A STUDY TO DETERMINE WHETHER MENTAL AGE SCORES ARE BEST DESCRIBED BY SINGLE-CYCLE, MULTI-CYCLE, OR STRAIGHT LINE GROWTH EQUATIONS

By

Richard McCallum Clark

AN ABSTRACT OF A THESIS

Submitted to the College of Education
Michigan State University of Agriculture and
Applied Science in partial fulfillment of
the requirements for the degree of

DOCTOR OF PHILOSOPHY

Department of Foundations of Education

The purpose of this study was to find which of three methods of describing the mental growth scores collected longitudinally for one hundred individuals would most accurately describe the growth pattern formed by the actual test scores of these individuals. The three methods used described mental growth as : (1) a straight line; (2) a single-cycle negatively accelerated curve; and (3) a multi-cyclic curve. It was assumed that a statistically significant difference in these three methods of describing the obtained mental age scores for an individual would indicate that the more accurate method represented a more nearly correct theoretical picture of the nature of the mental growth curve.

Cases were selected from the Dearborn data assembled by Doctor C. V. Millard from the Henry Ford School, Dearborn, Michigan, on the basis of a range of test scores obtained during the pre-adolescent period and on the basis of physical growth indications, extending into the adolescent period, and including a minimum of six mental age scores for the individual.

A straight line growth description was obtained by multiplying the mean I.Q. obtained by an individual by the chronological age at the time of each test administration. Single cycle growth curves were computed using the formula developed by H. Heinis, and multi-cycle equations were written using the Courtis technique.

Average deviations were obtained for each method on each case between the score actually obtained on the test and the derived theoretical score. Frequency distributions were drawn of the average deviations, and tests of statistical significance were made to compare the mean average deviation of each of the three methods. A mean average deviation of 4.7 months was found for mental test data described by multi-cycle equations, while mean deviations of 7.4 months and 8.2 months were found for single cycle and straight line methods of description. The difference between the mean average deviation found in writing multi-cycle equations was significantly lower, at the one percent level of confidence, than the mean average deviation of the other two methods.

A comparison of the mean average deviations obtained during the same ten-month period of chronological age showed that both the straight line and the single cycle methods of describing growth showed a statistically significant increase after 160 months of age, while the mean average deviations obtained by the multi-cycle method during each ten month interval was relatively constant.

It was concluded that the mental growth pattern shown by the actual test scores of an individual are more nearly described by multi-cycle growth equations than by either a single cycle or a straight line growth equation.

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THE PROBLEM AND DEFINITIONS OF TERMS USED

Since the development of standardized instruments for measuring intelligence, psychologists and educators have attempted to use these instruments in order to discover the existence of a general pattern of mental growth which is common to all humans. In 1919 Terman stated:

> The Standardization of the Binet scale on the basis of age-norms makes it a suitable instrument for the investigation of mental-growth curves. By applying it repeatedly to the same children we can find out whether constancy or irregularity rules. Prediction hinges on the question whether a child who is found by the test to be a given per cent above or below the mental level normal for his age continues to be accelerated or retarded to the same degree. The answer is found in the extent to which the I.Q. remains constant.[1]

Although efforts have been made to use intelligence test scores in an attempt to ascertain the nature of the mental growth curve, Freeman points out the factor which has limited most of the studies in this area, stating:

> The multitude of scores of children of various ages which have been gathered from the application of various mental tests yields a mass of material which give a basis for more valid estimates of the character of intellectual growth than we have previously possessed. It is true that these measures have usually been limited in one respect. They have been made upon different children of different ages. They have not, that is, given successive measures of the capacity of the same child at

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[1] Lewis M. Terman, The Intelligence of School Children (New York: Houghton Mifflin Company, 1919), p. 137.

successive periods in its growth. They therefore give us only a mass picture of the general characteristics of growth, and do not enable us to determine what the fluctuations in the case of individuals are.[2]

Dearborn and Rothney[3] illustrate how the use of norms derived from age groups can distort the true picture of individual growth through a comparison of a growth pattern for girls in physical and mental growth described by Boas, with growth patterns based on individuals. Dearborn and Rothney find that at some time between the ages of nine to fifteen, there is one year when practically every girl makes a more intense spurt than the average described by Boas. Thus, Dearborn and Rothney explain, "Since these spurts come at different life-ages in individual cases, a curve, constructed after the manner of Boas, tends to "smooth" the adolescent period and make it appear to be a more quiescent period than it actually is.[4]

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[2] F. N. Freeman, "Individual Differences in Mental Growth," Science Monthly, 37.

[3] Walter Dearborn and John Rothney, Predicting the Child's Development, (Cambridge: Science Art Publishers, 1941).

[4] Ibid., p. 232.

Baldwin and Stecher,[5] Krogman,[6] Millard,[7] Courtis,[8] and others have agreed that patterns of growth for individuals must be derived from the study of individuals over a time, rather than from the study of group norms. As Baldwin and Stecher state:

> All of these problems concerning the general trend of the growth curve, the rate of improvement of children of different intellectual ability, variability in mental development, the possibility of prediction in mental growth, and the relation between physical and mental growth can be solved only through a study of consecutive re-examinations and observation of the same group of children throughout a number of years.[9]

"Every child is unique;" affirm Gesell and Ilg, "but every child is also a member of one human species. Obedient to these species characteristics there are growth sequences which are rarely or never circumvented."[10] The presence

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5 Bird T. Baldwin and Lorle I. Stecher, "Mental Growth Curve of Normal and Superior Children," (University of Iowa Studies in Child Welfare, Vol. 2, No. 1. Iowa City, Iowa: University of Iowa).

6 Marion Wilton Krogman, "Trends in the Study of Physical Growth in Children," Child Development, Vol. 11, December, 1940.

7 C. V. Millard, Child Growth and Development in the Elementary School Years (Boston: D. C. Heath Company, 1951).

8 S. A. Courtis, "What Does the I.Q. Really Measure?" Nation's Schools, 11:21, January, 1933.

9 Baldwin and Stecher, op. cit., pp. 5-6.

10 Arnold Gesell and Frances Ilg, The Child From Five to Ten, New York and London: Harper and Brothers, 1946), p. 57.

of these two factors, uniqueness and sequence, both must be considered in studying any aspect of human growth. Krogman states, "We have long focussed upon the groups, and the position of the individual growth curve in the group, and have constructed averages--'norms of mediocrity,' Todd called them--degrees of departure from which there was a measure of aberrancy. We now look more intently at the individual growth curve as an expression of its <u>own</u> norm."[11]

This study utilizes the longitudinal method described by Millard[12] by examining growth patterns of specific individuals in an effort to gain insight into the specific sequences followed by human beings in terms of mental growth.

I. THE PROBLEM

<u>Statement of the problem</u>. The purpose of this study was to investigate the nature of mental growth by determining whether scores obtained by individuals on the Kuhlmann-Anderson Intelligence Test during the pre-adolescent period and adolescent period are best described by (1) a single cycle growth equation; (2) a multi-cycle growth curve; or, (3) a straight line. A secondary problem was to ascertain the variability of the I.Q. of the individual as shown by repeated testings.

<u>Importance of the study</u>. "When we study the maturation of individual organisms of any type or kind," contends Stuart

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[11] Krogman, <u>op</u>. <u>cit</u>., pp. 283-284.

[12] Millard, <u>op</u>. <u>cit</u>., pp. 1-20.

Courtis, "we find that progress toward maturity follows a single genetic pattern. This pattern has the form of a distorted S or skew curve, the second half of the curve taking a longer time than the first half."[13] Terman states, "If we had a perfect scale for determining the mental age level, and if the I.Q. remained absolutely constant, the 'curves' of mental growth would be a straight line from birth to the point of mental maturity."[14] "The common view is that the course of intellectual growth through this period (middle childhood to later adolescence) is represented by a negatively accelerated or parabolic curve," affirm Freeman and Flory.[15]

Thus, three distinct theories have been advanced concerning the mental growth sequence of individuals. Each of these theories has implications in terms of how mental test scores should be interpreted by teachers and school psychologists, how mental tests should be constructed, and what changes may be expected in an individual's I.Q. scores.

This study should also help to answer some of the theoretical questions in the field of child growth and development. The cyclic nature of physical growth has been

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13 S. A. Courtis, Towards a Science of Education (Ann Arbor, Michigan: Edwards Brothers, 1951), p. 9.

14 Terman, op. cit., p. 67.

15 Frank Freeman and Charles Flory, "Growth in Intellectual Ability as Measured by Repeated Tests," Monographs of the Society for Research in Child Development, 2:2, 1937.

demonstrated by Rusch,[16] Courtis,[17] Millard,[18] and Olsen.[19] Others have hypothesized the concept of growth interrelationships--a definite paralleling of all patterns of growth within an individual. Since physical and academic measurements are available on the subjects of this study, the data collected on mental growth may be used by others in studying the problem of growth interrelationships.

II. DEFINITIONS OF TERMS USED

Growth cycle. Used in this study was the definition given by Courtis: "A cycle is defined as a well-marked period of maturation during which the organism, forces and end products are constant."[20]

Single cycle growth curve. The theoretical growth curve derived by Heinis[21] is expressed by the logarithmic:

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16 Reuben R. Rusch, "The Relationship Between Growth in Height and Growth in Weight," (unpublished Master's thesis, Michigan State College, 1954).

17 Courtis, op. cit.

18 Millard, op. cit.

19 Willard Olsen, Child Development (Boston: Heath and Company, 1949).

20 Courtis, op. cit., p. 174.

21 H. Heinis, "A Personal Constant," The Journal of Educational Psychology, 17:173, 1926.

$$Y = b(1-e^{\frac{x}{d}})$$

x = age

a, b, and d represent positive constants

e = base of natural logarithms

<u>Personal</u> <u>constant</u>. According to Heinis, "the personal coefficient of any given individual is equal to the result of the intelligence examination divided by the normal degree of intelligence corresponding to his age, both measures being given in absolute graduation."[22]

<u>Mental</u> <u>growth</u>. For the purpose of this study, mental growth is defined as the pattern of increments shown by an individual on repeated testings with the Kuhlmann-Anderson[23] Intelligence Tests.

<u>Multi-cyclic</u> <u>growth</u>. Growth data which when graphed showing a pattern of acceleration and deceleration which shows more than one growth cycle.

<u>Isochron</u>. One per cent of the total time required for a growth curve to change from a development of 0.000000189 per cent to a development of 99.90917 per cent.

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22 Heinis, <u>loc</u>. <u>cit</u>.

23 F. Kuhlmann and Rose Anderson, <u>Kuhlmann-Anderson Intelligence Tests</u>, (Princeton, New Jersey: Personnel Press, 1952).

CHAPTER II

REVIEW OF THE LITERATURE

In order for any study concerning human growth to have scientific merit, it is essential that some kind of patterning of human growth be present within individuals, for unless some pattern exists, no description of human growth significant for individuals can be made. Although the literature shows many disagreements about just what patterns are present, there is much support for the concept that there are patterns--that an individual's growth is not completely erratic.

Gesell examined thirty cases fifteen years after they had been tested in the Yale Clinic, and although finding variations, he stated, "In no instance did the course of growth prove whimsical or erratic."[1] Wellman and others at Iowa caused considerable controversy with various studies showing the effects of environmental change on I.Q., which might seem to refute the idea of a growth pattern, but Wellman states, "Our results show that even when children are making tremendous changes in I.Q., the changes are lawful and predictable."[2]

One factor which has been examined as an operating

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[1] Arnold Gesell, "The Appraisal of Mental Growth Careers," Journal of Consulting Psychology, Vol. 3, No. 3, p. 73.

[2] Beth Wellman, "Mental Growth from Pre-School to College," Journal of Experimental Education, 6:136-138, 1937.

force in the patterning of growth is the advent of pubescense. The factor of puberty has been rather well accepted as having an effect in the area of physical growth. Chiasson and MacArthur in studying the growth rates of different races of rats find: "(1) The large and small races and both sexes follow the same pattern and course in allometric development; (2) The breaks in the tail and ear curves do coincide roughly with the attainment of maturity."[3]

Davenport reports, "The human growth curve shows two (and only two) outstanding periods of accelerated growth-- the circumnatal and the adolescent."[4] Eichorn in studying physical growth states, "The growth expression developed by strict mathematical methods from the cycle paths is a complete sigmoid and the point of inflection is located precisely at puberty."[5] Ruger and Stoessiger also found the advent of puberty affecting patterns of physical growth, stating: "Stature, Sitting Height, Span show the same peculiar growth curves: the rapid growth in early childhood, the slackening off at about 12 and the quickening up at 16, giving rise to what has been termed the 'pubescent dip' centering at about

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3 Leo Chiasson and John MacArthur, "Relative Growth in Races of Mice Produced by Selection," Growth, 9:306, (1945).

4 Charles Davenport, "Human Growth Curve," Journal of General Physiology, 10:215, (1926-1927).

5 H. L. Eichhorn, "The Growth-Reproduction Cycle," Growth, 20:262, (1956).

15 years of age. Then the post-puberty rapid rise to a maximum."[6]

There has been less success in relating the pattern of mental growth to puberty, perhaps in part due to lack of research in this area. Breckenridge and Vincent show effects of adolescence on physical growth, but state, "We have no comparable charts to show tempo of growth in intellect."[7] Abernathy drew growth curves on early, mid, and late maturing children and concluded, "There is no evidence from the present study of changes in rate of mental growth which may be explained as concomitants of physical events."[8]

Garrison states, "An inspection of the curves of different children show that some maintain fairly constant rates while others showed wide shifts. These shifts may occur at any age level and over a wide range of mental functions."[9]

Crampton,[10] Foster,[11] and King[12] studied the scholastic

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6 Henry Ruger and Brenda Stoessiger, "On the Growth Curves of Certain Characters in Man," Annual Eugenics, 2:82, (1927).

7 Marian Breckenridge and E. Lee Vincent, Child Development, (Philadelphia: W. B. Saunders, 1949), p. 9.

8 Ethel Mary Abernathy, "Relationships Between Mental and Physical Growth," Child Development, Vol. 1, No. 7, (1937), p. 60-61.

9 Karl Garrison, Growth and Development, (New York: Longmans, Green and Co., 1952), p. 195.

10 Ward C. Crampton, "The Influence of Physiological Age Upon Scholarship," Psychological Clinic, 1:115-120, (1907).

11 Wilfred Foster, "Physiological Age as a Basis for the Classification of Pupils Entering High School--Relation of Pubescence to Height," Psychological Clinic, 4:83-88, (1910)

12 Irving King, "Physiological Age and School Standing," Psychological Clinic, 7:222-229, (1914)

standing of postpubescents in relation to pre-pubescents, all finding a slight advantage for the post-pubescent group.

Gesell[13] and Stone and Doe-Kulmann[14] studied the mental growth pattern of children experiencing precocious puberty and found no rapid rise of mental development corresponding to the advanced physical development.

Shuttleworth, in his study of the physical and mental growth of children from ages six to nineteen, concludes, "The data establish the existence of some relationship between intelligence and MG-age, but the relationship is very tenuous and the nature of the underlying factors is unknown."[15]

Murdock and Sullivan,[16] Wechsler,[17] and Johnson,[18] find more definite evidence of the effect of adolescence on mental growth. In testing 560 children from six to fifteen

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13 Arnold Gesell, "The Appraisal of Mental Growth Careers," Journal of Consulting Psychology, Vol. 3, No. 3, pp. 73-79.

14 Calvin Stone and Lois Doe-Kulmann, "Notes on the Mental Development of Children Exhibiting the Somatic Signs of Puberty Praecox, Nature and Nurture, (National Society for the Study of Education, 1928), pp. 389-397.

15 Frank Shuttleworth, "The Physical and Mental Growth of Girls and Boys Age Six to Nineteen in Relation to Age at Maximum Growth," Monographs of the Society for Research in Child Development, Vol. 4, Serial 22, No. 3, (1939), p. 201.

16 Katherine Murdock and Louis R. Sullivan, "Some Evidence of an Adolescent Increase in the Rate of Mental Growth," Journal of Educational Psychology, 14:350-56, (1922).

17 David Wechsler, "Intellectual Development and Psychological Maturity," Child Development Monographs, Vol. 21, No. 1, (1950), p. 45.

18 William Johnson, "The Mental Growth Curve of Secondary School Students," (unpublished Doctor's thesis, University of Chicago, 1923), pp. 111-118.

years of age, Murdock and Sullivan[19] find pre-adolescent mental growth spurts as well as physical growth spurts, although reporting less mental than physical acceleration.

Wechsler states, "General characteristics of the curves of growth for most intellectual abilities resemble the growth curve for vocabulary. This is characterized by a rapid rise in test scores in the first years with a gradual slackening as age 15 is approached except for a brief acceleration, somewhere between ages 10 and 12, a rise sometimes referred to as the pubescent hump."[20]

Johnson[21] also found evidence of an adolescent spurt in mental growth following the twelfth or thirteenth year for girls and fourteenth or fifteenth year for boys.

While some investigators have considered puberty a time of accelerated mental growth, others suggest that this is a period of decelerating mental growth. Doll states:

> It seems that infancy is a period of intellectual germination rather than growth. Growth itself does not go rapidly forward until early childhood, say about 4 years of age. Then growth proceeds rapidly, following nearly a straight line course until adolescence, after which its rate is rapidly retarded until the age of final arrest at a point which is as yet indefinitely determined

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19 Katherine Murdock and Louis Sullivan, "A Contribution to the Study of Mental and Physical Measurements in Normal Children," American Physical Education Review, 28:209-215, 276-280, 328-330, (1923).

