slope the intercept was low and vice versa indicating some association between the two for both mental and motor growth. A random sample of 20 cases was taken and the relationship between the intercept and slope was computed. The results were as under :

$$a = 2.0880 - 1.1900\ b \quad \text{(mental)}$$
$$a = 1.7315 - 1.2567\ b \quad \text{(motor)}$$

The coefficient of correlation between the slope and intercept was -0.96 for mental and -0.99 for motor.

The strong correlation between the slope and intercept value implied that the growth curve is almost uniquely determined by the slope. Hence the variations noted in the individual growth curves should be attributed to the variations in the slope alone. In the light of this a study of the various factors that influence the slope was found necessary. One such factor which varied considerably over the subjects tested is the period of testings. To know about the effect of the period of testings on the curve the slopes were tabulated in a two way table with age of first testing on one side and the age of last testing on the other side. The details of this two-way analysis are summarised in Table-3a for mental growth and Table-3b for motor growth.

Table-3a: AVERAGE SLOPE OF MENTAL GROWTH CURVES CLASSIFIED AS PER THE AGE AT FIRST TESTING AND AGE AT THE LAST TESTING OF THE SUBJECTS

Age at the 1st testing	AGE AT THE LAST TESTING: Between 25-30 Number of subjects	Between 25-30 Average slope	Between 19-24 Number of sub-jects	Between 19-24 Average Slope	Between 1-18 Number of sub-jects	Between 1-18 Average Slope	OVERALL Number of sub-jects	OVERALL Average Slope
1	39	0.6458	4	0.6704	3	0.7257	46	0.6537
2	37	0.6343	4	0.7040	4	0.7672	45	0.6520
3	24	0.5932	2	0.6364	3	0.7620	29	0.6149
4	21	0.5441	-	-	2	0.8264	23	0.5513
5	12	0.5105	1	0.4842	2	0.5083	15	0.5085
6	7	0.4672	1	0.5045	1	0.4294	9	0.4671
7	7	0.4757	1	0.4379	1	0.5500	9	0.4853
8	6	0.4725	1	0.5859	-	-	7	0.4887
9	3	0.5009	1	0.4684	1	0.5160	5	0.4974
10	7	0.4925	2	0.5514	-	-	9	0.5056
Overall	163	0.5818	17	0.6134	17	0.6645	197	0.5917

Table-3b: AVERAGE SLOPE OF MOTOR GROWTH CURVES CLASSIFIED AS PER THE AGE AT FIRST TESTING AND AGE AT THE LAST TESTING OF THE SUBJECTS

Age at the 1st testing	AGE AT THE LAST TESTING: Between 25-30 Number of subjects	Between 25-30 Average slope	Between 19-24 Number of sub-jects	Between 19-24 Average slope	Between 1-18 Number of sub-jects	Between 1-18 Average slope	OVERALL Number of sub-jects	OVERALL Average slope
1	39	0.5875	4	0.6376	3	0.6362	46	0.5982
2	37	0.5969	4	0.6656	4	0.7375	45	0.6155
3	24	0.5606	2	0.6655	3	0.7398	29	0.5882
4	21	0.5243	-	-	2	0.7774	23	0.5403
5	12	0.4951	1	0.4715	2	0.5809	15	0.5049
6	7	0.4290	1	0.5731	1	0.4949	9	0.4523
7	7	0.3675	1	0.3777	1	0.5251	9	0.3861
8	6	0.3765	1	0.3882	-	-	7	0.3782
9	3	0.3807	1	0.4102	1	0.4320	5	0.3969
10	7	0.3417	2	0.3764	-	-	9	0.3496
Overall	163	0.5323	17	0.5598	17	0.6703	197	0.5466

The results of statistical analysis of data presented in Tables 3a and 3b show beyond doubt that the age at the first and last testings definitely influence the slope 'b' of the regression. The slope decreased with the increase in the age of first testing. This effect is fairly well pronounced

upto the age 6 months in respect of mental growth and upto the age of 7 months in respect of motor growth. The age at last testing had an opposite effect on the slope i.e the earlier the age of termination of tests the higher was the slope. Since the slope was an important characteristic which determines the growth rate it was decided to enumerate the effect of the factors that influence it. On the basis of the two-way analysis carried out earlier the following variables could be considered to have a major effect on the slope :-

i The number of testings made (X_1): The slope is estimated more accurately as the number of testings increases.

ii The score at first testing (X_2): The effect of any curvature in the line which is not straightened out completely by the transformation on the slope will be reflected by this.

iii Dispersion of ages at which the tests were carried out(X_3): The effect on slope of the spacing of ages of testing between the months 1 to 30 can be measured by this factor.

iv Co-variance between the ages and score (X_4): The inherent differences between the subjects in their growth will be measured by this factor

To know the extent of variation in the slope b that can be accounted by the above four factors a multiple linear regression model was developed and the regression equation estimated from a sample of twelve cases in respect of mental scores was as under :

$$b = \text{Constant} + 0.0089X_1 - 0.3388X_2 - 0.3203X_3 + 0.3441X_4$$

The above regression model explained about 70% of the variation in slope values. However it was noted that the major contributor (about 45%) to the slope variation was X_2 the score at first testing. This confirmed the results of earlier analysis given in Tables 3a and 3b because the score at first testing is directly dependent on the age

scores also the effect of the various factors on the slope value could be considered as identical.

Conclusions:

The above analyses lead to the conclusion that a general growth pattern based on the value of slope alone will not be relevant unless the necessary adjustments are made in respect of the initial scores and other factors. The age at initial and final testings and the number of testings were not uniform for the subjects studied and have therefore resulted in higher variation of the slope. Adjustments for the factors therefore become highly impracticable.

The items in the mental and motor scales were in general found to be in the increasing order of difficulty. But with the advancement of age of the subject the number of items in the scales to rightly assess the improvements in the mental and motor performance was limited. The effect of this scale limitation was that for almost all subjects the testings made beyond 24 months invariably yielded nearly same score thus flattening the curve at the fag end. This flattening of the curve between the period 24 to 30 months tended to reduce the value of slope. This fact was well brought out in Tables 3a and 3b where it may be noted that value of slope was higher as the age at last testing decreased. It is possible to eliminate the effect of this scale limitations by excluding the data recorded beyond 24 months. But the complete re-evaluation of growth curve was not done because it was feared that the effect of initial score which was more dominant would still persist.

CHAPTER IV

EVALUATION OF GROWTH PATTERNS - A Different Approach

Introduction

The attempt made for classification and evaluation of general growth curves based on regression lines of individual subjects did not succeed for reasons already explained in the earlier sections. In this context the problem should be approached at a different angle. A simple yet powerful method is to compare each case against some standard which can be considered as representative of normal growth and classify the cases as above normal, below normal and normal. In the absence of any previous data it was decided that the overall monthly averages observed at each age level (as presented in Tables A1 and A21 of the Final Report*) could be conveniently taken as norms for comparison. For any subject the deviation from the standard was computed for each month and the average deviation was tested for significance using the paired t-test. The case was defined as 'fast growth' if the deviation was found to be positive and significant. The case was defined as 'slow growth' if the average deviation was found to be negative and significant. Otherwise the case was considered as normal.

The classification of the growths as fast, normal and slow was evaluated separately for the mental and motor scores. Because of the limitation in the scale it was decided that the scores obtained by the subjects upto 24 months of age only will be taken into consideration for the classification. After classifying the subjects into the three categories a general growth curve for each category based on the averages could be evaluated.

The case numbers of subjects classified as fast, normal and slow in respect of the mental and motor growth are given in Appendix A, Tables 1 and 2. The details of the average monthly scores for the three categories are shown in Tables 3 and 4 of Appendix A for the mental and motor scales.

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* Vide footnote Page 2

Evaluation and comparison of growth curves of the categories

From Tables A3 and A4 in Appendix it may be noted that there exists significant differences between the average scores recorded for the three categories of growth viz, slow, normal and fast. It was noted that for these data also the regression equation $\log y = a + b \log x$ was the best fit. The details of the regression equation fitted as well as the value of r^2 are presented in Table-4 for the mental & motor scores.