20 Wechsler, op. cit., p. 43.

21 Johnson, op. cit., p. 111-113.

but is probably not higher than 14 years of age.[22]

Thurstone takes a different position, stating, "... test-intelligence grows nearly as rapidly at the age 14 as it does at the age of nine." He concludes, from data derived from repeated group mental tests, "It may be that this curve, if continued, would drop its acceleration to reach a limit in the early 20s or perhaps even at the age of 20, but it can hardly be extended to reach a limit much sooner than that."[23]

Conrad, Jones, and Hsiao reached still another conclusion from their study of the pattern of mental growth, stating, "...the developmental curve is linear to about sixteen to a peak between the ages of eighteen and twenty-one."[24]

From his study of 16,574 school-going children of European descent in the Union of South Africa, Wilcocks[25] found that the growth of intelligence from 120 to 192 months could be expressed in terms of a hyperbolic equation.

Odom studied the mental growth curve through the application of group intelligence tests and concluded, "The

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22 Edgar Doll, "The Growth of Intelligence," *Psychological Monographs*, Vol. 29, No. 2, (1920), pp. 7-10.

23 L. L. Thurstone, "A Method of Scaling Psychological and Educational Tests," *Journal of Educational Psychology*, (Oct., 1925), p. 446.

24 H. S. Conrad, H. E. Jones and H. H. Hsiao, "Sex Differences in Mental Growth and Decline," *Journal of Educational Psychology*, 24:161, (1933).

25 R. W. Wilcocks, "On the Distribution and Growth of Intelligence," *Journal of General Psychology*, 6:273-274.

mental growth curve is shown generally to be negatively accelerated when plotted from the results of group intelligence tests."[26] However, Odom found occasional exceptions to this pattern, with some curves slightly accelerated and others approximating a straight line.

A serious limitation of many of the studies cited above has been pointed out by Frank,[27] Dearborn and Rothney,[28] Shuttleworth,[29] Millard,[30] DeLong,[31] and others who indicate one of the factors which has limited many of the studies cited above--the use of group means to determine patterns of growth.

As early as 1921, Pintner affirmed:

> I feel that the time has now come for systematic measurement of the same group of children over several years, by means of both educational and mental tests, and combinations of these.[32]

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26 Charles Odom, "A Study of the Mental Growth Curve with Special Reference to the Results of Group Intelligence Tests," Journal of Educational Psychology, 20:415, (1929).

27 Lawrence Frank, "The Problem of Child Development," Child Development, 6:10, (1935).

28 Walter Dearborn and John Rothney, Predicting the Child's Development (Cambridge, Mass.: Sci-Art Publishers, 1941), pp. 232-234.

29 Shuttleworth, op. cit., pp. 200-201.

30 C. V. Millard, Child Growth and Development in the Elementary School Years (Boston: D. C. Heath Company, 1951), p. 59.

31 Arthur R. DeLong, "A Longitudinal Study of Individual Children," Michigan Education Journal, November, 1951.

32 Rudolf Pintner, "Intelligence and Its Measurement: A Symposium," The Journal of Educational Psychology, Vol. 12, No. 3, (1921), p. 142.

Shuttleworth states, "The most essential prerequisite for any study of growth is the repeated application of measurements which are comparable from year to year."[33] Frank argues in the same vein, stating:

> Again it is necessary to calculate the line of secular trend for each of these fluctuating structures and functions so that its movements toward maturity may be studied both as a process having presumably a law of its own, and as a member in a series of concomitant changes, the rates of which will be related one to the other.[34]

Toops and Pintner point to one of the usual assumptions of cross-sectional research, "...that the rth percentile child at any given chronological age will be the rth percentile child at any succeeding chronological age."[35] They point out that such an assumption would necessarily cover up any spurt in an individual pattern.

Freeman and Flory state:

> The customary method of studying mental growth is the cross-section method....Since different children are tested at successive ages it is impossible to be sure that the selection of cases at each successive age is a similar sample of the population as that at the other ages. In fact, we may go further and say that it is pretty certain that the successive age groups are not similar samples of the population.[36]

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33 Shuttleworth, op. cit., p. 200.

34 Frank, op. cit., p. 10.

35 Herbert Toops and Rudolf Pintner, "Curves of Growth of Intelligence," Journal of Experimental Psychology, Vol. 3, No. 3, (1920), p. 241.

36 Frank Freeman and Charles Flory, "Growth in Intellectual Ability as Measured by Repeated Tests," Monographs of the Society for Research in Child Development, Vol. 2, No.2, (Washington, D. C., 1937), pp. 2-3.

Thus, as Hillard states, "It is now rather generally accepted that cross-sectional data have resulted in misinterpretations in the prediction and analysis of individual growth rhythms."[37] Froehlich[38] as late as 1944 in reviewing the literature on mental development, points to the dearth of comprehensive longitudinal studies.

In 1926, Heinis reported the results of his work in which he examined group intelligence test data and derived a mathematical formula which he called a "personal constant." Heinis states:

> ...one can see that the growth of human intelligence does not normally stop form the time of birth till old age. This progress though remaining positive diminishes from year to year, so that by the age of 40 the normal man has practically attained his maturity. As to the child, his development is rapid especially during the first years. Already at the age of 5 he has accomplished half his mental evolution.[39]

Heinis used his procedure in an analysis of Kuhlmann's[40] data derived from a ten year study of 639 feeble-minded children who showed a tendency toward a regular decrease in I.Q. scores. Using the Heinis method, the Personal Constant derived was much more consistent than had been the individual's

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37 Hillard, op. cit., p. 59.

38 Gustav Froehlich, "Mental Development During the Preadolescent and Adolescent Periods," Review of Educational Research, Vol. 14, No. 5, (1944), p. 401.

39 H. Heinis, "A Personal Constant," The Journal of Educational Psychology, 17:163-186, (1926).

40 F. Kuhlmann, Tests of Mental Development (Minneapolis: Educational Publishers, Inc., 1947).

I.Q. scores.

Kuhlmann,[41] who saw in Personal Constant an improvement over the I.Q. concept, prepared growth curve values for year and month using the Heinis formula. This material, after being checked and slightly modified by Hilden, is presented in tabular form in Kuhlmann's[42] book, Tests of Mental Development. Hilden[43] also used the Heinis method on Kuhlmann's sub-normal group and concluded that the Personal Constant is a more accurate expression of the rate of mental development.

Cattell[44] has been one of the few to study the Heinis Personal Constant and to compare it with the I.Q. Cattell concurred with the work done by Kuhlmann[45] and Hilden[46] in concluding that the Personal Constant is more constant than the I.Q. for children below average in intelligence, but found the PC less constant than the I.Q. for above average children.

Allen[47] in studying the relationship between the

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41 Ibid., p. 215.

42 Ibid., p. 215.

43 A. H. Hilden, "A Comparative Study of the Intelligence Quotient and Heinis' Personal Constant," Journal of Applied Psychology, 17:355-375, (1933).

44 Psyche Cattell, "The Heinis Personal Constant as a Substitute for the I.Q.," Journal of Educational Psychology, 24:221-228, (1933).

45 Kuhlmann, op. cit., p. 215.

46 Hilden, op. cit., pp. 355-375.

47 Mildred H. Allen, "Relationship Between Kuhlmann-Anderson Intelligence Tests and Academic Achievement in Grade IV," Journal of Educational Psychology, 35:229-239, (1937).

Kuhlmann-Anderson Intelligence Tests and academic achievement of fourth grade children found a correlation of .77 between mental age and achievement; of .74 between I.Q. and achievement; of .70 between personal constant and achievement.

Both the Personal Constant and the I.Q. provide a description of an individual's mental growth from only one measurement, although a different pattern of mental growth is assumed for the different measures. Freeman[48] points out that if I.Q. is constant, one would find a linear relationship between M.A. and C.A. Crissey states:

> Numerous studies have attempted to show that I.Q. remains constant, if constancy is defined as variability within an average of 5 I.Q. points or a fairly high correlation between initial test and retest. This point of view is taken by Burt, Terman, Baggs, Hirsch, Poull, Rugg and Colloton, Rogers, Darling and McBride, Rosenow, Brooks, Jordan, Cattell and Goulet, and others."[49]

Katz[50] studied the constancy of Stanford-Binet I.Q. from three to five years of age using data collected on 160 girls and 143 boys by the Brush Foundation. In spite of a

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[48] Frank N. Freeman and others, "The Influence of Environment on Intelligence, School Achievement, and Conduct of Foster Children," National Society for the Study of Education, 17:159, (1928).

[49] Orlo L. Crissey, "Mental Development as Related to Institutional Residence and Educational Achievement," University of Iowa Studies, Vol. 13, No. I, (Iowa City, Iowa: University of Iowa, April 1937), p. 13.

[50] Evelyn Katz, "The Constancy of the Stanford-Binet I.Q. From Three to Five Years," Journal of Psychology, 12:159-181, (1941).

high test-retest correlation for the group, Katz found that approximately 40 percent of the children showed fluctuations of 20 or more I.Q. points.

Cattell[51] in another study of Stanford Binet I.Q. variations of more than 400 children found that four cases or about one-tenth of one percent, vary over 40 I.Q. points. One percent gained over 30 points, five percent over 19 points, ten percent over 14 points, and twenty-five percent over 7 points.

Lincoln[52] studied test-retest changes in the I.Q.'s of superior children, finding a range from a loss of 36 I.Q. points to a gain of 35 points. Forty percent of the cases varied 10 points or more.

O'Neill's[53] study of the variations in the intelligence quotient of 105 children showed similar results. The range was from a gain of 37 points to a loss of 35 points. Sixteen percent of the cases fluctuated 20 or more points.

Clarke and Clarke[54] studied 100 adolescent and adult

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51 Psyche Cattell, "Stanford-Binet I.Q. Variations," School and Society, 45:617-618, (1937).

52 Edward A. Lincoln, "A Study of Changes in the Intelligence Quotients of Superior Children," Journal of Educational Research, 29:272-275, (1935-1936).

53 H. C. O'Neill, "Variations in the Intelligence Quotient of 105 Children," Child Development, 8:357-363, (1937).

54 A. D. Clarke and A. M. Clarke, "How Constant is the I. Q.?" Lancet, Vol. 265, No. 6791, pp. 877-880, (1953).

defectives using the Wechsler. Test-retest results showed large increments made by some of the subjects.

DeLong, who directed a six-year longitudinal study called the Holt Study, considered the stability of six measures taken and concluded:

> I.Q. was found to be less stable than any of five quotients considered and significantly less stable than height and arithmetic. . . . What we refer to as intelligence is not sufficiently stable to be represented by a single number or point on a scale.[55]

Courtis states:

> The only safe basis for the interpretation of the scores of an individual is his own growth curve. An individual's score in a single test is meaningless for prediction; it merely gives a picture of his status at the time of the test.[56]

Observing the similarity of the growth pattern of various biological organisms to the patterns of non-biological phenomenon, Courtis[57] hypothesized that a curve derived by Benjamin Gompertz[58] and presented in 1825, was a universal growth curve. Winsor presents a bibliography and discussion of the use of the Gompertz curve as a growth curve in many

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55 A. R. DeLong, "The Meaning of Individual Scores on Group Tests," Paper read to the National Council on Measurements (Atlantic City, New Jersey: February 18, 1957).

56 S. A. Courtis, Towards a Science of Education (Ann Arbor: Edwards Brothers, 1951).

57 S. A. Courtis, Maturation Units and How to Use Them (Ann Arbor: Edwards Brothers, 1950).

58 Benjamin Gompertz, Philosophical Transactions of the Royal Society of London for the Year MDCCCXXV, Part I, Printed by W. Nicol, St. James, Pall Mall, Printers to the Royal Society, MDCCCXXV.

scientific areas. Courtis[59] reduced the complex mathematical function $y = ke^{ceat}$ to a simpler form, $y = ki^{rt}$ by adjusting Naperian Lologarithms to a new unit called the "isochron", thus eliminating negative values of the Naperian Lologarithms. Courtis[60] has made available a complete discussion of the theory involved in the use of the Gompertz Curve as well as a guide for performing the actual operations involved in using his adaptation of the function.

The Courtis technique has been utilized in the field of education by Millard[61-62] in his study of spelling and in preadolescent reading maturation, by Kunkle[63] in studying reading maturation, and by Nally[64] in establishing the relationship between growth in height and beginning of reading. Long and Dearborn[65] used the function on a few of the Harvard cases, fitting the data to one-cycle curves.

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59 S. A. Courtis, *Maturation Units and How to Use Them* (Ann Arbor: Edwards Brothers, 1950).

60 *Ibid.*, p. 173.

61 C. V. Millard, "The Nature and Character of Pre-adolescent Growth in Reading Achievement," *Child Development*, Vol. 11, No. 2, pp. 71-114, 1940.

62 C. V. Millard, "An Analysis of Factors Conditioning Performances in Spelling," Unpublished Doctor's Thesis (Ann Arbor, Michigan: University of Michigan, 1937).

63 Faye L. Kunkle, "Growth and Prediction in Reading Achievement," Unpublished Master's Thesis (East Lansing, Michigan: Michigan State College, 1950).

64 Thomas Nally, "The Relationship Between Achieved Growth in Height and the Beginning Growth in Reading", Unpublished Doctor's Thesis (East Lansing: Michigan State, 1953).

65 H. H. Long and W. F. Dearborn, "The Curve of Mental Growth," *Predicting the Child's Growth* (Cambridge, Mass: Sci-Art Publishers, 1941), pp. 201-237.

Kowitz[66] studied the relationship of physical growth to classroom behavior. Rasch[67] examined the relationship of growth in height to growth in weight, and also the number of cycles present in height growth. Udoh[68] found the relationship of menarche to achieved growth in height, and Greenshields[69] used a developmental basis to find the relationship between consistent I.Q. scores, decreasing I.Q. scores, and reading scores. Lee[70] examined the relation of the heights of girls to the advent of menstruation.

Meredith[71] found the Courtis technique unsatisfactory when he used it to predict the growth of six boys selected from the Iowa studies. However, DeLong and Nally[72] were able to point to errors which Meredith had made in his application of the technique.

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66 Gerald T. Kowitz, "An Exploration Into the Relationships of Physical Growth Patterns and Classroom Behavior in Elementary School Children," Unpublished Doctor's Thesis (East Lansing, Michigan: Michigan State University, 1954).

67 Reuben R. Rasch, "The Relationship Between Growth in Height and Growth in Weight," Unpublished Master's Thesis (East Lansing, Michigan: Michigan State University, 1954).

68 Ekanem (Benson) Udoh, "Relationship of Menarche to Achieved Growth in Height," Unpublished Doctor's Thesis (East Lansing, Michigan: Michigan State University, 1955).

69 C. M. Greenshields, "The Relationship Between Consistent I.Q. Scores, Decreasing I.Q. Scores, and Reading Scores Compared on a Developmental Basis," Unpublished Master's Thesis (East Lansing, Michigan: Michigan State University, 1955).

70 S. M. Lee, "The Advent of Menstruation in Relation to Adolescent Development in Height," Unpublished Master's Thesis (Ann Arbor, Michigan: University of Michigan, 1938)

71 H. Meredith, "Rhythm of Growth," Studies in Child Welfare, Vol. 11, No. 3, University of Iowa, 1935.

72 T. P. Nally and A. R. DeLong, "An Appraisal of a Method of Predicting Growth," Child Development Laboratories, Michigan State College, Series II, No. 1, 1952.

CHAPTER III

THE GROUP STUDIED AND METHODS USED

I. THE GROUP

Source of data. The population used as a basis of this study was selected from the Dearborn Data, available at the Child Development Laboratories at Michigan State University. These data were collected by the teachers of the Henry Ford School, Dearborn, Michigan, under the direction of C. V. Millard, then Superintendent of the Henry Ford School in Dearborn. Height, weight, mental, and academic measures were made on more than 300 children as they progressed from kindergarten through the ninth grade. Children were dropped from the study when they left the Henry Ford School, and others were added when they entered the school. Thus, records are not complete for all the children. Even among the children enrolled throughout the study, occasional measurements were missed when the child was absent from school.

In general, each child's height and weight measurements were taken three times a year; mental tests were administered annually; and Stanford Achievement tests were given yearly from the second grade on. On some occasions mental and academic measures were more frequent. In Millard's opinion, "The children in this school are, in general, typical of the higher level of social status found in an industrial community.

Very few of the cases represent social extremes."[1]

Selection of cases. Selected from the entire collection of data were one hundred cases, picked according to the following criteria: (1) at least six mental age scores covering a chronological period of at least 40 months; (2) at least six height measurements covering a period of 40 months; and (3) data fitting the first two criteria were examined in terms of selecting the cases with the widest range of chronological age. Table I shows the number of measurements and the range of measurements of the cases used.

II. METHODS AND PROCEDURES

The mental growth data available on each of the one-hundred cases was described by: (1) using mean I.Q. as the rate of mental growth; (2) deriving a mean "Personal Constant" from the table values of mental growth derived from the Heinis formula and presented by Kuhlmann; and (3) deriving two-cycle Courtis equations.

Using the mean I.Q. In using the mean I.Q. as the rate of mental growth, Intelligence Quotients were derived from each test given an individual. Then the sum of the I.Q.'s was divided by the number of tests administered, and the result was used as the rate of mental growth. This rate was then multiplied by the age in months of the child when each test was given, and the product was compared with the mental

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[1] C. V. Millard, "The Nature and Character of Pre-adolescent Growth in Reading Achievement," Child Development, Vol. 2, No. 2, 1940, pp. 71-73.

TABLE I

NUMBER OF MEASURES AND AGE RANGE OF CASES USED

Number of measures	Number of cases	Range in months	Cases
6	7	40 to 44.5	3
7	11	45 to 49.5	8
8	23	50 to 54.5	39
9	25	55 to 59.5	5
10	25	60 to 64.5	6
11	8	65 to 69.5	0
12	1	70 to 74.5	2
		75 to 79.5	3
		80 to 84.5	0
		85 to 89.5	10
		90 to 94.5	5
		95 to 99.5	3
		100 to 104.5	8
		105 to 109.5	4
		110 to 114.5	1
		115 to 119.5	1

age obtained from the test. Deviations were then obtained between the theoretical straight line of mental growth and the actual mental measurements obtained on the tests. Table II shows a sample computational process, while Figure I shows graphically a comparison of the theoretical straight line growth of Case 35F compared with the actual measures derived from the tests.

Deriving "Personal Constants". Mean Heinis Personal Constants were derived by finding the ratio between the absolute growth value derived from the mental age determined by the Kuhlmann-Anderson test to the absolute mental age value of the chronological age of the child when the test was taken. This procedure gave a Personal Constant for each test taken by an individual. The sum of these Personal Constants was then divided by the number of tests taken, giving a mean Personal Constant for each individual. This mean Personal Constant was then multiplied by the mental growth equivalent of the chronological age at which the test was given. The result was the theoretical mental growth equivalent, which was translated from the table back into a mental age score and compared with the mental age score actually obtained from the test. Table III illustrates the procedures followed, and Figure II shows graphically the theoretical curve derived from the mean Personal Constant for Case 35F compared with the actual mental measurements obtained.

TABLE II

SAMPLE COMPUTATIONAL PROCESS
USING MEAN I.Q. AS RATE
CASE 35F

Age in months (1)	Mental age in months (2)	I.Q. (3)	Theoretical mental age (4)	Difference between (2) and (4)
101	115	114	120.2	5.2
113	132	117	134.4	2.4
125	144	115	148.8	4.8
128	155	121	152.3	2.7
131	155	118	155.9	.9
137	164	120	163.0	1.0
141	176	125	167.8	8.2
144	180	125	171.4	8.6

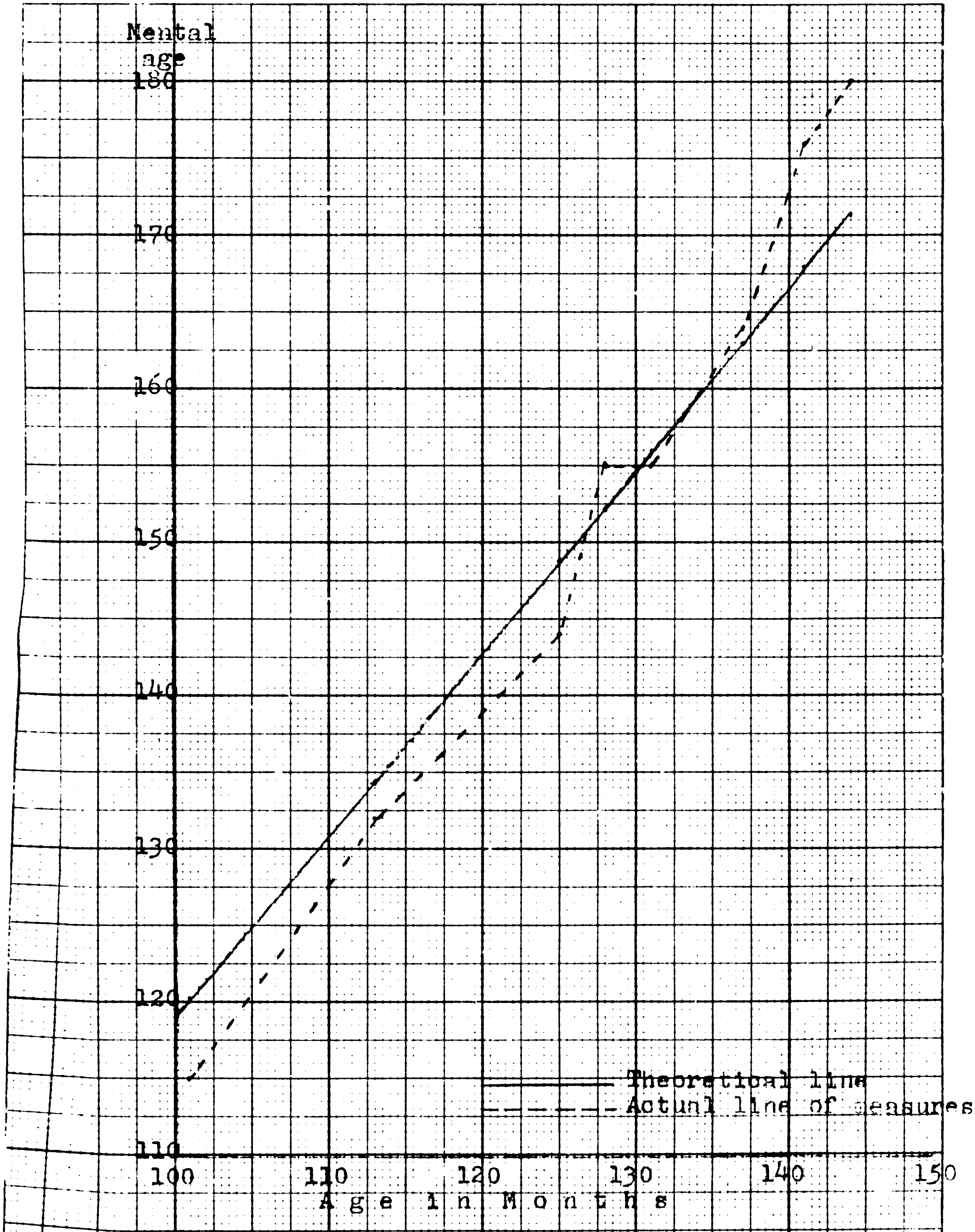

Figure 1

COMPARISON OF THE THEORETICAL STRAIGHT LINE GROWTH OF CASE 35F COMPARED WITH THE ACTUAL MEASURES DERIVED FROM THE TESTS

TABLE III

SAMPLE COMPUTATIONAL PROCESS FOR DERIVING HEINIS CURVE CASE 35F

C.A.	M.A.	C.A. Mental Growth Value	M.A. Mental Growth Value	Ratio	Predicted Value	Difference
101	115	307	327	1.0651	116	1
113	132	324	346	1.0679	132	0
125	144	339	362	1.0560	149	5
128	155	342	367	1.0730	152.5	2.5
131	155	345	367	1.0637	156	1
137	164	351	374	1.0655	172	4
141	176	355	381	1.0732	172	4
144	180	358	384	1.0726	177	3

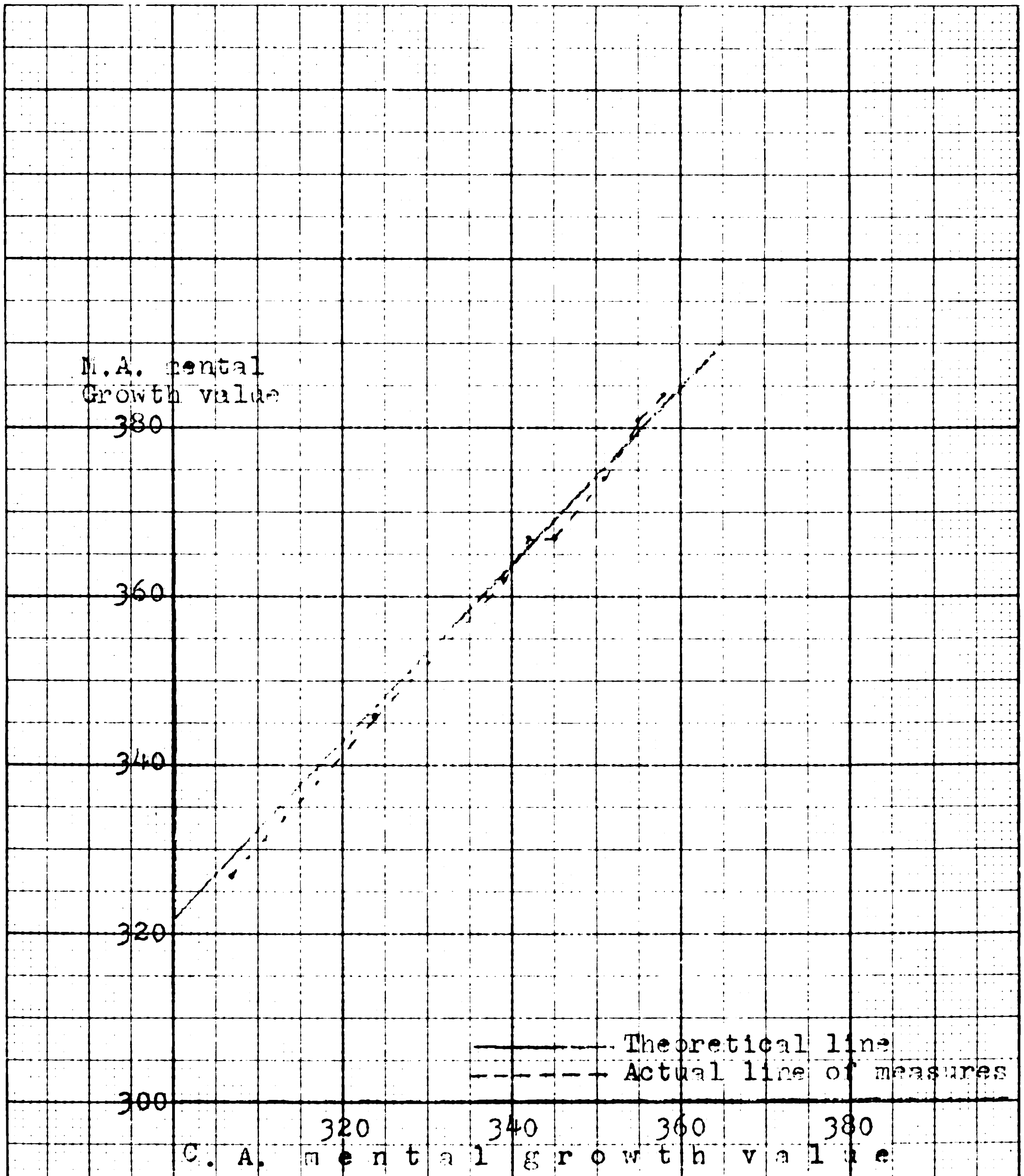

Figure 2

THEORETICAL CURVE DERIVED FROM THE MEAN PERSONAL CONSTANT FOR CASE 35F COMPARED WITH THE ACTUAL MENTAL MEASUREMENTS

<u>Deriving two-cycle Courtis equations</u>. Two-cycle Courtis equations were derived for each case using essentially the procedure outlined by Courtis in <u>Maturation Units and How to Use Them</u>.[2] The first step was to graph mental measurements against chronological age on single-cycle logrithmic paper. To make judgements about the time of cycle breaks more accurate, logrithmic graphs were also constructed for growth in height and for growth in reading on the same individuals. All three graphs were studied in deciding where to draw the curve of growth showing the maximum of the first cycle. After the maximum for the first cycle had been determined from the logrithmic graph, the percentage of the maximum of the first cycle was figured for each mental measurement. These percentages were then graphed on isochronic paper, and the line of best fit was drawn by inspection. Courtis equations were then written to describe the first cycle of growth. Residuals were computed and were graphed on single-cycle logrithmic paper to determine the second cycle maximum. The percentages of the residuals of the computed maximum were figured, and the results were plotted on isochronic paper and the second cycle equation written. Deviations of the derived theoretical two-cycle curve and the measurements from the tests were computed. Table IV shows the computational procedures involved in the Courtis equations, and Figure III shows the comparison between the theoretical curve and the test measurements.

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[2] S. A. Courtis, <u>Maturation Units and How to Use Them</u> (Ann Arbor, Michigan: Edwards Brothers, 1950).

TABLE IV

SAMPLE COMPUTATIONAL PROCESS FOR DERIVING COURTIS EQUATIONS CASE 35F

First cycle — y = 153(.70750t - 29.87)

Age	Score	Percent of Max.	Isochrons	Percent	Predicted Value	Difference
101	115	75.2	41.68	73.3	112.1	- 2.9
113	132	86.3	50.17	87.5	133.9	+ 1.9
125	144	94.1	58.66	94.5	144.6	+ .6
128	155		60.78	95.5	146.1	- 8.9
131	155		62.90	96.3	147.3	- 7.7
137	164		67.15	97.6	149.3	-14.7
141	176		69.93	98.2	150.2	-25.8
144	180		72.10	98.5	150.7	-29.3

Second cycle — y - 46(1.06388t - 115.53)

Age	Score	First Cycle Value	Resi-dual	% of Max.	Iso-chrons	%	Pred. Value	Error
101	115	112.1			0			-2.9
113	132	133.9			0			+1.9
125	144	144.6			17.46	3.0	1.4	+2.0
128	155	146.1	- 8.9	19.4	20.65	7.8	3.6	-5.3
131	155	147.3	- 7.7	16.8	23.85	15.7	7.2	- .5
137	164	149.3	-14.7	32.0	30.23	37.6	17.3	+2.6
141	176	150.2	-25.8	56.1	34.48	52.8	24.3	-1.5
141	180	150.7	-29.3	63.7	37.68	62.9	28.9	- .4

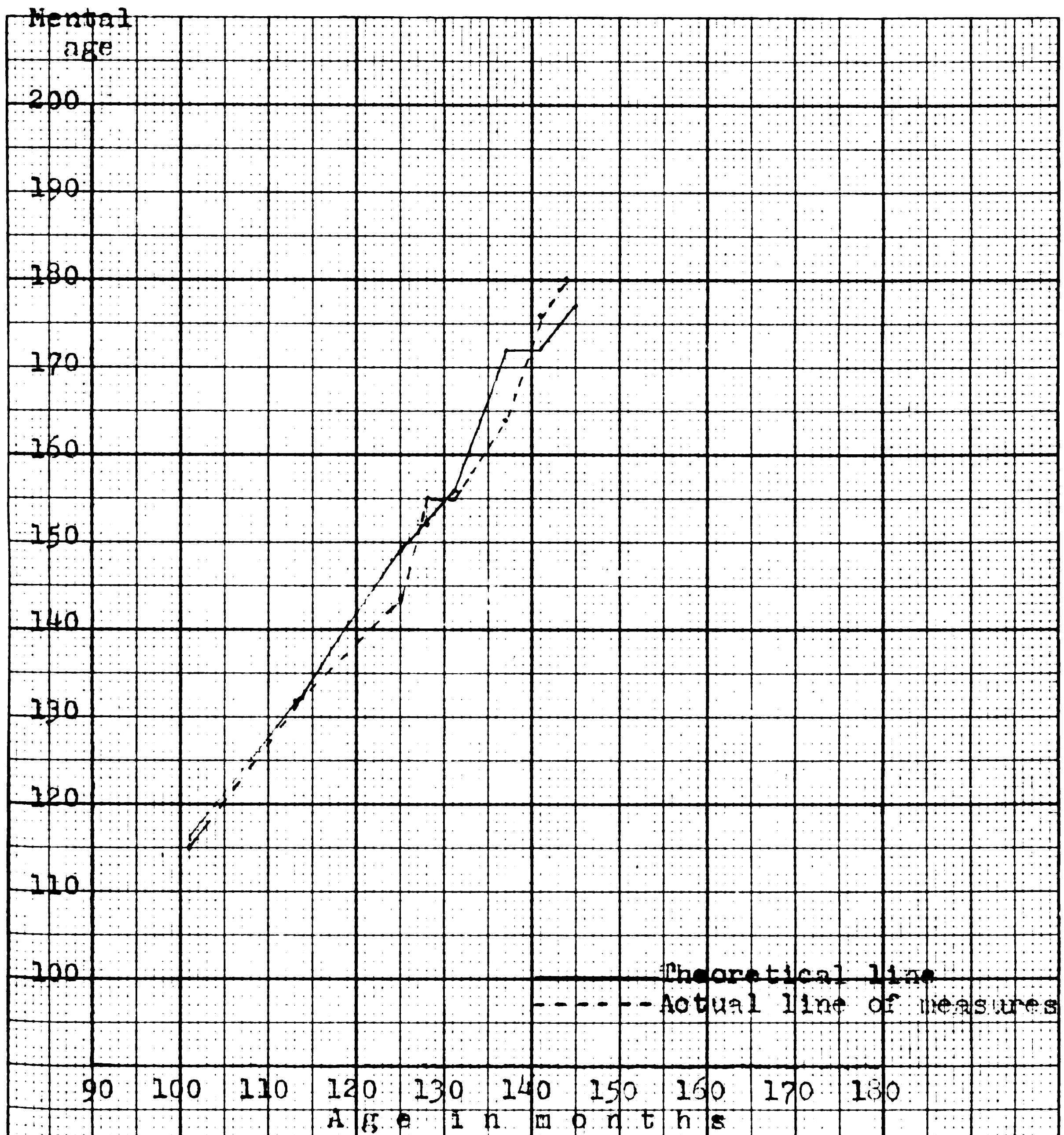

FIGURE 3

COMPARISON BETWEEN
THE THEORETICAL CURVE
AND TEST MEASUREMENTS
CASE 35B

For each case the average deviation in months of the theoretical description of mental growth from the actual measurements of growth derived from the mental tests were found. This difference was called the average error. Standard deviations were computed for each error distribution and tests of significance were run comparing the errors obtained from each of the three methods.