Table-4: REGRESSION EQUATION FOR THE MENTAL AND MOTOR GROWTHS

Scale	Category of growth	Regression Equation	r^2
Mental	Slow	$\log y = 1.2520 + 0.6731 \log x$	0.977
	Normal	$\log y = 1.2965 + 0.6483 \log x$	0.978
	Fast	$\log y = 1.2923 + 0.6670 \log x$	0.985
Motor	Slow	$\log y = 0.9230 + 0.6323 \log x$	0.975
	Normal	$\log y = 0.9589 + 0.6208 \log x$	0.974
	Fast	$\log y = 0.9892 + 0.6100 \log x$	0.970

Statistical tests were next carried out to find out the differences in the regression parameters for the three categories. The results indicate that -

i the small differences in the slope and intercept values are highly significant for both mental and motor scores.

ii the regression lines fitted could be considered as best because the value of r^2 in all cases exceed 0.97.

iii for mental scores the intercepts of the normal and fast categories are same but the slope for fast growth curve was higher.

iv in case of motor scale the differences between the intercepts for the three categories are well pronounced than the slope values.

A plot of actual averages against age for the three categories of growth are shown in Charts B1 and B2 of Appendix B. A study of the charts reveals the following :

i For mental scores there was no appreciable difference upto 9th month between the normal and fast growth patterns.

ii After the 9th month the three curves corresponding to mental scale tended to diverge.

iii For motor scores the differences between the three categories were very small upto third month.

iv The average scores for the slow category (motor) between 12 and 18 months is considerably low.

In order to know the extent to which the theoretical curve developed approximates the observed values the actual monthly averages for normal cases were projected along with the calculated values from corresponding curve in Charts B3 and B4 of Appendix B for the mental and motor scales. The figures show that the curves fitted are fair approximations of the observed growth pattern.

Association between mental and motor growths

The association between the mental and motor faculties of the individual subjects was also examined. Table-5 gives the two-way classification of the subjects in respect of their mental and motor growth.

Table-5: ASSOCIATION BETWEEN MENTAL & MOTOR GROWTH

		Mental Growth			
		Fast	Normal	Slow	Total
Motor Growth	Fast	35	16	6	57
	Normal	26	42	31	99
	Slow	4	13	35	52
	Total	65	71	72	208

Table-5 indicates that the subjects are almost equally divided into the three groups in respect of their mental response whereas in respect of motor performance nearly half of them show normal performance the rest being equally divided as fast and slow. Statistical tests have confirmed this. Further tests have also revealed positive association

between the two growths i.e a subject showing fast or normal performance in motor growth is more likely to show fast or normal performance in mental growth. Also as many as 1[illegible] cases were found to be of same category in respect of both mental and motor growth which is very significant because under the assumption of no association such cases are not likely to exceed 80.

CHAPTER [illegible]

VELOCITY OF GROWTH

Introduction

The velocity of growth of Indian children in respect of the mental and motor performance assessed under Bayley scale were reported in Tables A5 and A25 of the Final Report*. The velocity was expressed as the increase in the average total score of all subjects who have reported for testing in two consecutive months (referred to as related samples). The speed curves relating to the motor and mental growth in which the increase in scores are plotted against the month are presented in Figures B3 and B9 of the Final Report. Eventhough the growth velocity data was treated separately for boys and girls, statistical tests reveal that the growth velocity is the same for both sexes in respect of mental as well as motor scale. The growth velocity was at the peak in the 5th month for mental scale and in the 6th month for motor scale. A sharp fall was observed in the speed of growth after the peak and the speed of growth was fairly stationary from 8th month onwards

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* Vide Footnote Page [illegible]

for mental scale and from 12th month onwards for the motor scale. Further after 20 months the difference between the related samples was not very significant in all cases to assert a positive growth.

The velocity curve

A suitable form of the curve that will depict the variations in the speed of growth over the months was next attempted. Apart from the early peak secondary peaks were also noted but the periodicity of the peaks were not pronounced in either of the curves. Therefore a curve that will have an early peak followed by a downward slope was thought of as a reasonable representation. Further in evaluating the curve the data for only those months for which the speed of growth was significant were considered relevant. The simplest form of curve that was found to fit well for the mental and motor scales was -

$$y = (x - a)^2 e^{-kx}$$

where y = speed of growth

x = age in months

a, k = parameters of the curve

In both scales a pair of values for a and k could be obtained which explained around 93% of the variations in the growth velocity. The observed growth velocity along with the calculated growth velocity for each month are presented in Tables 6a and 6b respectively for the mental and motor scales.

Table-6a: MONTHWISE OBSERVED AND CALCULATED GROWTH VELOCITY (MENTAL SCALE)

Curve fitted : $Y_c = (X+2.2)^2 e^{-0.31X}$

Age (X)	Observed Velocity (Y)	Calculated Velocity (Y_c)
2	9.39	9.49
3	10.72	10.67
4	10.71	11.12
5	13.20	11.00
6	12.15	10.47
7	8.21	9.66
8	4.76	8.71
9	3.75	7.70
10	4.99	6.71
11	5.39	5.76
12	5.24	4.89
13	5.12	4.11
14	4.80	3.42
15	3.34	2.83
16	3.44	2.32
17	3.56	1.90
18	3.64	1.54
19	3.49	1.24
20	2.92	1.00

Table-6b: MONTHWISE OBSERVED AND CALCULATED GROWTH VELOCITY (MOTOR SCALE)

Curve fitted : $Y_c = (X+0.35)^2 e^{-0.36X}$

Age (X)	Observed Velocity (Y)	Calculated Velocity (Y_c)
2	3.55	2.69
3	3.51	3.81
4	3.66	4.48
5	3.80	4.73
6	5.31	4.65
7	4.66	4.35
8	3.83	3.91
9	2.91	3.42
10	2.47	2.93
11	2.18	2.46
12	1.30	2.03
13	1.86	1.65
14	2.01	1.33
15	1.72	1.06

The relevant details are also illustrated in figures B5 and B6 of Appendix B. It may be noted from the tables as well as from the charts that for the fitted curve peak region coincides with the peak region of the observed curve. However the steep fall in velocity after the early peak is not as steep for the fitted curve as in observed data. The ratio of error sum of squares to total sum of squares in respect of the curves fitted is between 6 and 7% for the mental and motor growth. As this ratio is lower than 10% it could be said that curves fitted characterise the velocity pattern for all practical purposes.

CHAPTER VI

SUMMARY, DISCUSSIONS, AND COMMENTS

Summary

The mental and motor growths did conform to certain scientific patterns. In almost all cases the equation of the form $\log y = a + b \log x$ was found to be the best fitting curve. However the values of the parameters a and b were found to vary widely over the subjects for both mental and motor growth. This could be mainly attributed to the variation between subjects in respect of months of first testing, the initial score and the number and months of testing. Also the limitations of the mental and motor scales especially after twenty four months tended to interfere with the comparisons. Extensive analysis done for mental scale revealed that almost all the subjects for which testing commenced beyond four months registered lower slope values. Further a majority of the cases for which testing was terminated before 20 months recorded higher slope values. This is probably due to the fact that the interference due to scale limitations is absent in such cases and hence a higher growth rate is maintained.

Judgement based on the comparison of slope values will not bring into light the true differences between the capabilities of individual children because of interference from other factors. Hence a new approach of comparing each subject against a common standard and classifying them into certain categories was evolved. The overall average scores obtained for the longitudinal study was taken as the standard. With reference to this standard the subjects were classified into three categories as having fast growth (above normal) normal growth and slow growth (below normal). Based on the averages of the three categories general curves for the respective categories in the form $\log y = a + b \log x$ were obtained for the mental and motor scales. One important result noted was that in respect of mental growth the subjects were equally divided in the three categories whereas in respect of motor growth about half the subjects were normal the remaining being equally distributed in the other two categories. The mental and motor performances of the subjects showed some degree of association because a child showing fast mental performance is very likely to reveal fast or normal motor performance.