Average errors for each of the three methods were then grouped into ten-month intervals in order to show the average error for the different methods at different chronological ages. Tests of significance were run to see in which ten-month interval the errors were statistically different from the mean error for each method.

Five cases were selected at random, and the theoretical line of growth for each of the three methods was compared with the actual measurements. Judgements were made concerning the dynamics of the growth pattern found through this procedure.

CHAPTER IV

ANALYSIS OF DATA

The one hundred cases used for this study were administered a total of 878 mental tests. The major purpose was to find which of the three methods used would most accurately fit the actual test scores obtained. Table V shows the average error and the standard deviation for the Courtis multi-cycle equations, for Heinis equations, and for equations derived by using the mean I.Q. as the rate of mental growth.

The average deviation from the actual mental test scores was 4.7 months using multi-cycle equations, 7.4 months using Heinis equations, and 8.2 months using the mean I.Q. as rate. A test of the significance of the difference of means, showed that the error obtained for multi-cycle equations was lower, at the one percent level of confidence, than the error for the other two methods. The difference between the error obtained from Heinis equations was not significantly different from the error obtained by using mean I.Q. as rate.

Figures 4, 5, and 6 show the frequency distribution of the errors obtained for the one hundred cases by each of the three methods of describing mental growth.

Since a general look at the data obtained from the three methods of describing growth showed that multi-cycle growth equations had described the data most closely, further analysis was undertaken to see if there was any particular growth period when errors from the three methods used were

TABLE V

AVERAGE ERRORS AND STANDARD DEVIATIONS FOR MULTI-CYCLE EQUATIONS, HEINIS EQUATIONS, AND I.Q. EQUATIONS

Method	Average Error	Standard Deviation
Multi-cycle equations	4.7 months[1]	2.31
Heinis equations	7.4 months[2]	3.56
I.Q. equations	8.2 months[3]	3.63

[1] Significantly lower than average error of other two methods at the one percent level of confidence.

[2] Significantly higher than multi-cycle error, but not significantly different from mean error from I.Q. equations.

[3] Significantly higher than mean error of multi-cycle equations, but not significantly different from mean error of Heinis equations.

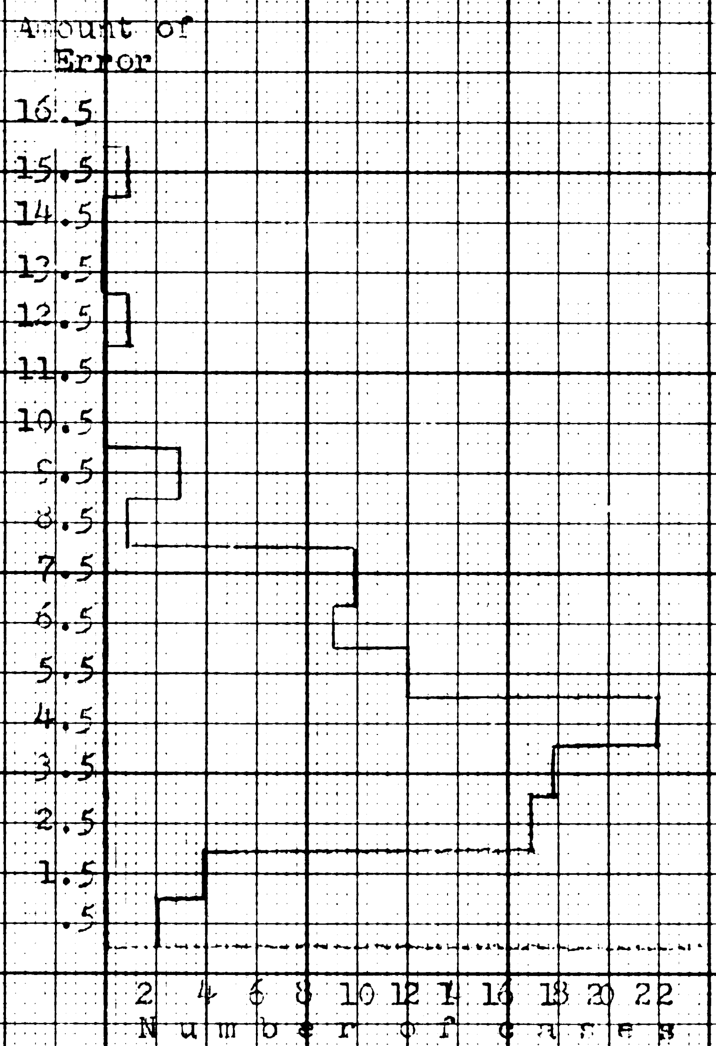

FIGURE 5

DISTRIBUTION
OF MEAN ERROR
FOR COURTIS EQUATIONS

greatest. Figure 7 shows the mean error of each of the three methods during ten-month intervals from 60 months through 190 months. A study of this figure shows that multi-cycle equations best describe the data during each ten-month period except for the period from 80 to 90 months, when I.Q. was the best indicator by a margin of .2 of a month, a statistically insignificant difference.

More important is the pattern of average errors of the Heinis equation and of mean I.Q.'s. It may be noted that the mean error for the Heinis equation increases each ten-month period from 130 through 180 months.

Table VI shows the mean error of each of the three methods during ten-month intervals from 60.5 to 200 months, as well as the number of measures within each ten-month period. Statistical analysis was made to determine during what time periods there might be significant deviations from the mean error over all time periods for each of the methods used. For the multi-cycle method, the mean error of 7.9 months obtained between 80.5 and 90 months was significantly higher than the mean error of 4.7 months obtained for multi-cylce equations using all the measures. Also, the error obtained on the multi-cycle method between 180.5 and 190 months of 2.3 months was significantly lower than the over-all error of 4.7 months. For Courtis multi-cycle equations, no other ten-month period showed an average error significantly different from the over-all average error.

There is nothing intrinsic in the data which can

TABLE VI

COMPARISON OF ERRORS FOR MULTI-CYCLE EQUATIONS, HEINIS EQUATIONS, AND I.Q. EQUATIONS DURING TEN-MONTH INTERVALS FROM SIXTY MONTHS TO TWO-HUNDRED MONTHS

Age Range in Months	Number of Measures	Mean Error Multi-cycle	Mean Error Heinis	Mean Error I.Q.
60.5- 70	9	2.5	5.8	6.3
70.5- 80	18	3.6	6.3	10.0
80.5- 90	21	7.9	8.3-	7.7
90.5-100	29	4.0	4.6	8.3
100.5-110	41	3.0	4.7	5.8
110.5-120	52	5.0	7.1	8.5
120.5-130	92	5.3	6.0	6.8
130.5-140	110	4.0	6.1	6.8
140.5-150	128	4.9	7.0	7.0
150.5-160	151	4.6	8.5	8.8
160.5-170	117	5.5	10.3	9.7
170.5-180	86	5.7	12.3	18.5
180.5-190	20	2.3	17.8	14.5
190.5-200	3	.7	15.0	15.5

explain the relatively high error for multi-cycle equations during the period from 80.5 to 90 months. A possible factor might be the Kuhlmann-Anderson test series itself. A study of the over-lapping test booklets will show that the first and second grade booklets are largely concerned with non-reading tasks. However, by the third grade, the reading skill becomes much more of a factor in determining the test score. Thus, a child who starts late in beginning to read, might show considerable test fluctuation during this period.

Greenshields[1] in studying the relationship between consistent I.Q.'s, decreasing I.Q.'s, and reading scores, concluded that individuals' inability to score on the verbal subtests of the Kuhlmann-Anderson at the same level at which they scored on the non-verbal subtests resulted in a drop of their I.Q. scores.

An explanation for the significantly low error found in multi-cycle equations from 180.5 to 190 months may come from the flexibility found in the Courtis technique. Between the ages of fifteen and sixteen there is much individual difference in patterns of mental growth. Some individuals have already leveled off and are making very little gain, while others are proceeding at a rapid rate which may extend for several more years. Of the three methods used, only the Courtis technique can take into account these individual

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1 C. M. Greenshields, "The Relationship Between Consistent I.Q. Scores, Decreasing I.Q. Scores, and Reading Scores Compared on a Developmental Basis," Unpublished Master's Thesis (East Lansing, Michigan: Michigan State University, 1955)

differences. Especially in cases where the individual has clearly begun to level off in his mental growth, the individual's theoretical growth curve will come very close to the final actual mental growth score.

The mean error of the Heinis equations of 10.3 months from 160.5 to 170 months, of 12.3 from 170.5 to 180 months, and of 17.8 months from 180.5 to 190 months were all significantly higher, at the five per cent level of confidence, than the over-all mean error for the Heinis equations of 7.4 months. It may be noted that the average error for the Heinis equations increases from 130.5 through 190 months.

The errors obtained by using mean I.Q. as rate resemble the error pattern obtained from Heinis equations in showing an upward trend after 130 months. However, in using I.Q. as rate, only the errors of 18.5 months from 170.5 to 180 months, and 14.5 from 180.5 to 190 months are significantly different at the five per cent level from the over-all error of 8.2 months.

Figure 8 shows the distribution of the range of the I.Q.'s for the hundred cases used. The mean range of I.Q. was 18.4 I.Q. points.

A detailed summary of the data can be found in Appendix A. Courtis first and and second cycle equations and the mean error for each case are presented. Also a summary of Heinis equations includes the high Personal Constant ratio, the low Personal Constant ratio, the range of the ratios, the mean Personal Constant, and the mean error for each case.

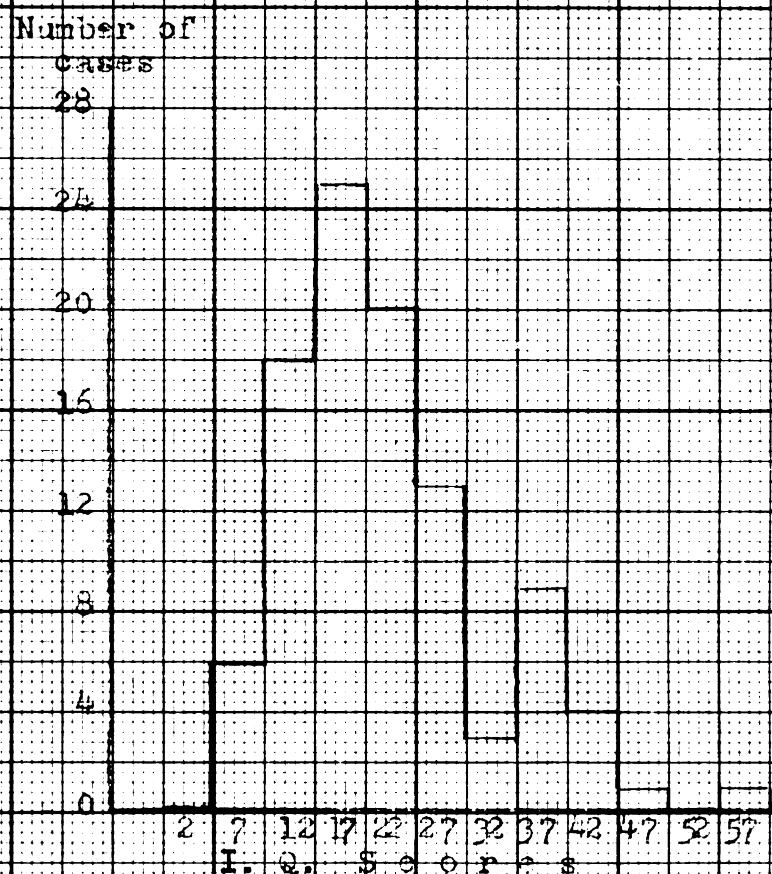

FIGURE 8

DISTRIBUTION OF RANGE OF I.Q. SCORES

The summary of I.Q. used as rate includes the high I.Q., the low I.Q., the mean I.Q., and the mean error.

To illustrate some of the actual dynamics taking place in the mental growth of individuals and how each of the methods of describing growth works in terms of these dynamics, five cases were selected at random and the actual measurements were compared with the theoretical line of growth determined for that case.

Case 1F pictures a girl who shows a drastic change in her rate of mental growth from the first cycle to the second cycle, but whose growth within cycles is rather consistent. Between the ages of 98 months and 125 months, she was given four intelligence tests. Her I.Q. for the four tests was 116, 119, 118, and 118, respectively. She was given four more tests from 132 months to 151 months. Her I.Q. on these tests was 131, 134, 130, and 143. Of the three methods used in this study, only the Courtis method has a theoretical framework which can explain this pattern.

It may be noted that the only score far removed from the theoretical line described by the Courtis equation was the test result at 145 months which fell well below the prediction line. The data show that this girl gained 12 months mental age from 132 months of age to 138 months; 4 months mental age from 138 months of age to 145 months; and 27 months mental age from 145 months of age to 151 months. Thus, it could be argued that the four-month gain in mental age between 138 and 145 months of age is very low in view of the