The growth velocity for both mental and motor development attained a prominent peak in the first six months and thereafter the velocity decreased considerably. Some secondary peaks were also noted. Further the velocity recorded in many cases after 16th month was not found to be statistically significant. A curve that closely approximates the velocity pattern was fitted. It had only a single peak which coincided with first prominent peak of the observed velocity curve. The ratio of error sum of squares to total sum of squares for the fitted velocity curve was about 6% in respect of mental as well as motor growth.

Discussions

Eventhough the form of curve viz. $\log y = a + b \log x$ was proved to fit very well to the growth data it has its own limitations. It may be noted from Charts-B3 and B-4 that the observed average scores of the children of normal category are below the curve in the initial and later stages of study period whereas they are all above the curve in the middle period. Therefore some systematic bias is bound to occur whenever the averages are predicted from the curve i.e the curve underestimates the scores at certain age levels and overestimates at some other age levels. This is due to the fact that the original curve when transformed into logarithmic scale does not form a straight line but is slightly curved. However when one is confined to the study of only the individual cases the curve may serve as a best guide line because the points are not likely to deviate further from curve. To examine this four cases (Nos 218, 236, 249 & 281) were selected from among those for which more than 25 testings were carried out. The actual scores of these cases alongwith the fitted curve for the mental and motor growth are illustrated in Charts B7, B8, B9 and B10 of Appendix B. It may be noted from these charts that points are more closely located around the curve. But in all these curves the points corresponding to middle period are generally above the curve.

It should also be mentioned here that for a majority of cases the linear regression equation of the form $y = a + bx$ where y is the score and x is the age will also yield fair approximation of the growth pattern. To verify this for the four cases referred earlier the simple regression was also worked out and the value of r^2 i.e the proportion of variation of the variable y explained by the relationship were calculated. A comparative idea of the r^2 values for the two relationships $y = a + bx$ and $y = Ax^b$ is given in table 7

Table 7 - COMPARISON OF LINEAR AND ALLOMETRIC GROWTH CURVES

Case No	r^2 Mental Growth $y=a+bx$	r^2 Mental Growth $y=Ax^b$	r^2 Motor Growth $y=a+bx$	r^2 Motor Growth $y=Ax^b$
218	.93	.97	.85	.95
236	.94	.96	.86	.96
249	.95	.97	.77	.92
281	.94	.98	.83	.95

Hence for mental growth a simple regression which is the easiest to fit will be a close second to the curvilinear approximation $y = Ax^b$. However for motor growth the simple regression is not very appropriate because the points deviate more from the regression line.

Evidently the growth patterns are not linear but for practical purposes a first approximation to the growth can be conveniently obtained by fitting a straight line. The next improvement is fitting of a curve of the form $y = Ax^b$, which takes into account some extent of the curvature in the growth pattern. In all the 208 cases the value of b was between 0 and 1.0.

The curve $y = Ax^b$ for growth patterns in which b is +ve and less than 1.0 theoretically implies that speed of growth monotonically decreases with the increase in age the maximum being between 1 and 2 months. But the data on growth velocity considered in detail in Chapter V show that the speed of growth over the months does not decrease monotonically and that there is a peak in the first six months that is prominent. The slight deviation of the observed curve from the theoretical form of $y = Ax^b$ is mainly because of these velocity differences. Only by selecting an higher order curve involving more than two parameters one can incorporate the velocity differences in the growth pattern. The computations involved for fitting and comparison of such higher order curves will be enormous. Hence in the present analysis it was decided to study only curves with two parameters. In this context it can be said that the form of curve viz. $y = Ax^b$ is the best fit for the growth data.

Comments

The growth curve patterns developed here for the longitudinal study using BSID Research Form (1961) could be considered as general because the form of observed growth curves were almost identical for similar growth studies conducted in other parts of the world. This fact may be verified from Charts in Appendix B of Final Report* wherein the growth curve for the present study is illustrated alongwith other studies done in USA, UK, Israel and low socio-economic urban and rural samples in India using the same BSID Form.

The analysis for curve fitting in this report were all confined to the first 30 months which forms only a part of the total growth period. Yet this period is significant because it covers the early developmental stages. No attempts were made in this study to project the future performances.

Moreover, projection of future performance based on first 30 months data might not be reliable in the light of repeated observations with reference to low predictive value of testings during infancy.

Growth patterns observed in this longitudinal study were categorised as slow, normal and fast and the differences between them eventhough small were significant. But when the subjects were selected for testing they were medically checked up and found to be normal. Hence the small differences can as well be neglected and the curve for the normal category can be considered as the general growth curve

* Vide Footnote - Page 2.

A P P E N D I X - A

Table-A1: CLASSIFICATION OF THE SUBJECTS INTO THE THREE CATEGORIES OF MENTAL GROWTH

Growth Category	Code number of subjects									
Slow	11	12	13	22	23	25	30	36	44	56
	59	61	76	80	81	83	84	85	88	89
	93	94	96	103	106	109	123	130	142	144
	145	146	150	152	160	169	175	178	182	184
	189	196	200	201	204	206	213	213	214	219
	222	223	225	226	227	234	237	239	242	245
	247	250	252	254	256	259	268	269	274	277
	278	283								
Normal	1	17	19	31	32	37	47	49	50	52
	54	60	63	67	70	74	75	77	78	86
	90	92	95	105	112	115	116	117	118	120
	125	126	138	139	140	141	143	149	151	154
	159	164	167	168	177	179	180	181	186	188
	191	193	194	195	198	205	209	216	217	218
	230	233	236	244	253	258	262	265	266	275
	279									
Fast	2	5	6	9	14	18	20	21	27	33
	38	40	42	43	46	51	55	65	66	68
	71	79	82	87	97	104	107	111	119	122
	124	127	129	131	134	136	137	156	163	165
	172	190	192	224	228	229	235	238	241	248
	249	251	255	257	260	261	264	270	272	273
	276	281	282	284	285					

Table-A2: CLASSIFICATION OF THE SUBJECTS INTO THE THREE CATEGORIES OF MOTOR GROWTH

Growth Category	Code number of subjects									
Slow	2	30	44	49	52	56	59	75	80	84
	87	89	94	106	118	120	126	142	150	152
	160	168	175	177	178	184	200	205	206	212
	213	214	218	219	223	226	227	233	234	235
	237	239	242	248	250	252	256	258	274	275
	278	283								
Normal	14	18	19	20	22	23	32	33	36	37
	40	42	43	46	47	50	54	60	61	67
	70	74	78	81	83	85	86	88	92	93
	95	96	103	107	109	112	115	119	123	124
	125	127	129	130	137	138	140	143	144	145
	146	149	151	154	159	164	167	169	179	180
	181	186	188	189	192	193	194	195	196	198
	201	204	216	217	222	224	225	228	229	230
	236	238	244	245	247	251	253	254	255	259
	260	261	262	268	269	272	276	277	285	
Fast	1	5	6	9	11	12	13	17	21	25
	27	31	38	51	55	63	65	66	68	71
	76	77	79	82	90	97	104	105	111	116
	117	122	131	134	136	139	141	156	163	165
	172	182	190	191	209	241	249	257	264	265
	266	270	273	279	281	282	284			

Table-A3: MONTHWISE AVERAGE MENTAL SCORES AND THE STANDARD DEVIATION FOR THE THREE GROWTH CATEGORIES

Age (months)	GROWTH CATEGORY								
	SLOW			NORMAL			FAST		
	Number of subjects	Average Score	Standard Deviation	Number of subjects	Average Score	Standard Deviation	Number of subjects	Average Score	Standard Deviation
1	17	16.06	3.34	10	19.40	3.78	19	18.05	2.44
2	26	25.15	3.37	28	25.68	3.49	23	27.74	3.29
3	35	34.49	3.66	33	36.00	3.40	28	38.21	4.31
4	35	44.69	3.95	32	48.06	5.06	33	48.64	3.89
5	41	55.10	5.66	44	60.75	5.07	36	63.50	4.60
6	48	68.35	6.81	41	72.85	5.07	43	74.06	3.25
7	47	78.47	2.46	45	80.58	2.55	46	80.77	2.85
8	52	83.06	2.60	48	84.83	2.37	47	85.49	2.23
9	56	86.64	2.59	43	88.40	2.85	47	89.23	3.41
10	47	89.81	2.79	50	93.46	3.63	51	96.16	3.91
11	48	95.25	3.65	50	98.90	3.51	48	101.04	3.41
12	55	99.87	3.46	51	103.39	3.27	45	107.20	4.15
13	49	105.12	3.53	47	108.45	3.38	52	111.96	3.75
14	49	109.88	3.11	47	112.70	2.40	54	116.13	3.12
15	51	112.10	3.34	46	115.96	3.00	56	119.25	3.84
16	46	116.20	2.65	44	118.59	2.84	50	123.04	4.72
17	45	118.42	2.59	43	122.30	2.69	50	127.10	5.40
18	43	121.33	2.78	41	124.83	2.96	52	130.54	5.61
19	40	123.80	3.41	46	127.93	3.52	45	135.29	6.44
20	45	125.02	3.94	39	130.23	3.70	47	138.40	7.01
21	48	127.73	3.92	43	133.19	4.46	41	140.85	7.48
22	42	130.81	5.16	40	137.05	5.00	45	146.24	6.73
23	39	133.67	5.10	42	140.55	5.82	44	148.68	6.47
24	44	136.95	6.07	38	144.34	5.37	44	151.98	4.83
25	36	141.75	6.57	38	148.58	4.57	45	155.11	4.93
26	42	145.83	7.34	34	152.24	5.82	44	156.18	4.34
27	33	147.70	5.86	40	154.08	5.15	43	158.02	3.21
28	36	149.58	6.24	33	156.21	4.79	43	159.37	2.32
29	39	152.54	5.13	37	157.38	3.09	43	160.23	1.48
30	40	153.10	5.65	36	158.50	2.77	38	160.16	1.82

Table-A4: MONTHWISE AVERAGE MOTOR SCORES AND THE STANDARD DEVIATION FOR THE THREE GROWTH CATEGORIES

Age (months)	GROWTH CATEGORY								
	SLOW			NORMAL			FAST		
	Number of subjects	Average Score	Standard Deviation	Number of subjects	Average Score	Standard Deviation	Number of subjects	Average Score	Standard Deviation
1	14	8.79	0.97	19	9.32	1.11	13	9.46	1.05
2	22	11.45	1.53	37	12.54	1.82	18	13.44	1.50
3	24	15.54	1.74	48	15.96	1.99	24	16.75	1.82
4	28	17.89	1.17	45	19.78	1.87	27	21.07	2.13
5	33	21.30	2.13	57	23.35	2.45	31	25.39	2.46
6	39	26.10	2.52	57	28.40	2.26	36	31.50	2.04
7	35	31.03	2.88	66	33.18	2.50	37	35.81	2.01
8	40	35.10	2.35	68	37.06	2.29	39	39.28	2.10
9	43	38.14	2.74	68	40.00	2.06	35	42.49	1.56
10	35	40.66	2.45	74	42.54	2.00	39	44.54	1.29
11	39	43.00	2.14	66	44.73	1.64	41	46.10	1.73
12	42	44.00	2.02	75	45.80	1.59	34	48.26	2.25
13	33	45.45	2.15	69	47.80	2.62	46	49.96	2.07
14	39	46.15	2.92	68	49.81	2.33	43	52.35	2.08
15	40	47.80	2.74	69	51.26	2.36	44	53.73	1.77
16	34	48.59	3.47	60	52.58	2.09	46	54.13	1.22
17	32	50.44	2.71	65	53.74	1.48	41	55.20	1.44
18	31	51.84	2.42	63	54.57	1.13	42	55.48	1.25
19	31	52.48	3.79	66	54.68	1.03	34	55.82	1.91
20	31	53.13	2.97	52	55.37	1.60	38	55.95	1.66
21	36	54.30	1.83	60	55.58	1.06	36	56.81	2.12
22	35	54.66	1.21	56	56.33	2.27	36	57.64	2.52
23	31	54.65	1.36	63	56.76	2.38	31	59.39	3.30
24	32	55.13	2.08	64	57.48	2.46	30	60.03	3.21
25	28	56.14	2.17	58	58.69	2.69	28	56.14	2.17
26	32	56.88	2.55	54	59.87	2.66	32	56.88	2.55
27	25	57.44	3.18	58	61.19	2.82	25	57.44	3.18
28	29	59.10	3.13	53	62.00	3.09	29	59.10	3.13
29	31	60.87	3.22	56	62.64	2.82	31	60.87	3.22
30	31	61.74	3.67	52	64.35	2.24	31	61.74	3.67