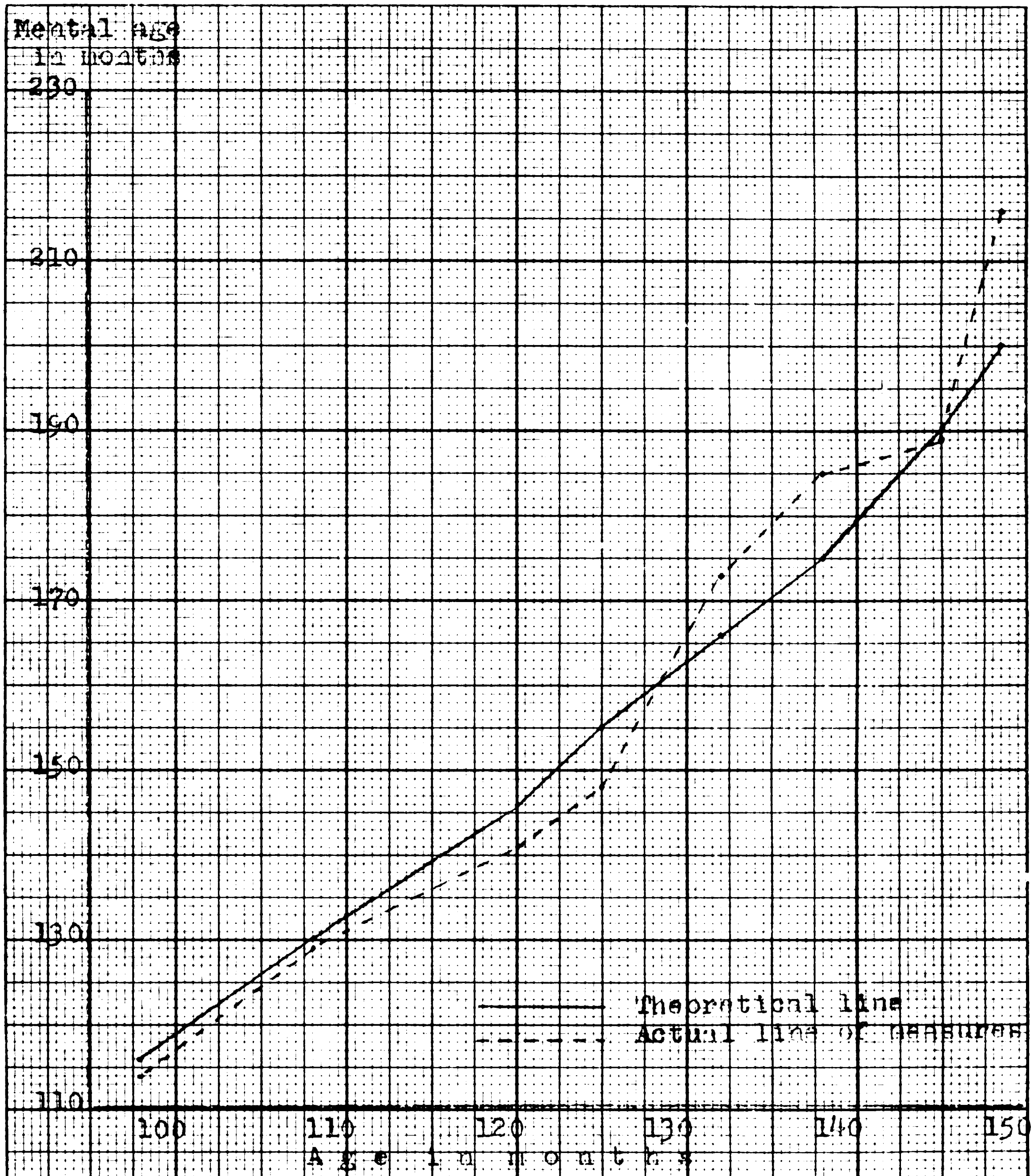

FIGURE 9

LINE OF GROWTH OBTAINED
FROM MEAN PERSONAL CONSTANT AS
COMPARED WITH ACTUAL MEASUREMENTS
CASE 1F

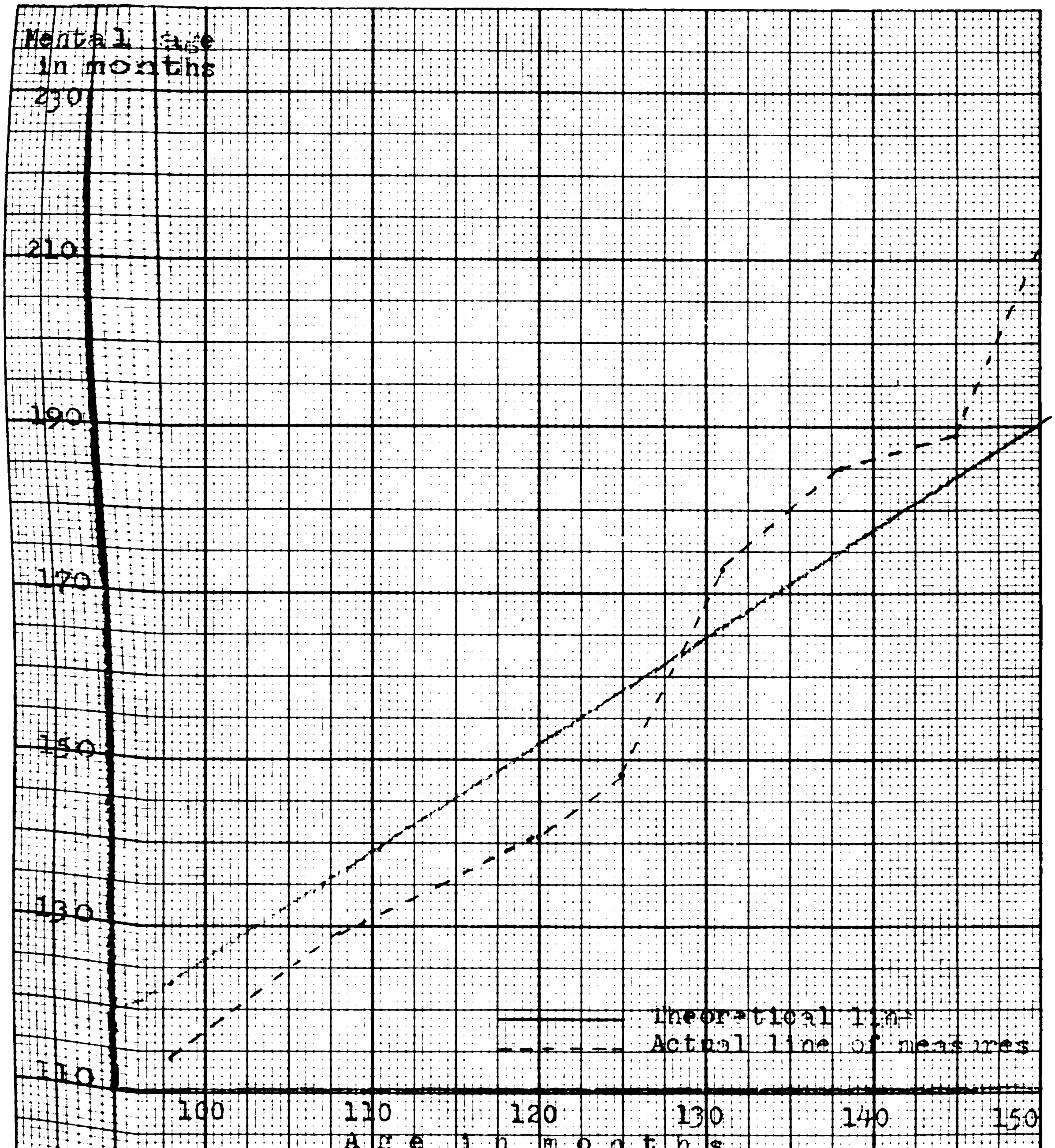

FIGURE 10

LINE OF GROWTH OBTAINED
FROM MEAN INTELLIGENCE QUOTIENT
COMPARED WITH ACTUAL MEASUREMENTS
CASE 1F

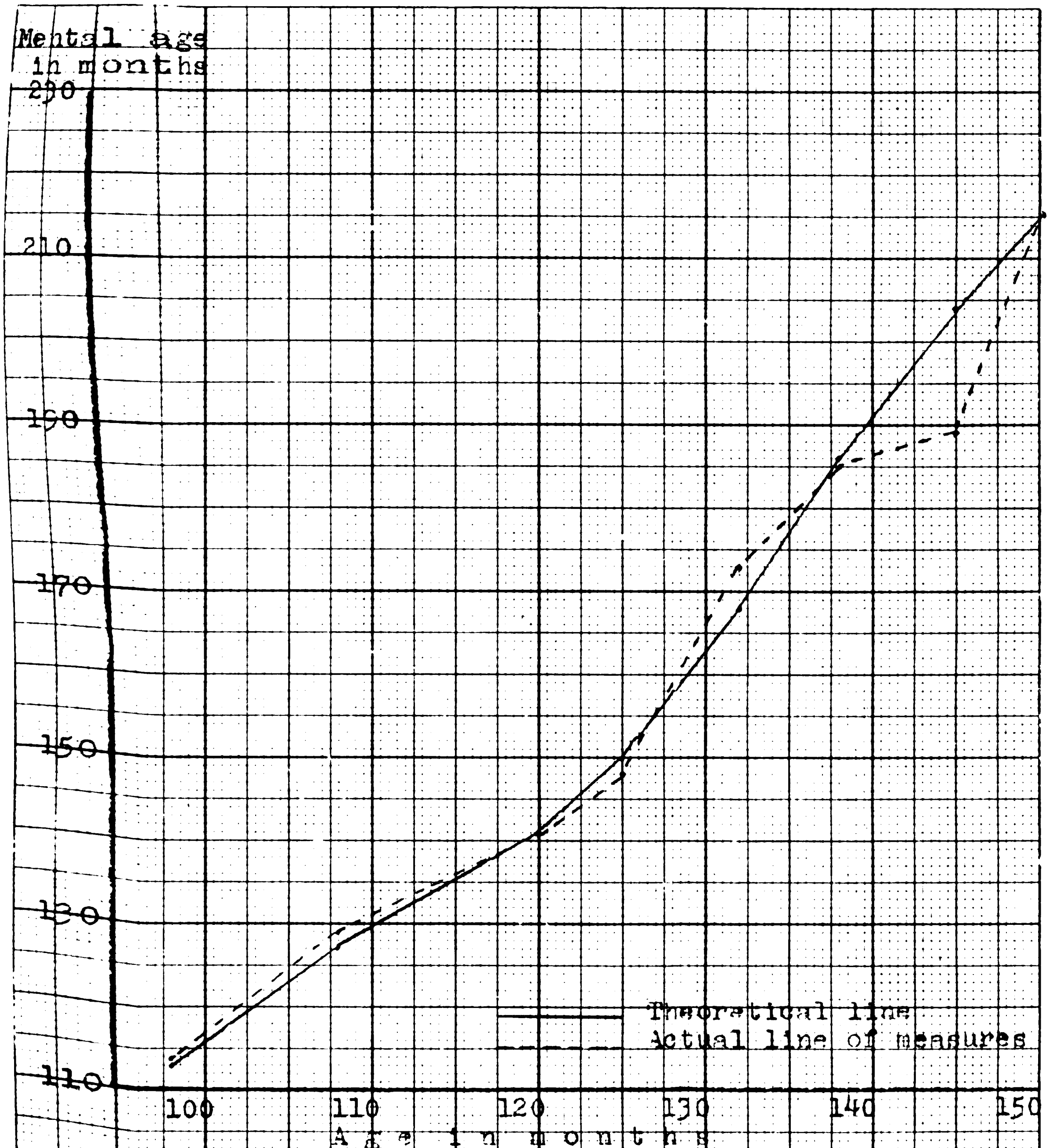

FIGURE 11

LINE OF GROWTH OBTAINED
FROM MULTI-CYCLE EQUATIONS
COMPARED WITH ACTUAL MEASUREMENTS
CASE 1F

rest of the data, and that the theoretical line represents a truer picture. The Heinis equation for case 1F is not able to cope with the change of rate shown by this individual as well as does the Courtis equation. If this individual maintains the same rapid rate, even for a short period of time, the Heinis equation will show increasing error.

Using mean I.Q. as rate, points out clearly the change in rate which 1F is showing, with the first four points below the theoretical line, and the last four points above. The consistency of the pattern would seem to make the concept of a constant I.Q. difficult to defend.

Case 23M is an example of a boy showing an erratic test pattern. He was given a total of ten intelligence tests, and on three occasions his mental age fell below the mental age obtained on the previous testing. Children showing such erratic patterns would seem to be good subjects for future research work.

In 23M it can be seen that the Heinis equation used does not balance the errors above and below the theoretical line of growth. A study of the Mental Growth Units used in the Personal Constant shows that in an erratic pattern, low scores at an early age will influence the mean more than low scores at a later age. To illustrate specifically, if an individual has a mental age of five at a chronological age of six years, the ratio in mental growth units is 254/226, or a I.C. of .8900. If the same individual has a mental age of ten at a chronological age of twelve years, the ratio