Chart-B1: OBSERVED MENTAL GROWTH CURVES OF CHILDREN IN FAST, NORMAL AND SLOW GROWING CATEGORIES

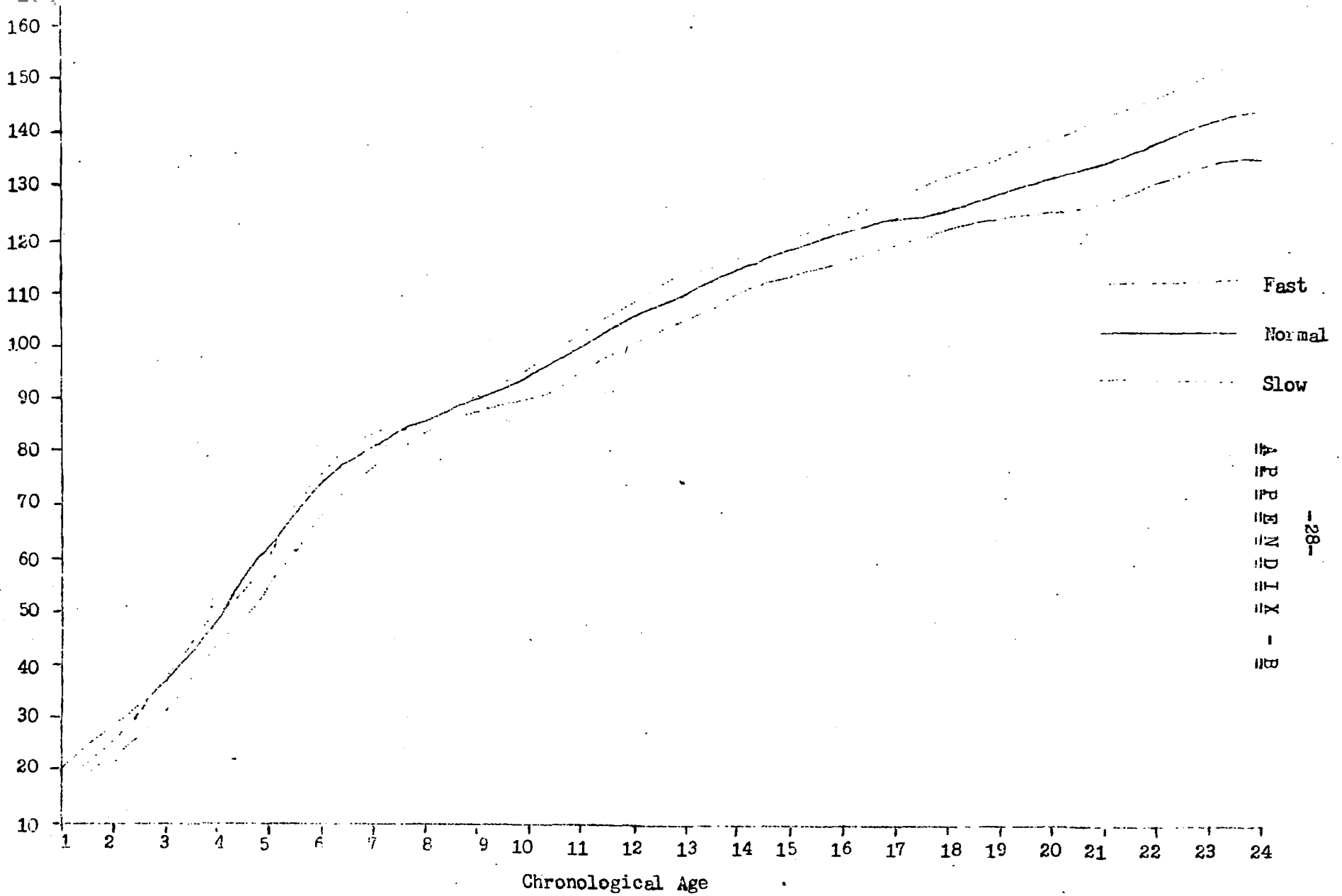

Chart-B2: OBSERVED MOTOR GROWTH CURVES OF CHILDREN IN FAST, NORMAL AND SLOW GROWING CATEGORIES

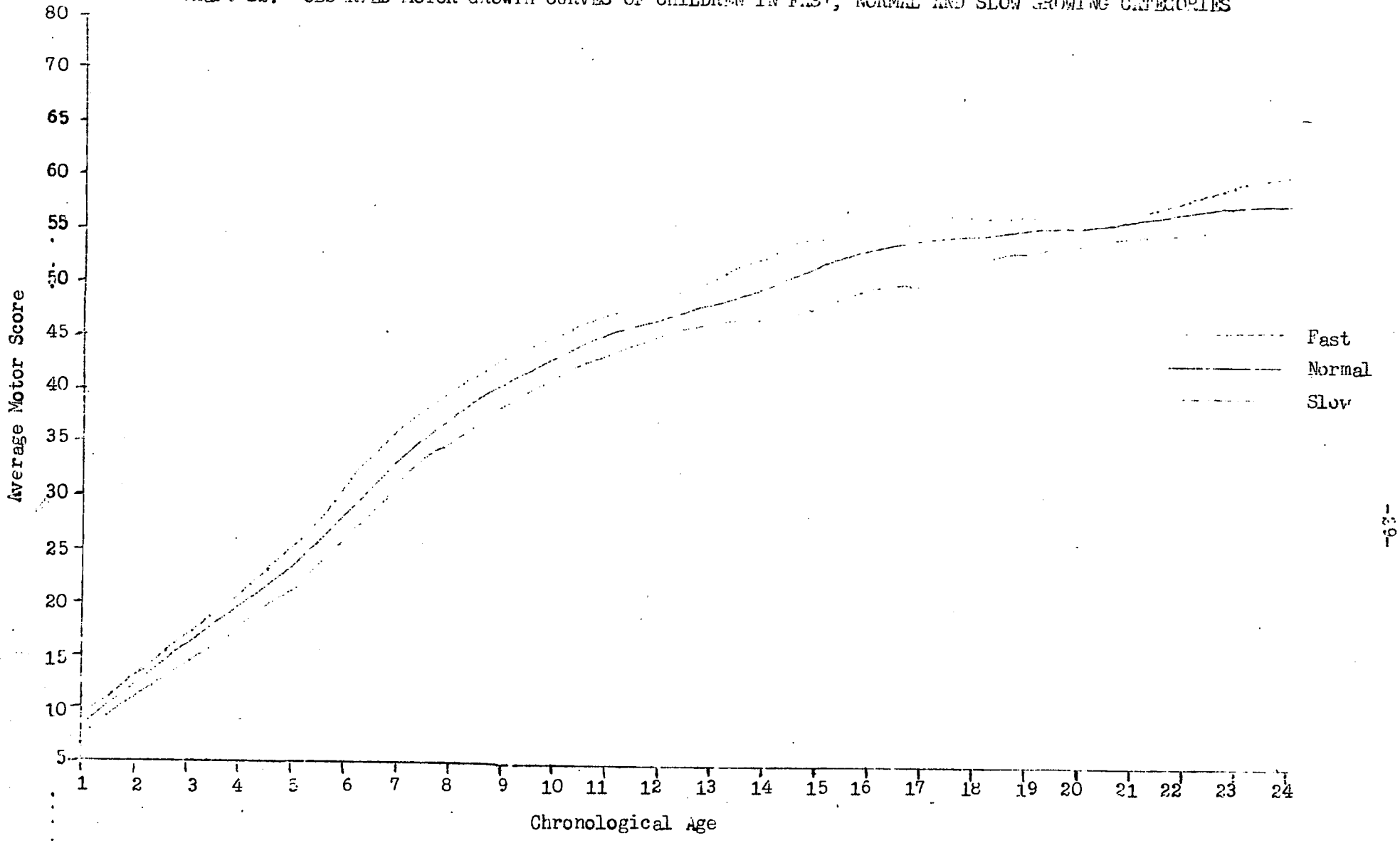

Chart-B3: OBSERVED AND CALCULATED MENTAL GROWTH CURVES OF CHILDREN IN THE NORMAL GROWTH CATEGORY

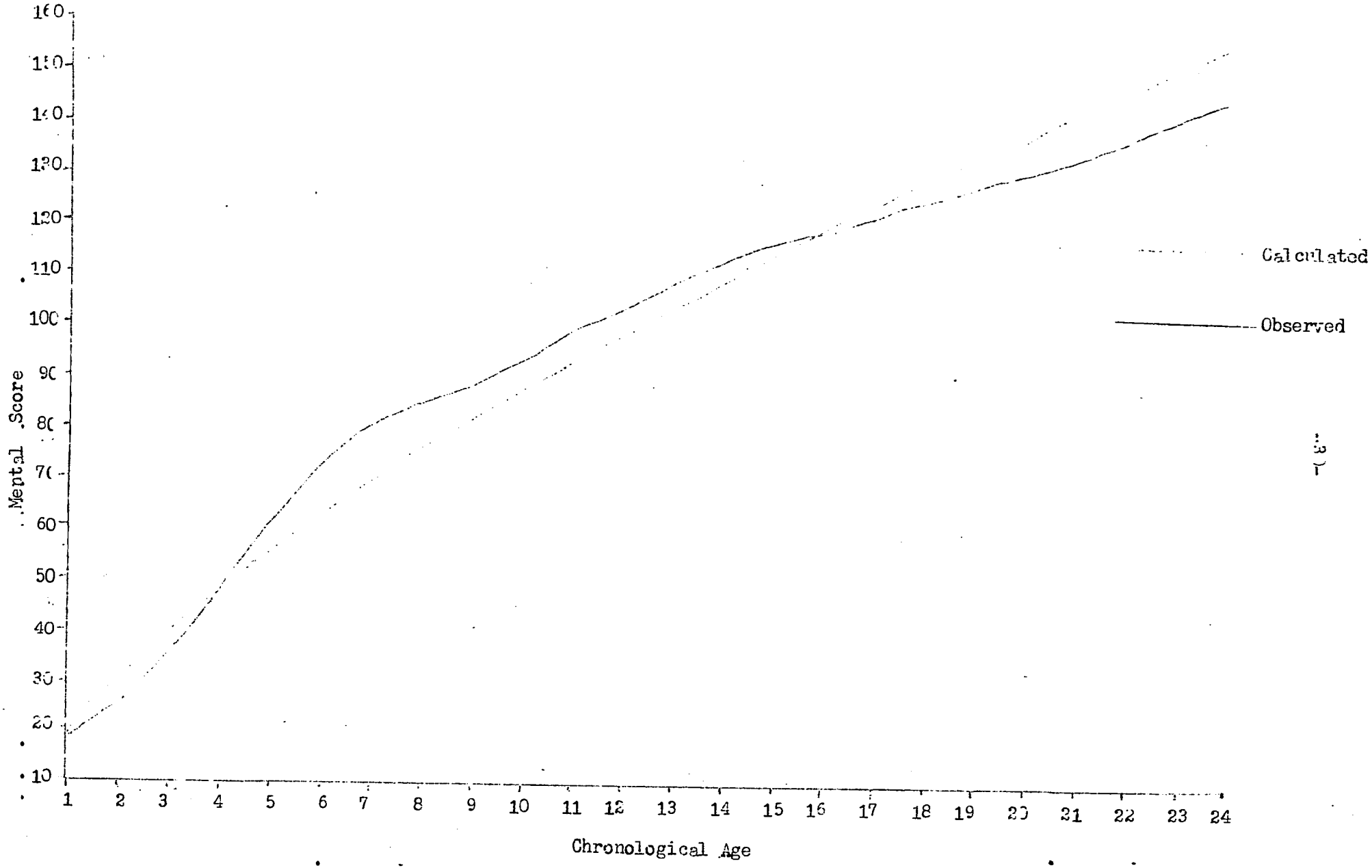

Chart-B4: OBSERVED AND CALCULATED MOTOR GROWTH CURVES OF CHILDREN IN THE NORMAL GROWTH CATEGORY

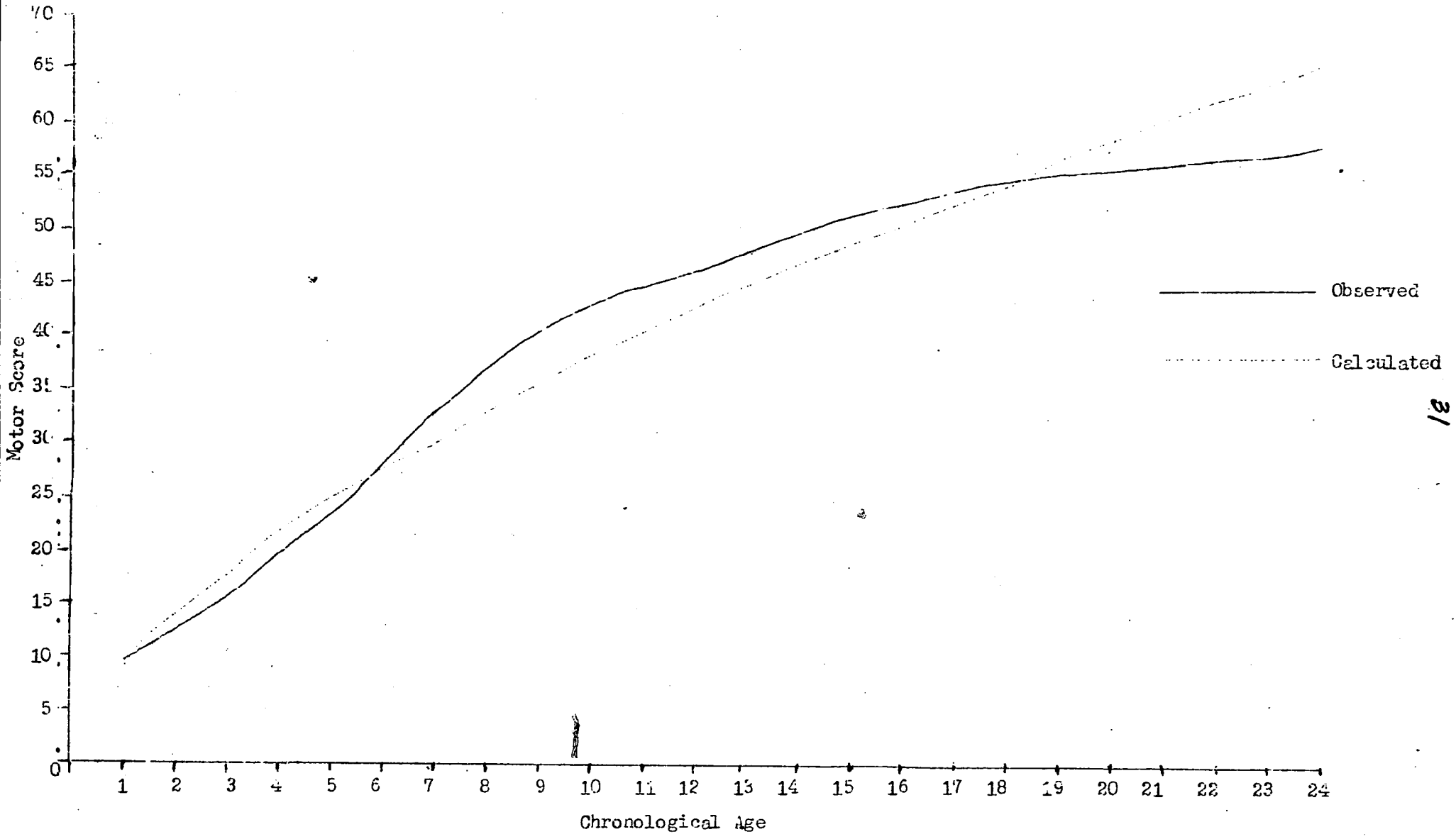

Chart-B5: OBSERVED & CALCULATED VELOCITY CURVES OF MENTAL GROWTH