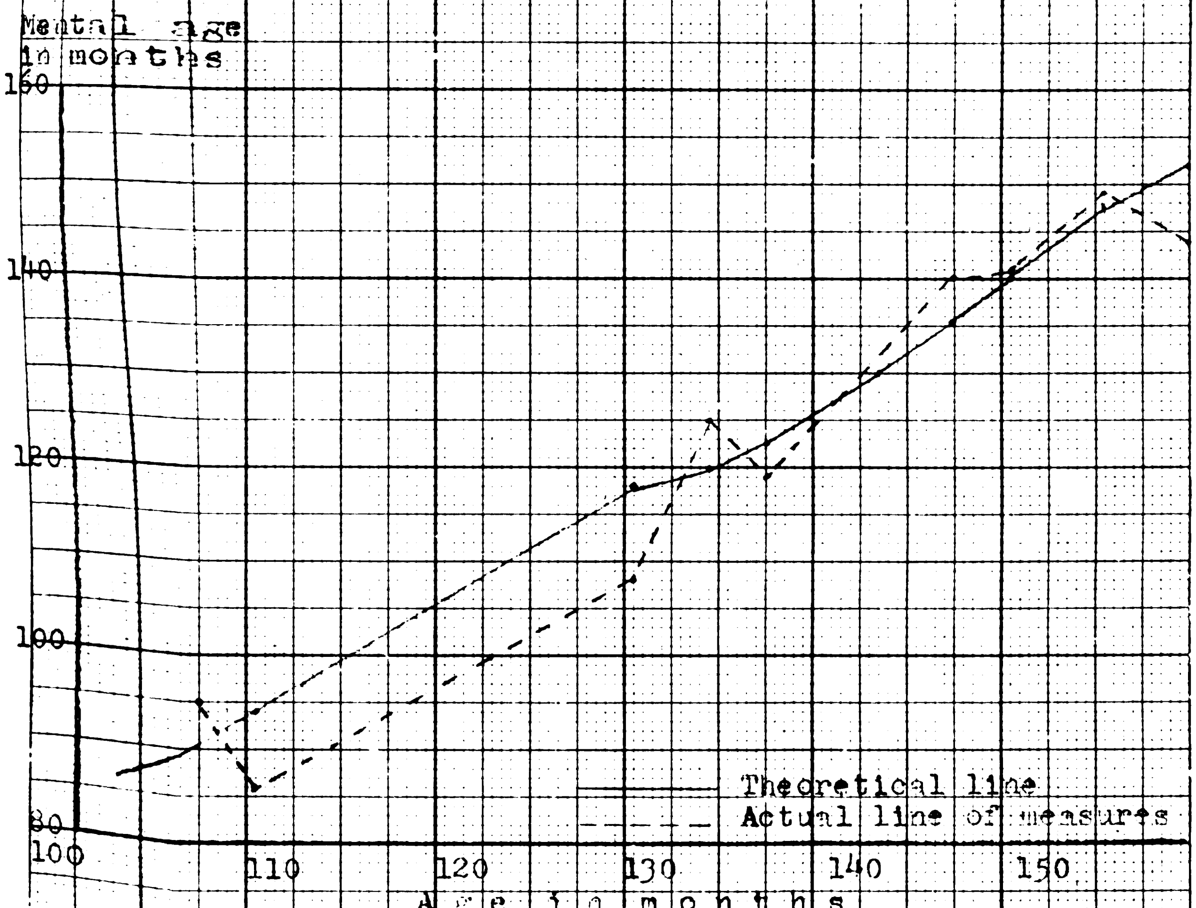

FIGURE 12

LINE OF GROWTH OBTAINED
FROM MULTI-CYCLE EQUATIONS
COMPARED WITH ACTUAL MEASUREMENTS
CASE 23M

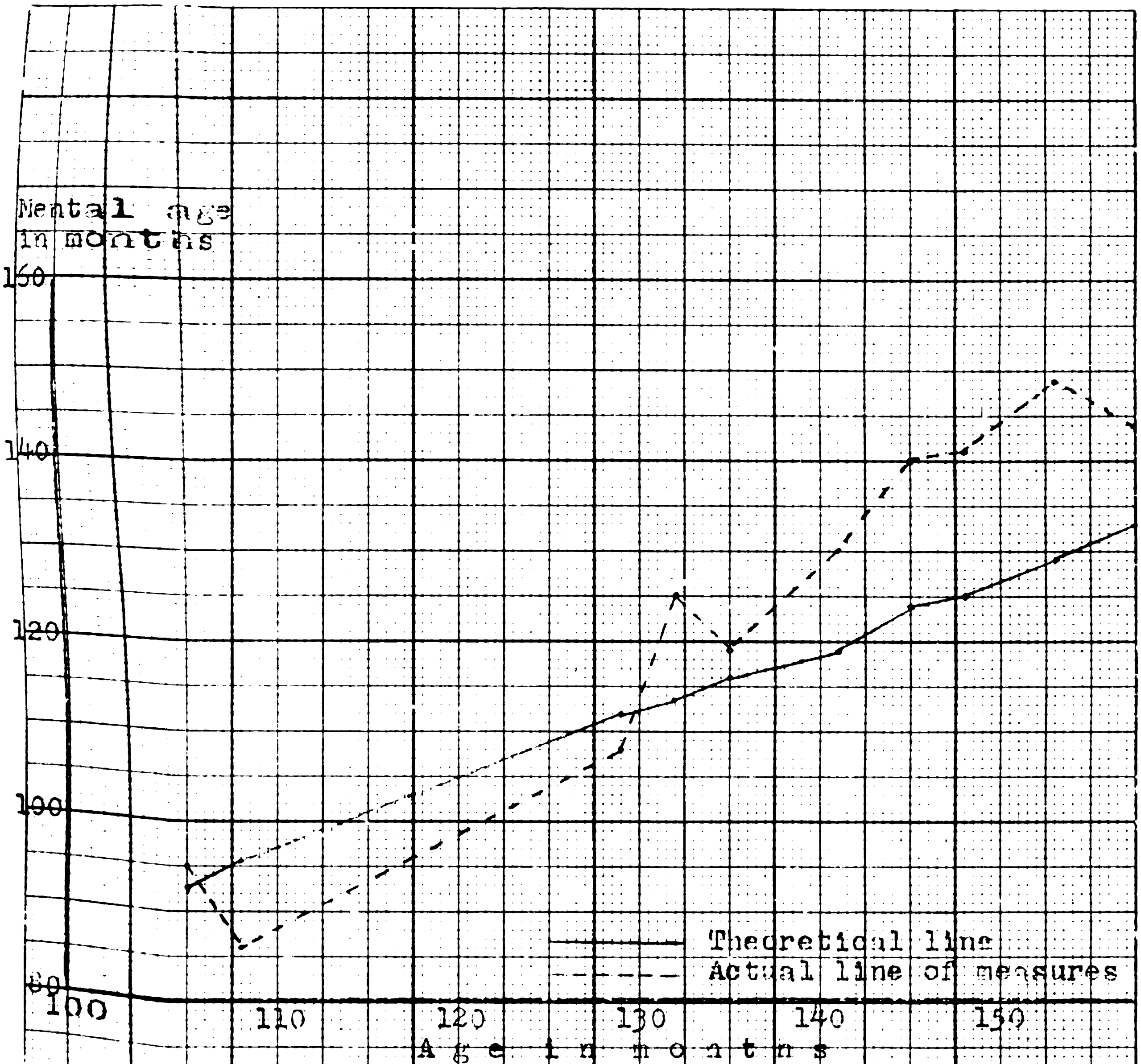

FIGURE 13

LINE OF GROWTH OBTAINED
FROM MEAN PERSONAL CONSTANT
COMPARED WITH ACTUAL MEASUREMENTS
CASE 23M

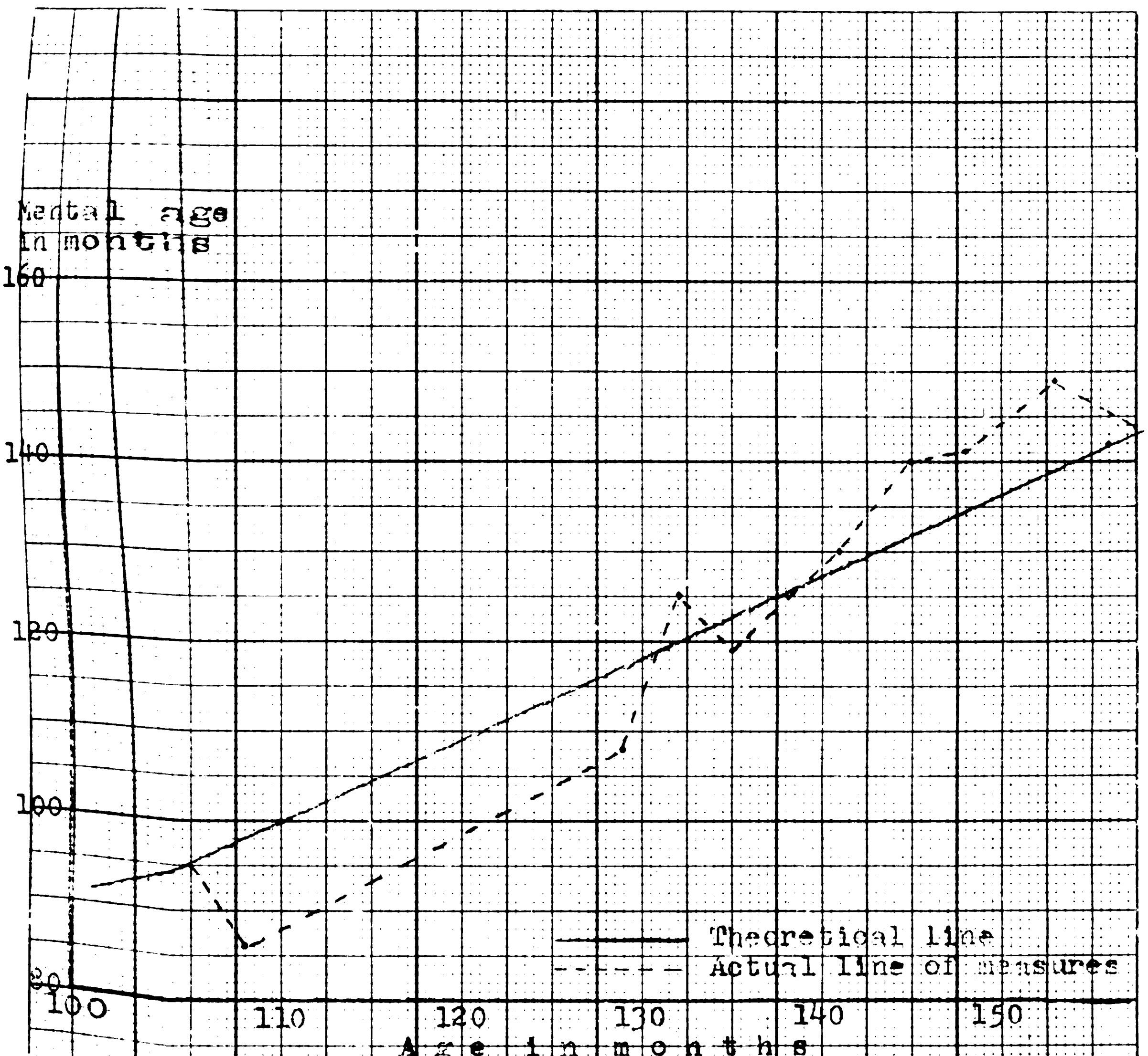

FIGURE 14

LINE OF GROWTH OBTAINED
FROM MEAN INTELLIGENCE QUOTIENT
COMPARED WITH ACTUAL MEASUREMENTS
CASE 23M

would be 358/333, or a P.C. of .9302.

Thus, in the Heinis Personal Constant, if the ratio between mental and chronological age is less than one, and constant, the P.C. will increase with age. If the ratio between mental and chronological age is more than one but remains constant, P.C. will decrease with age.

Although less clear-cut than in 1F, 33M also shows a change in rate from the first to the second cycle. It may be noted that the mean I.Q. for the first five measures of intelligence average 87, while the average of the last five I.Q.'s is 94.

The graph of the line described by the mean I.Q. compared with the actual measures also shows more deviation above the line than below the line, although the difference is much less than on the graph of the Personal Constant. In the procedure of averaging I.Q.'s, as in averaging Personal Constants, scores at an early age may be given a slightly heavier weight, in terms of number of months deviation from the mean line. For example, if an individual had an I.Q. of 90 at six years of age and an I.Q. of 110 at twelve years of age, the mean I.Q. would be 100. However, a graph of the actual measures against the mean line would show an error of seven months below the mean line at six years and fourteen months above the mean line at twelve years. Note that in the example given, the amount of error per unit time is equally divided above and below the mean line.

Case 32F shows rapid mental growth during the first

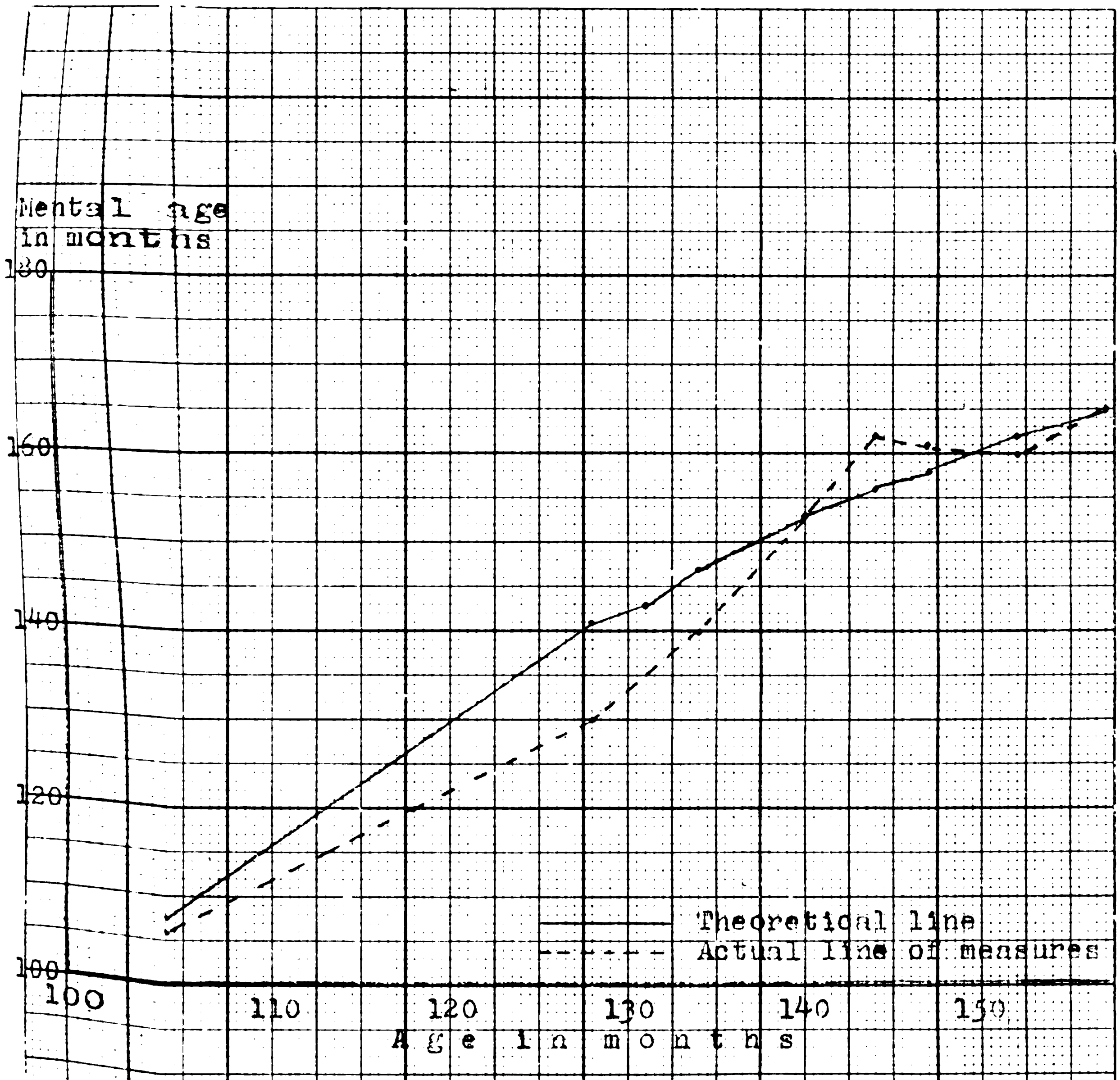

FIGURE 15

LINE OF GROWTH OBTAINED
FROM MULTI-CYCLE EQUATIONS
COMPARED WITH ACTUAL MEASUREMENTS
CASE 32F

cycle, but an early second cycle maximum which the Courtis equation predicts to be low. This case represents a more constant I.Q. than do most of the cases, since on the nine tests administered, the high I.Q. was 113 and the low I.Q. was 102. However, attention should be given to the four mental age scores achieved between 144 months of age and 157 months. These scores were 162 months, 161 months, 160 months, and 165 months. Thus, on four tests covering a period of more than a year, almost no mental gain was shown. The Courtis equation for this case indicates a second cycle maximum of 178 months, which will mean that this individual will show falling I.Q.

Case 50F has two mental age scores which fall below the scores of preceding tests, although the Courtis equation is able to describe the rest of the growth pattern very accurately. The Courtis equation describes the first cycle as relatively slow, with a very rapid second cycle. On both the Heinis equation and the I.Q. equation, the error is balanced almost equally above and below the line. Again, the change in rate is confirmed by the average of the first five I.Q.'s which average 114 compared with the last I.Q.'s which average 122.

The same situation is even more drastically illustrated by Case 163M, a case which shows an extremely rapid second cycle. The I.Q. range for this case is 35 points, and there is also a wide range in the Personal Constants obtained on the different tests. As before, the change in rate is shown