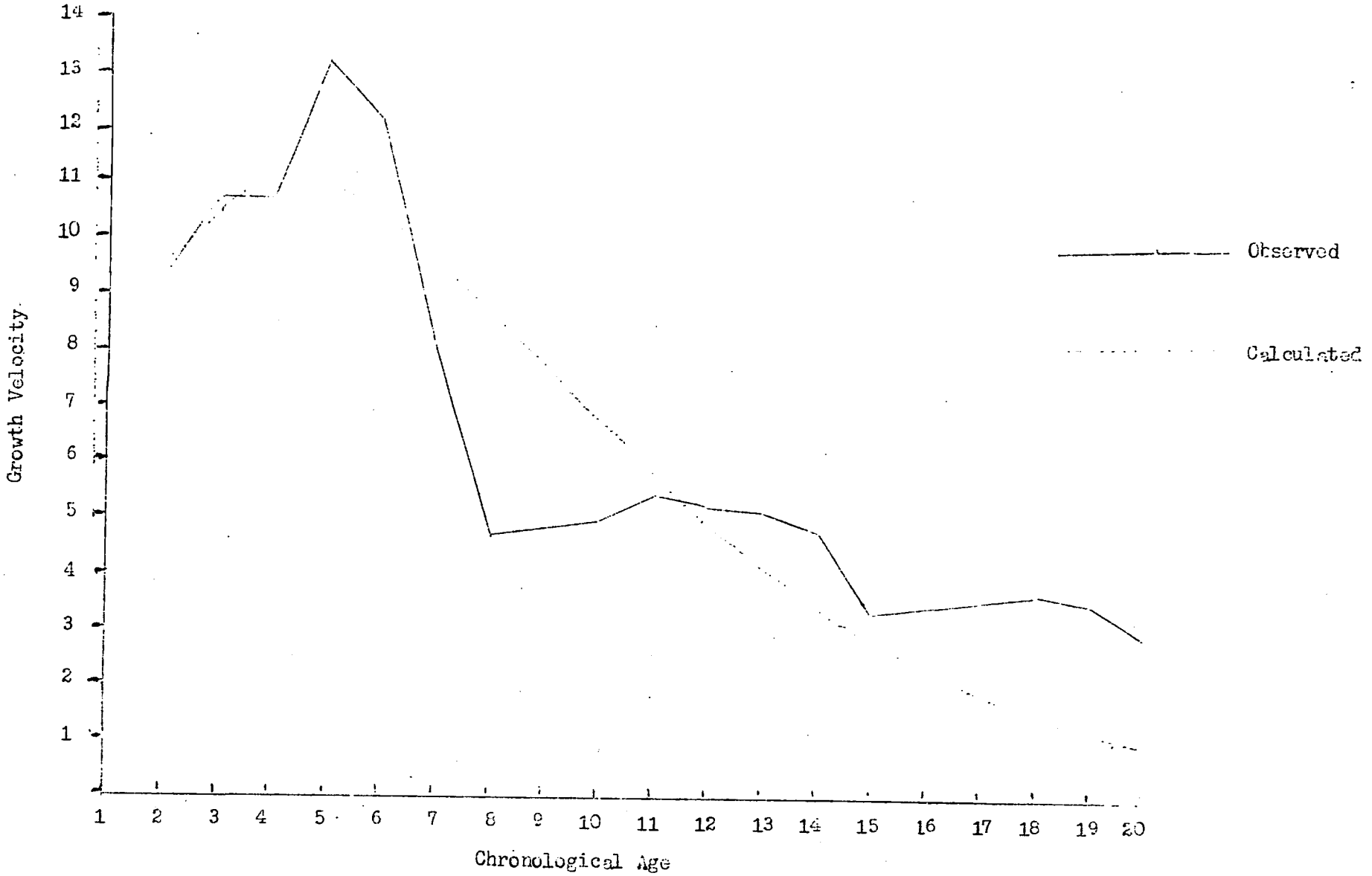

Chart-B6: OBSERVED & CALCULATED VELOCITY CURVES OF MOTOR GROWTH

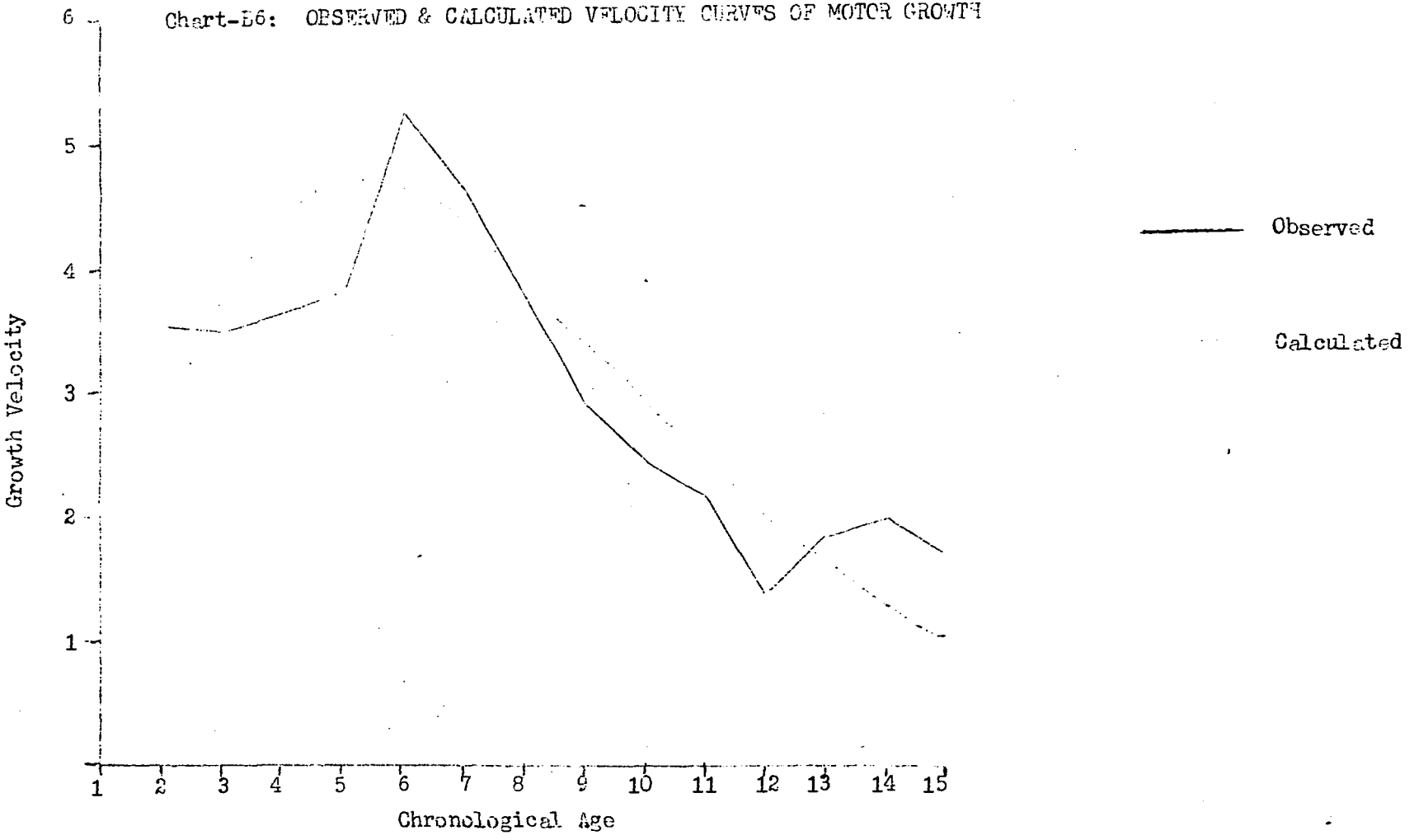

Chart-B7: OBSERVED & CALCULATED GROWTH CURVES (Case No 218)

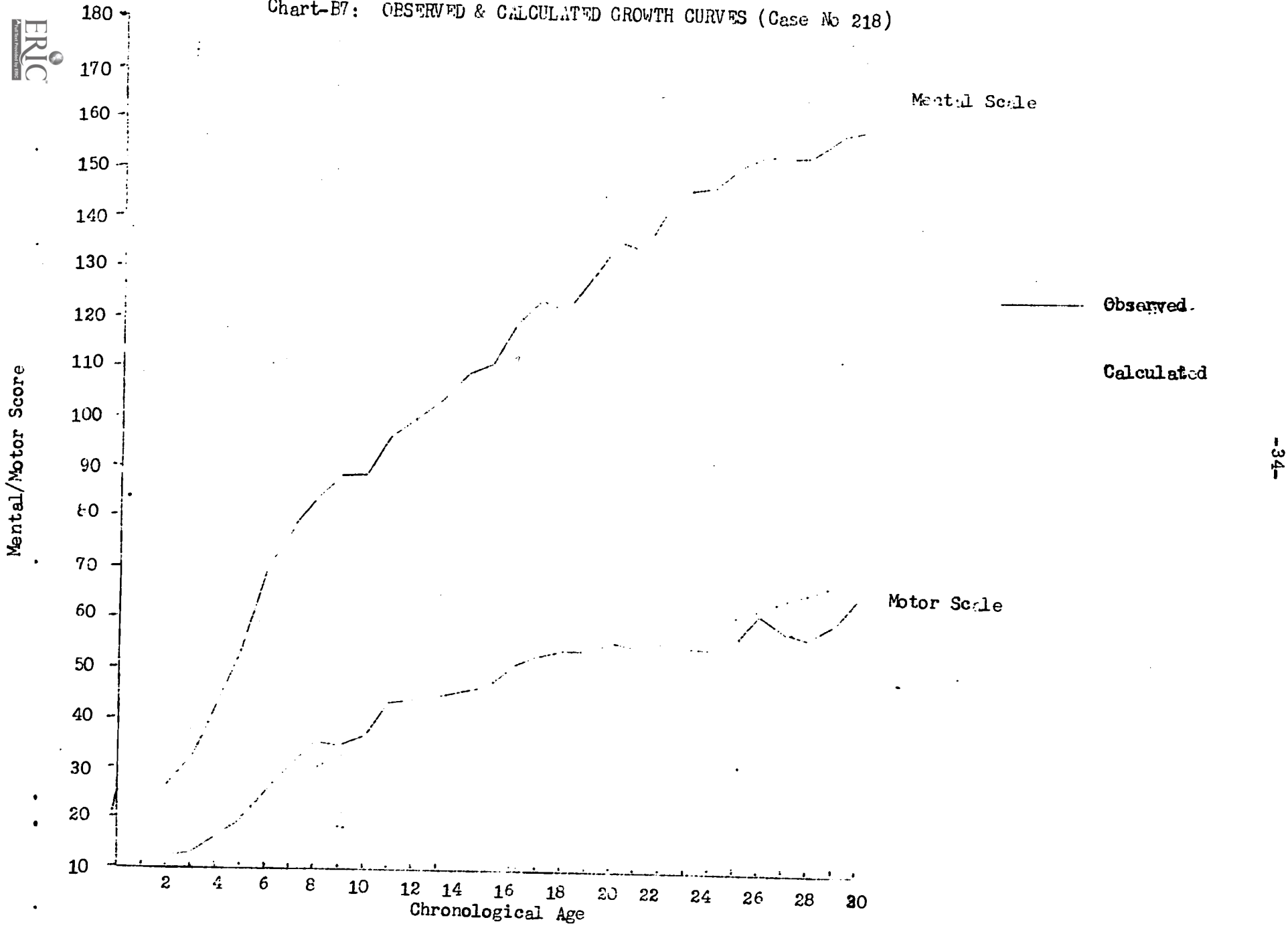

Chart-B8: OBSERVED & CALCULATED GROWTH CURVES (Case No 236)

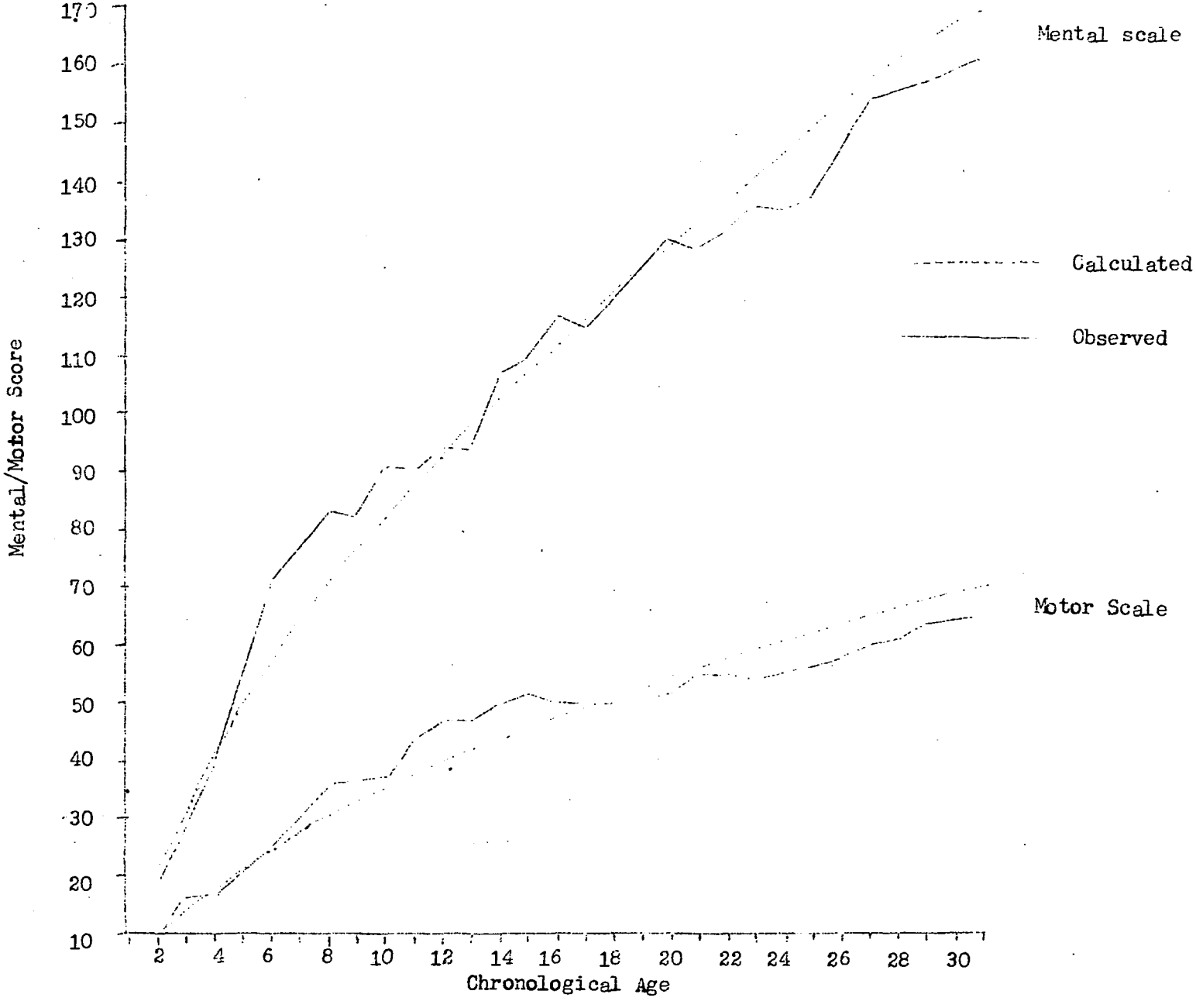

Chart-B9: OBSERVED & CALCULATED GROWTH CURVES (Case No 249)

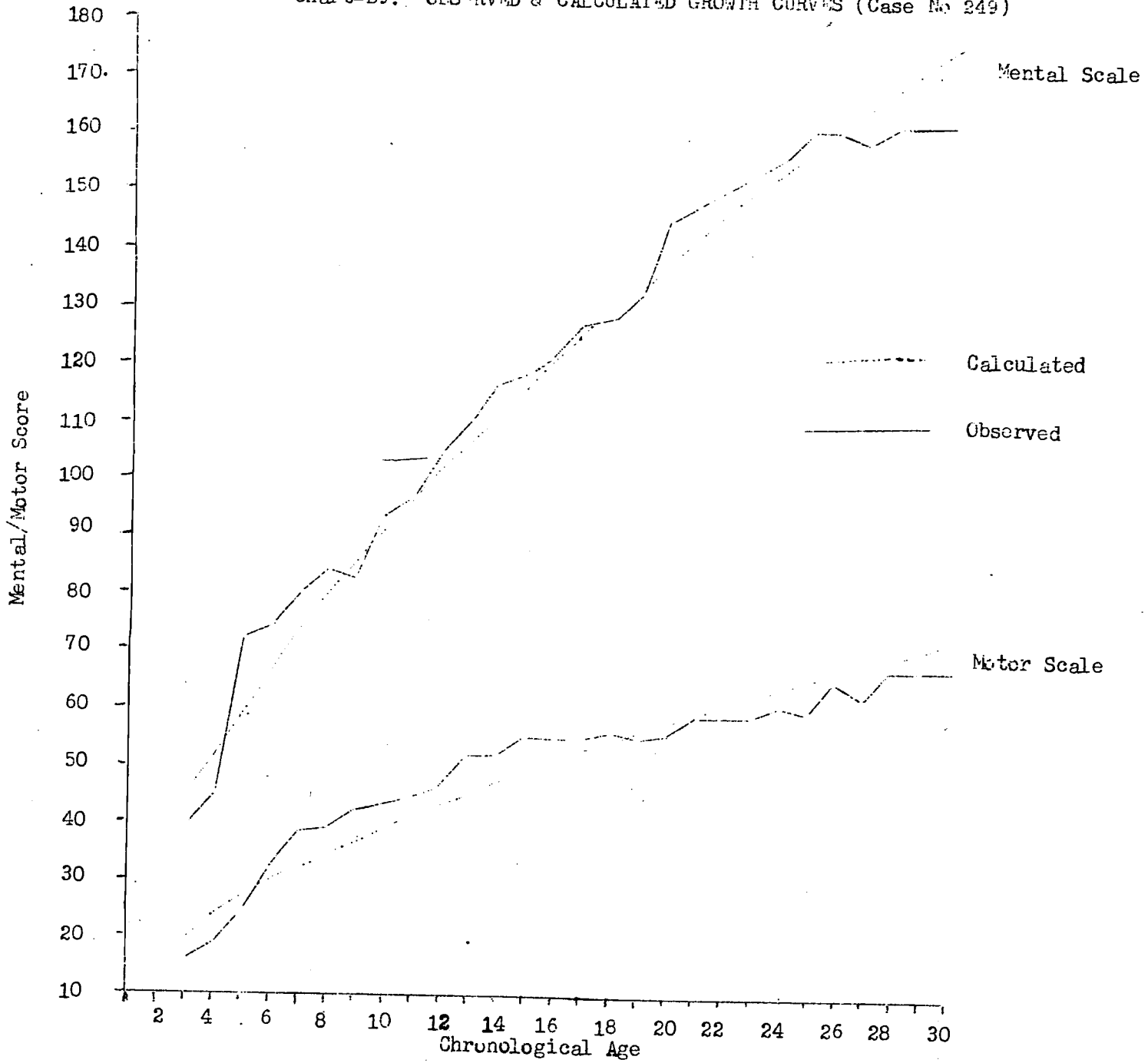

Chart-B10: OBSERVED & CALCULATED GROWTH CURVES (Case No 281)