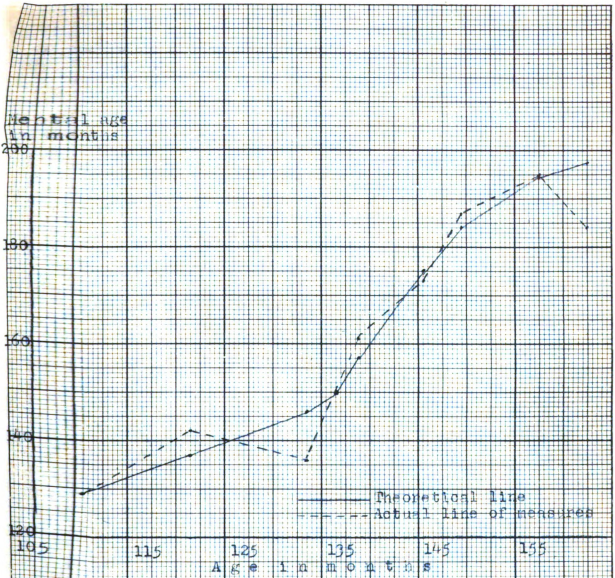

FIGURE 18

LINE OF GROWTH OBTAINED
FROM MULTI-CYCLE EQUATIONS
COMPARED WITH ACTUAL MEASUREMENTS
CASE 50F

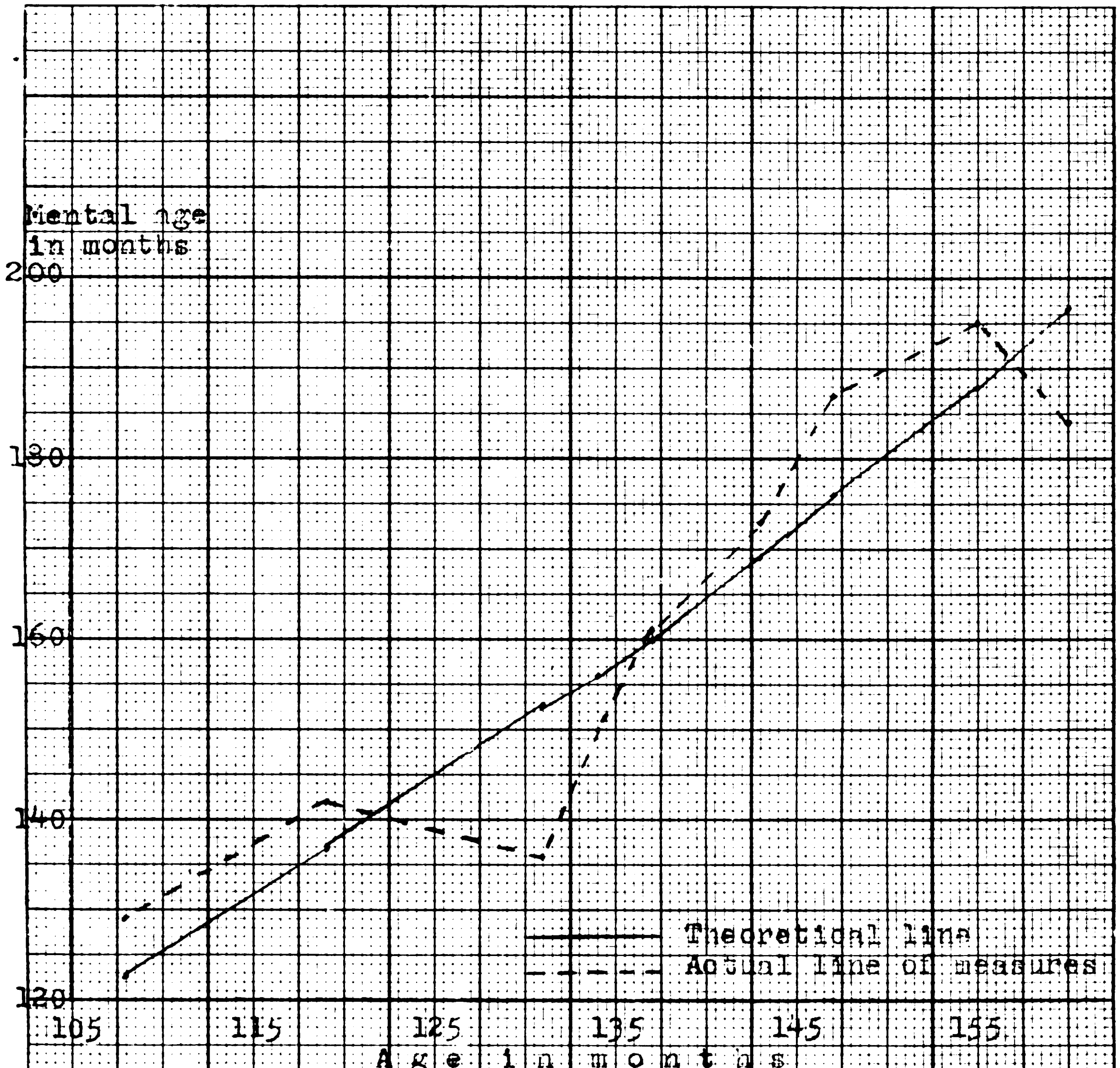

FIGURE 19

LINE OF GROWTH OBTAINED
FROM MEAN PERSONAL CONSTANT
COMPARED WITH ACTUAL MEASUREMENTS
CASE 50F

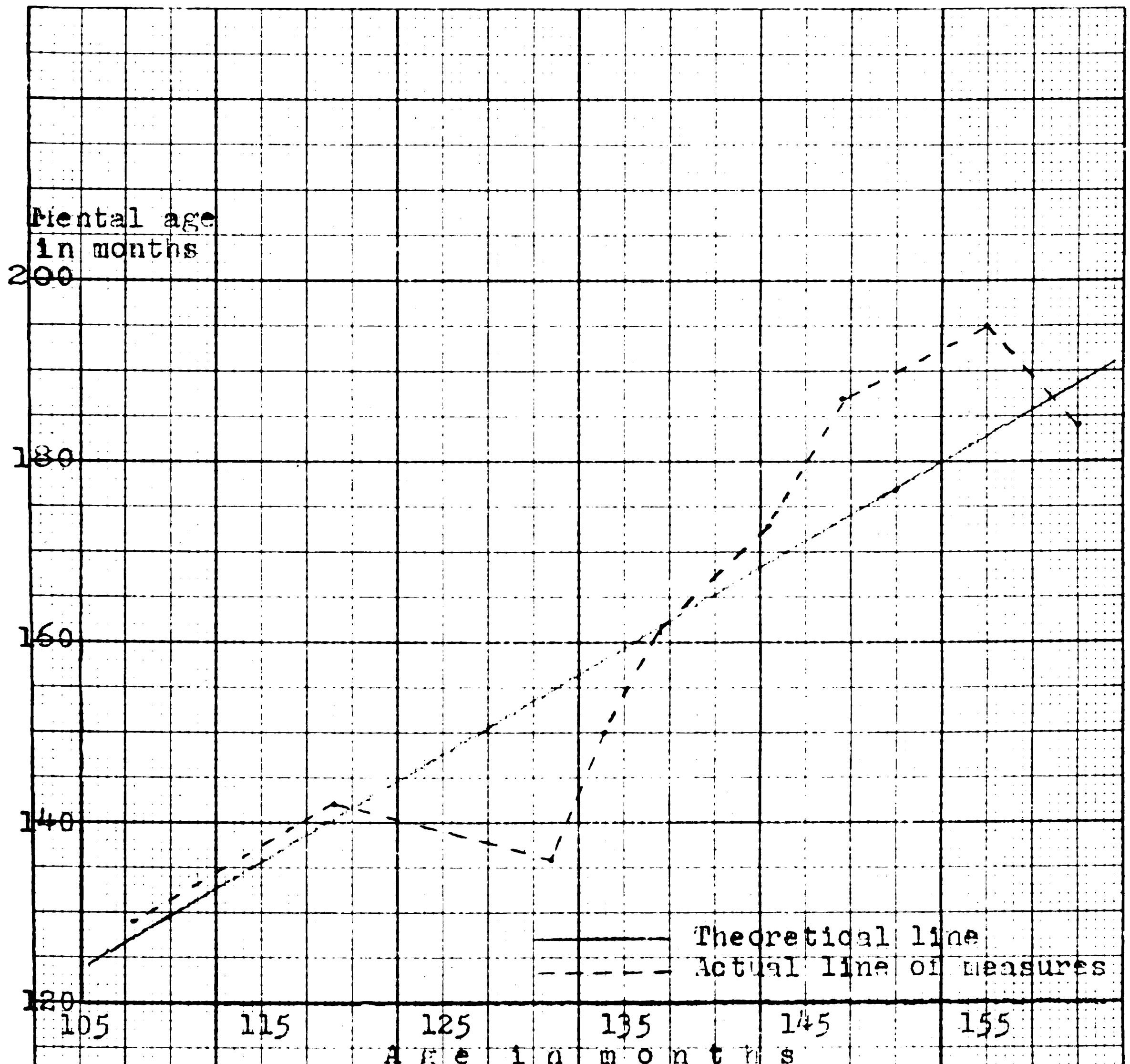

FIGURE 20

LINE OF GROWTH OBTAINED
FROM MEAN INTELLIGENCE QUOTIENT
COMPARED WITH ACTUAL MEASUREMENTS
CASE 50F

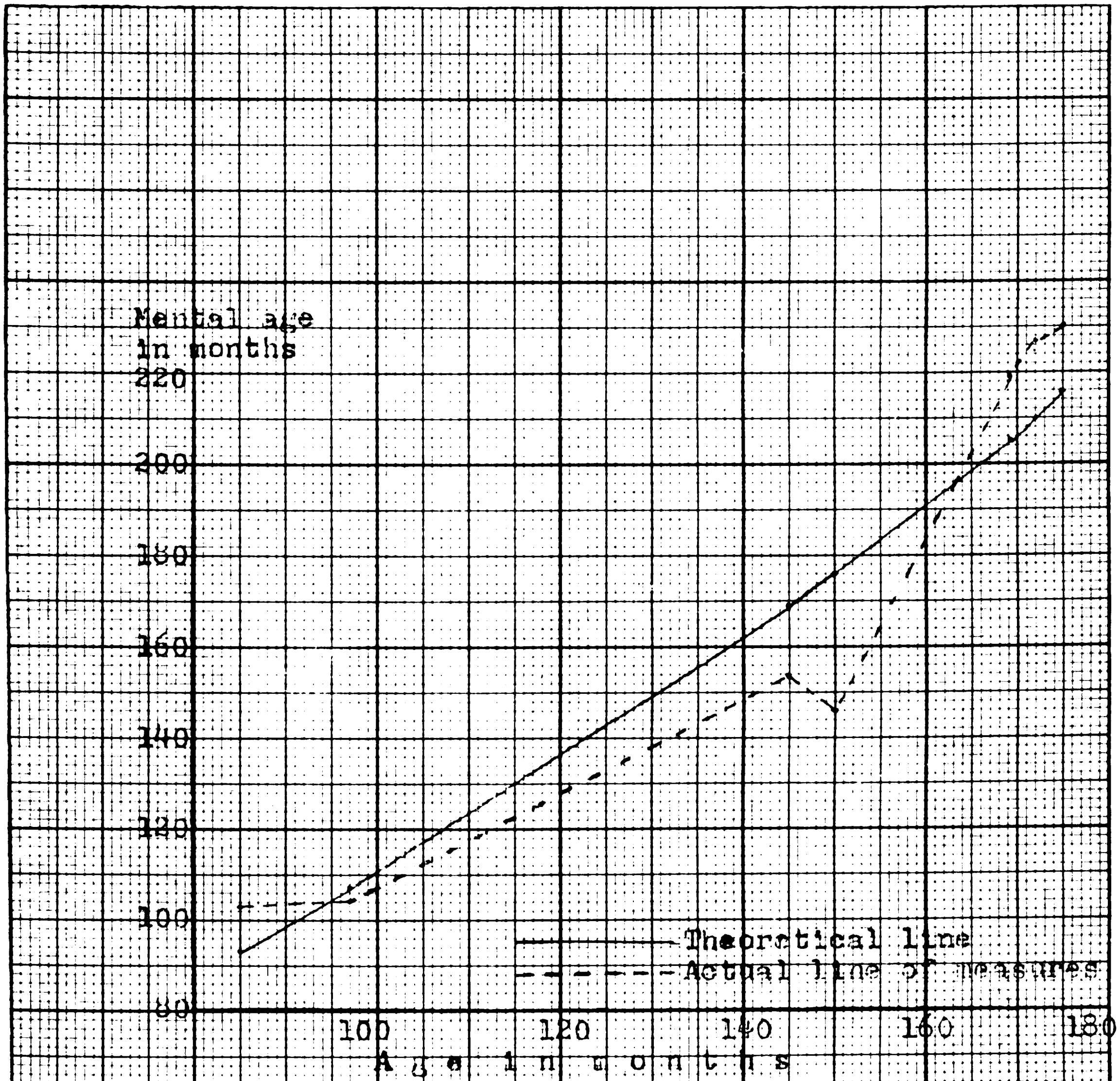

FIGURE 22

LINE OF GROWTH OBTAINED
FROM MEAN PERSONAL CONSTANT
COMPARED WITH ACTUAL MEASUREMENTS
CASE 163M

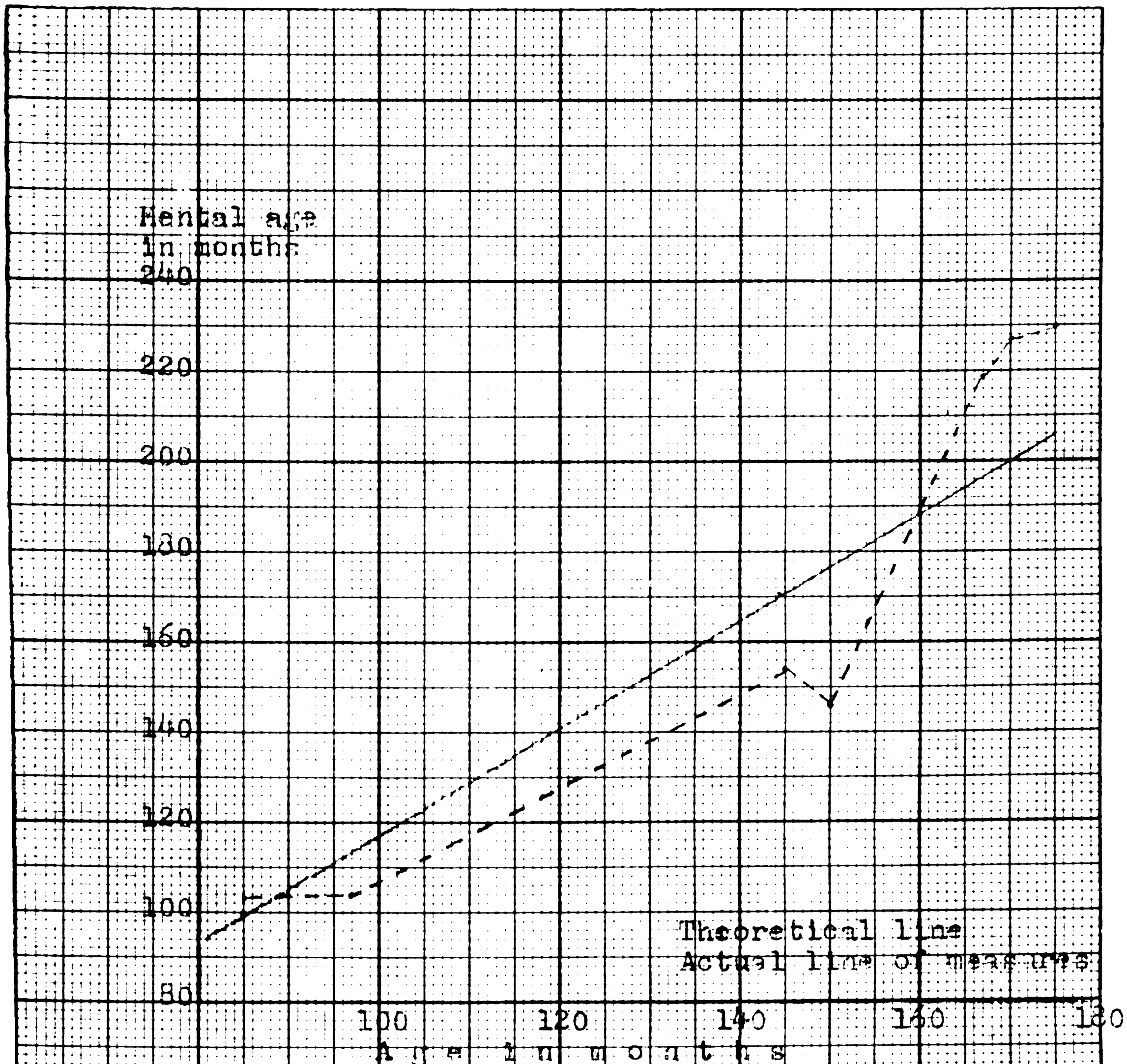

FIGURE 23

LINE OF GROWTH OBTAINED
FROM MEAN INTELLIGENCE QUOTIENT
COMPARED WITH ACTUAL MEASUREMENTS
CASE 163M

by the mean I.Q.'s for the first four tests which average 108, while the average I.Q. for the last three tests jumps to 131.

CHAPTER V

CONCLUSIONS AND IMPLICATIONS FOR FURTHER RESEARCH

I. CONCLUSIONS

Two major conclusions are apparent from the analysis of the data: (1) multi-cycle equations derived by using the Courtis technique were significantly superior to the other two methods of describing mental growth; and, (2) the error derived by using the mean Personal Constant as rate and by using mean I.Q. as rate showed a significant increase at older age levels. The reason for these two outcomes may be found in the fact that multi-cycle equations have a different and more accurate theoretical basis than the theory underlying the Personal Constant or the Intelligence Quotient.

Both the Heinis Personal Constant and the Intelligence Quotient are based on these two assumptions: (1) that there is a line of normal mental growth which can describe the average person from birth to maturity; and, (2) that a given individual's mental growth can be best described by a ratio of his mental growth to the line of average growth.

A multi-cycle concept, on the other hand, implies that an individual's growth cannot be described by any one line or curve from birth to maturity, and that the individual's pattern will change at different growth stages. Since this pattern of change may differ in several ways in terms of a specific individual, then no ratio between a line of averages and a line derived for an individual can truly describe growth.

While the Personal Constant and the Intelligence Quotient consider rate as the only variable in the mental growth of individuals, the multi-cycle theory considers two other parameters of growth. One of these is incipiency or starting point. While the I.Q. and the P.C. assume that growth starts from zero and proceeds at a constant rate, the multi-cycle concept assumes that rate may change in a new cycle and that one factor in plotting this new cycle will be the incipiency. Thus, a child who grows rapidly during the first cycle may have a high starting point when he enters a new cycle. If his rate slows down in the new cycle then he will show a falling I.Q.

Studies of physical growth have shown the possibility of a cycle break about the time that most children enter school. Since most studies based on longitudinal data start after the child is already in school, then the initial score obtained for the child may be based on a different starting point in terms of the growth pattern he will follow for the next few years than zero.

Another factor taken into consideration by the Courtis technique is the maximum to which the individual is growing. Thus, a child with a low rate and a low incipiency may reach a high maximum provided he maintains his rate for a long enough period of time. On the other hand, a child with a high rate, may be going toward a low maximum, which he will reach in a short period of time. By considering the three parameters of the Courtis equation--rate, incipiency, and

maximum, it is frequently possible to explain a falling I.Q. or an increasing I.Q. as a natural function of an individual's growth pattern.

Consideration should be given to the fact that data based on group standardized tests, such as the data which formed the raw material for this study, cannot be expected to be free from errors. For the purpose of this study, the pattern of scores actually obtained from the tests was considered as the true path of mental growth. However, there is no theoretical framework which can assimilate an erratic mental growth pattern--a pattern in which scores achieved at a higher age fall below mental age scores obtained earlier. When such a situation occured, any of the methods used to describe the pattern would show error, although the true error is almost certainly in the data.

Since the Heinis Personal Constant was found in this study to be slightly more accurate than the mean I.Q. in describing mental growth, some of the advantages and disadvantages of this measure may be considered. One of the arguments that Heinis uses in advocating the Personal Constant rather than the I.Q. is based on his opinion that the I.Q. range between individuals is too large. He points out that the height range of a large group of adults selected at random may be only twenty inches, while the I.Q. range for the same group may be eighty or more points. It is true that the Personal Constants of a group of individuals will show a much smaller range numerically than would I.Q.'s derived

from the same tests, but it must be remembered that the range of any series of measurements numerically is a product of the unit of measurement used. Range of adult height, for example, could be more than doubled numerically simply by using centimeters rather than inches as the unit of measure.

The Personal Constant can be considered to be a refinement over the I.Q. in the sense that it actually attempts to describe a curve of mental growth which is assumed to be the pattern which mental growth actually follows. Advocates of a constant I.Q. are not really arguing that mental growth is a straight line process, but rather that an individual will maintain a constant ratio to the mean mental growth of the group, whatever the amount of that growth might be. Thus, there is little argument that an individual actually shows more mental growth in terms of a percentage of his adult capacity between zero and five years of age than he does between the ages of ten and fifteen years. In terms of I.Q., a year's mental growth can be defined as the average increment made from one year to the next by a large number of people of a given age taking the test. The situation is further complicated by the fact that the tasks or test items used at an early age level are not the same tasks or test items used at a later age. If one agrees that an individual makes more real mental growth between the ages of five years and six years than he does between the ages of fifteen years and sixteen years, then the mental age concept from which the I.Q. is derived is really calibrated in different units at different ages. For this reason, Terman, Freeman, and others who argue for the constancy of I.Q., present a single-cycle negatively accelerated curve as the theoretical mental growth curve.

Heinis, through the use of his growth units and the Personal Constant, attempts to present the actual pattern of mental growth. In terms of his units of mental growth, a child from five to six, in order to maintain a ratio of one, would gain 28 mental growth units. To maintain the same ratio from fifteen to sixteen years, he would gain only 6 mental growth units.

The theoretical framework developed by Courtis differs from that of Heinis in that Courtis advocates a different logrithmic curve as best describing growth, and that he advances the multi-cycle concept. The results of this study would indicate that the theoretical framework advanced by Courtis better represents how growth actually takes place.

II. IMPLICATIONS FOR FURTHER RESEARCH

The findings of this study suggest several areas in which further research is indicated. The results help to support the multi-cyclic concept of mental growth in children from the time of school entrance into the adolescent period. There is evidence to suggest that another growth cycle is present in individuals starting around birth and continuing until about the age of six. At present there is little longitudinal data available for this age range which would make is possible to check whether such cycles in mental growth can be found. Research in this area might shed light on problems of when to start children to school, what to expect in first grade, and how to interpret mental test scores of children of this age.

Another factor which should be studied in order to get a clearer picture of the actual pattern of mental growth is the meaning of mental age as it is presently defined at different age levels. Since it is now generally agreed that a year of mental growth means different things at different chronological ages, an attempt should be made to find an instrument or a way of checking in which the measuring scale would remain constant. Since vocabulary has been found to correlate highly with whatever is measured by intelligence tests, perhaps a study of the vocabulary growth curves of a number of individuals would be fruitful. Such a study could hold the task to be performed constant, thus keeping the measuring instrument constant throughout the study.

The whole area of growth inter-relationships needs much additional study. Millard's[1] study of 22 children showed, in general, that children whose growth curves in various areas were coordinated in terms of the timing of the cycles were judged to have better social-emotional adjustment than were children whose patterns of growth showed more divergence. Studies similar to Millard's need to be repeated

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1 C. V. Millard, "A Comparison of Organismic Concordance-Discordance Ratings with Projective Appraisals of Personal Adjustment," Merrill-Palmer Quarterly, Vol. 3, No. 3, pp. 198-210, Spring, 1957.

using larger numbers of children to find what relationships are present between cycles of growth in various areas, and what these differences imply in terms of behavior and education.

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APPENDIX A

I. FIRST AND SECOND CYCLE COURTIS EQUATIONS AND MEAN ERRORS

Case	First Cycle Equation	Second Cycle Equation	Average Error
1F	y = 164(.37411t+3.24)	y = 80(.84571-84.70)	3.5
5M	y = 122(.48667t-8.85)	y = 32(.89818t-111.28)	3.3
11M	y = 145(.71036t-27.59)	y = 45(1.32050-156.09)	5.9
18M	y = 170(.69550t-36.97)	y = 28(1.44588-169.55)	1.7
19F	y = 159(.58794t-17.38)	y = 34(.81875t-77.58)	4.62
19M	y = 155(.66727t-27.30)	y = 19.2(.78000t-77.47)	7.04
20M	y = 180(.53411t-22.54)	y = 58(1.54222t-219.36)	2.8
21F	y = 155(.49259-11.25)	y = 45(.70428-74.68)	4.8
22F	y = 166(.70115-21.63)	y = 60(1.11600-113.65)	6.8
23M	y = 127(.68950-32.52)	y = 33(1.16000t-138.28)	4.86
24F	y = 159(.86083-39.07)	y = 62(1.16123-181.76)	7.2
25F	y = 168(.38032+1.13)	y = 80(.31320t-80.47)	3.0
25M	y = 143.5(.41544-.70)	y = 19(.92923-91.77)	2.8
26M	y = 163(.67166t-34.49)	y = 44(.85250t-105.82)	4.41
27M	y = 166(.39250t-3.80)	y = 50(1.30750-177.39)	2.79
28F	y = 147(.96175-59.50)	y = 61(.63100-58.46)	3.7
28M	y = 157(.53970t-14.90)	y = 42(1.457000-182.57)	2.5
29F	y = 143(.60275t-23.15)	y = 43(.71333t-79.26)	3.61
30M	y = 175(1.46388t-11.96)	y = 27(.90964t-108.30)	4.2
31F	y = 128(.96055-58.04)	y = 46(1.63798-52.12)	4.5
32F	y = 143(.50187t-10.90)	y = 30(.46384t-33.60)	3.18
33F	y = 139(.60083t-32.78)	y = 60(.36909-34.24)	5.4
34M	y = 169(.72774-46.38)	y = 39(1.09181t-142.11)	4.6
35F	y = 153(.70750t-29.78)	y = 46(1.06388-115.53)	2.1

Case	First Cycle Equation	Second Cycle Equation	Average Error
36M	y = 125(.66960-35.21)	y = 45(.93111t-118.15)	3.84
37F	y = 193(.42720t-8.33)	y = 50(1.13450-134.07)	7.61
37M	y = 144(.31152t+5.72)	y = 32(1.05391-117.66)	5.43
38F	y = 150(.72967t-33.13)	y = 85(68320t-69.79)	4.5
40M	y = 150(.31780t+11.30)	y = 80(.41181t-30.16)	6.2
41F	y = 155(.45769t-5.12)	y = 46(1.66714-215.371)	2.57
41M	y = 160(.34100+9.54)	y = 40(.98703-118.25)	4.73
42F	y = 139(.56321t-24.82)	y = 40(.51320t-52.71)	2.86
42M	y = 170(.60522t-31.06)	y = 60(.79809t-96.86)	4.07
43F	y = 155(.42782-9.76)	y = 25(.98952-112.97)	3.2
44M	y = 133(.49650t-19.23)	y = 77(.61920t-75.07)	7.34
45F	y = 142(.29100+14.10)	y = 100(.841070-104.18)	7.9
45M	y = 162(.32266+5.21)	y = 46(1.42200-170.06)	6.41
46M	y = 172(.45406-10.99)	y = 46(.94187-119.81)	5.81
48M	y = 140(.26322t+14.78)	y = 36(1.26043-145.55)	2.06
49M	y = 187(.47926t-12.54)	y = 100(1.26285-167.96)	7.6
50F	y = 150(.49720t-4.93)	y = 51(.36932-72.41)	4.2
50M	y = 152(.32835t+.24)	y = 54(.52757t-51.54)	4.4
51M	y = 169(.26647t+12.41)	y = 110(.64728t-74.87)	5.09
52F	y = 154(.63000t-32.29)	y = 53(.60444t-63.19)	5.2
52M	y = 152(.31160+13.86)	y = 61(1.40733t-160.30)	2.5
53F	y = 110(.42151t-6.66)	y = 60(1.89125t-269.51)	7.87
55F	y = 173(.690t-34.03)	y = 66(1.10240t-139.21)	6.03
55M	y = 145(.65600t-30.44)	y = 61(1.02500t-129.95)	5.23
58F	y = 160(.17383+18.21)	y = 55(.79250t-98.22)	5.61
59F	y = 173(.49068-19.821)	y = 36(1.14090-155.65)	7.41

Case	First Cycle Equation	Second Cycle Equation	Average Error
60M	y = 152(.29728t+9.62)	y = 81(.96652t-128.71)	6.63
61M	y = 144(.28861t+11.791)	y = 69(1.89333-292.17)	4.2
62F	y = 154(.40903+2.24)	y = 53(.95724-115.82)	2.8
63F	y = 185(.40633+1.71)	y = 110(1.24684t-142.10)	12.95
63M	y = 135(.3433t+9.23)	y = 65(.62354t-63.52)	5.32
64F	y = 150(.26000t+17.21)	y = 64(1.40869t-198.09)	3.0
65F	y = 167(.65285-36.36)	y = 35(.81397-136.32)	2.9
68F	y = 160(.33058t+6.32)	y = 60(.98555t-128.67)	5.1-
70F	y = 155(.32075t+9.94)	y = 70(1.96000t-270.90)	4.9
71F	y = 155(.40826+5.20)	y = 32(1.43353t-191.52)	1.5
74F	y = 150(.28285+10.99)	y = 96(.92516-116.29)	3.56
77M	y = 154(.31766+10.53)	y = 75(1.13428t-167.57)	1.0
78F	y = 151(.32258+12.[illegible]9)	y = 70(.78524t-99.19)	3.20
78M	y = 149(.26083+15.78)	y = 120(.86000-101.98)	9.15
80F	y = 140(.30086+12.31)	y = 56(.72916.79.41)	4.55
80M	y = 159(.29977+7.41)	y = 74(1.00166t-135.13)	.97
82F	y = 177(.26220+14.27)	y = 43(1.61066-225.63)	4.50
83M	y = 129(.63680-42.47)	y = 70(1.62950-261.55)	4.2
84F	y = 192(.23342+11.90)	y = 84(1.00789t-137.26)	3.85
87M	y = 162(.23015t+13.52)	y = 98(1.54600-236.30)	9.2
90F	y = 171(.53411t-23.351)	y = 32(1.65923t-230.69)	4.83
103F	y = 130(.56320t-22.42)	y = 45(1.30100t-159.75)	5.95
106F	y = 169(.81291t-57.57)	y = 41(1.35187t-180.02)	4.92
109M	y = 88(.67709t-20.99)	y = 29(.72250t-81.13)	2.9
112F	y = 157(.36185t+2.88)	y = 36(.43038t-23.55)	8.05
130M	y = 165(.43645t-1.83)	y = 41(1.59000-209.26)	7.73

Case	First Cycle Equation	Second Cycle Equation	Average Error
131M	y = 163(.41833t-4.07)	y = 39(.85950t-96.39)	2.40
137F	y = 172(.25903t+10.29)	y = 44(.80409t-97.78)	6.5
137M	y = 157(.30487t+7.15)	y = 68(1.19833t-171.98)	1.4
139M	y = 153(.81320t-6373)	y = 50(1.8766t-298.42)	7.08
145F	y = 143(.22105+17.94)	y = 102(.73676t+79.25)	6.68
146M	y = 140(.60400t-23.93)	y = 52(.65320t-73.65)	3.3-
157F	y = 170(.26800t+8.55)	y = 65(1.29800t-205.49)	4.21
161F	y = 222(.34533t+4.92)	y = 45(1.93812t-263.97)	5.48
163M	y = 166(.27448t+12.59)	y = 85(1.14615t-151.91)	5.0
165F	y = 158(.23296+15.02)	y = 41(1.29222t-180.09)	6.59
170F	y = 149(.55416-23.56)	y = 42(.72120-80.76)	2.4
171M	y = 162(.22546t+16.88)	y = 30(.90937t-119.86)	4.96
175M	y = 150(.74750t-59.10)	y = 39(1.72666-259.74)	[illegible].27
177F	y = 132(.30256+4.80)	y = 80(1.25000t-182.17)	15.1
180M	y = 126(.38451t-6.63)	y = 47(1.03150t-158.39)	2.83
183M	y = 142(1.05666t-97.51)	y = 33(.90600t-113.67)	3.78
184F	y = 130(.33434t+10.58)	y = 65(.56437t-59.88)	3.3
185M	y = 156(.74758t-46.40)	y = 83(.66961t-78.37)	3.18
190F	y = 158(.28945t+11.08)	y = 48(1.57272t-219.17)	3.80
193M	y = 167(.85291t-62.89)	y = 30(1.62455t-213.89)	3.13
205F	y = 161(.44667t-12.94)	y = 52(.82718t-100.83)	4.88
207F	y = 160(.45695t-8.18)	y = 91(1.41388t-200.93)	7.49
208M	y = 155(.62468t-27.51)	y = 29(.99695t-126.29)	3.5
210F	y = 167(.22100t+14.32)	y = 49(.78074-90.04)	3.49

II. HIGH AND LOW HEINIS PERSONAL CONSTANTS, RANGE, MEAN PERSONAL CONSTANT, AND ERROR

Case	High	Low	Range	Mean	Error
1F	1.0989	1.0648	.0341	1.0824	6.06
5M	.9408	.9117	.0291	.9382	2.44
11M	1.0558	1.0141	.0417	1.0361	3.81
18M	1.0857	1.0451	.0406	1.0577	3.56
19F	1.0795	1.0388	.0407	1.0655	3.45
19M	1.080	1.012	.068	1.043	5.63
20M	1.0614	1.000	.0614	1.0392	6.00
21F	1.0607	.9883	.0724	1.0299	4.00
22F	1.181	1.113	.068	1.135	6.44
23M	.9917	.8868	.1049	.9403	10.45
24F	1.154	1.100	.054	1.116	5.1
25F	1.0997	1.0597	.0400	1.0812	6.90
25M	1.0284	.9972	.0312	1.0094	2.88
26M	1.0398	1.0079	.0319	1.0273	3.50
27M	1.0498	1.0111	.0387	1.0300	8.17
28F	1.111	1.040	.071	1.0668	4.5
28M	1.0630	1.0199	.0431	1.0461	5.78
29F	1.0165	.9888	.0277	1.0084	3.25
30M	1.0545	1.0118	.0427	1.0403	3.40
31F	1.028	.932	.096	.9921	9.0
32F	1.0391	1.0058	.0333	1.0240	4.17
33F	1.003	.941	.062	.965	5.89
34M	1.0489	.9938	.0551	1.0310	5.05
35F	1.0732	1.0560	.0172	1.0671	2.31
36M	.9736	.8975	.0761	.9438	3.57

Case	High	Low	Range	Mean	Error
37F	1.1299	1.0716	.0583	1.0950	10.85
37M	1.0197	.9567	.0630	.9918	6.50
39F	1.083	1.029	.0054	1.0633	5.2
40M	1.065	1.000	.065	1.036	6.57
41F	1.0602	1.0197	.0405	1.0441	6.70
41M	1.0933	1.0187	.0746	1.0453	7.17
42F	.9946	.9495	.0451	.9693	3.8
42M	1.0669	.9940	.0729	1.0371	6.05
43F	1.0163	.9835	.0328	1.0011	4.83
44M	1.0654	1.0317	.0337	1.0449	8.33
45F	1.1060	1.0578	.0482	1.0824	6.83
45M	1.0563	.9970	.0593	1.0287	9.63
46M	1.0736	1.0147	.0589	1.0429	5.78
48M	1.0191	.9653	.0538	.9955	5.38
49M	1.1345	1.0478	.0867	1.0808	13.17
50F	1.0786	1.0144	.0642	1.0567	7.78
50M	1.0156	.5670	.4486	.9227	34.59
51M	1.0797	1.0000	.0797	1.0494	8.50
52F	1.0517	.9542	.0975	1.0171	14.63
52M	1.0965	1.0000	.0965	1.0804	5.41
53F	1.0781	.9660	.1121	1.0311	14.27
55F	1.0843	1.0524	.0319	1.0703	6.65
55M	1.0372	.9891	.0481	1.0138	6.01
58F	1.0053	.9093	.0960	.9742	8.30
59F	1.0369	.9675	.0694	1.0059	10.23
60F	1.0392	.9706	.0686	1.0017	10.23

Case	High	Low	Range	Mean	Error
61M	1.0263	.9435	.0828	.9917	11.15
62F	1.0517	.8613	.1904	1.0124	13.05
63F	1.1774	1.1094	.0680	1.1141	20.05
63M	1.0940	.9658	.0282	1.0152	7.63
64F	1.0926	1.0054	.0372	1.0269	7.44
65F	1.0477	1.0000	.0477	1.0248	5.22
70F	1.0660	.9917	.0743	1.0400	6.64
71F	1.1296	1.0027	.1269	1.0484	15.94
71M	1.0546	.9597	.0949	1.0177	10.1
77M	1.1438	.9757	.1681	1.0272	10.56
78F	1.1180	1.0026	.1154	1.0280	8.35
78M	1.0815	1.0189	.0626	1.0595	13.31
80F	1.0183	.9738	.0445	1.0006	6.61
80M	1.0343	.9762	.0581	1.0060	7.92
82F	1.1440	1.0189	.1251	1.0557	9.31
83M	.9847	.8989	.0858	.9471	12.39
84F	1.0631	.9783	.0848	1.0358	3.75
87M	1.0369	1.0000	.0369	1.0487	12.93
90F	1.0402	.9939	.0463	1.0250	4.95
103F	1.0108	.9191	.0917	.9762	5.65
106F	1.0532	.9891	.0641	1.0339	10.56
109M	.8659	.8017	.0642	.8331	3.13
112F	1.0268	.9696	.0572	1.0068	6.25
130M	1.1301	1.0139	.1162	1.0720	11.44
131M	1.0514	1.0349	.0165	1.0425	2.00
137F	1.0575	1.0086	.0489	1.0225	6.67

Case	High	Low	Range	Mean	Error
137M	1.0238	.9703	.0535	1.0002	11.17
139M	1.0105	.9426	.0679	.9834	7.83
145F	1.0775	1.000	.0775	1.0435	8.90
146M	1.0213	.9605	.0608	.9885	6.59
157F	1.0257	.9759	.0498	1.0046	7.64
161F	1.1738	1.0896	.0842	1.1153	13.13
163M	1.066	.992	.074	1.049	14.50
165F	1.0268	.9696	.0572	1.0067	6.38
170F	1.0166	.9667	.0499	1.0007	4.67
171M	1.0793	.9836	.0957	1.0251	9.06
176M	1.0350	.9512	.0838	.9994	12.00
177F	1.0916	1.0111	.0805	1.0349	15.92
180M	.9589	.8873	.0716	.9290	15.92
183M	1.0079	.9488	.0591	.9828	6.80
184F	1.0272	.9727	.0545	.9931	5.57
185M	1.0611	1.0197	.0414	1.0384	6.60
190F	1.0236	.9753	.0483	1.0095	5.36
193M	1.0524	1.0176	.0348	1.0416	3.0
205F	1.0377	.9972	.0405	1.0183	7.14
207F	1.0821	.9972	.0849	1.0429	14.03
208M	1.0358	.9861	.0497	1.0116	4.43
210F	1.0246	.8104	.2142	.9662	12.21
217F	1.0374	.9802	.0572	1.0141	8.44

III. HIGH AND LOW INTELLIGENCE QUOTIENTS, RANGE, MEAN, AND ERROR

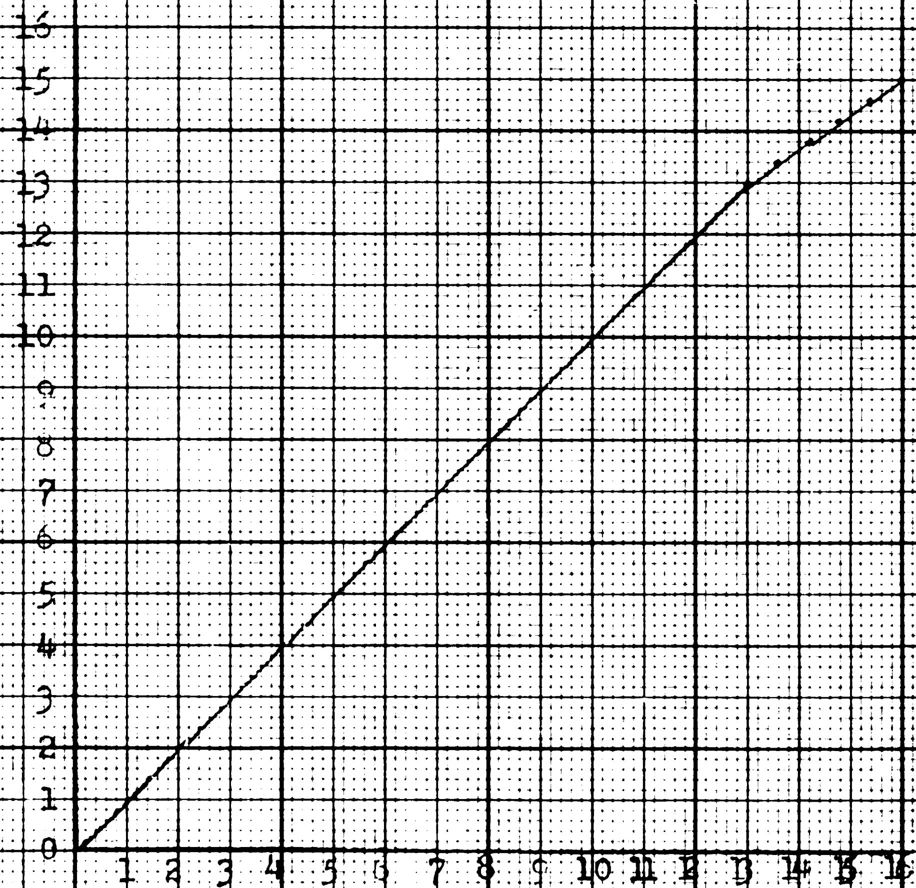
Case	High	Low	Range	Mean	Error
1F	143	116	27	126	10.75
5M	90	81	9	85	2.75
11M	118	102	16	110	4.63
18M	123	110	13	117	5.68
19F	126	110	16	119	5.7
19M	123	103	20	111	5.75
20M	126	100	26	113	7.00
21F	113	97	16	109	4.00
22F	147	130	17	140	4.73
23M	97	80	17	91	5.71
24F	145	126	19	136	7.00
25F	143	116	27	126	10.79
25M	107	99	3	102	2.90
26M	112	103	9	108.4	3.42
27M	123	103	20	111	9.50
28F	122	111	11	118	4.6
28M	122	105	17	114	6.05
29F	106	97	9	101.2	3.56
30M	116	101	15	110.9	5.33
32F	113	102	11	107	4.5
33F	101	87	14	91	5.33
34M	113	93	20	110	5.32
35F	125	114	11	119	4.23
36M	92	80	12	86.6	3.53
37F	156	119	35	137.3	12.90

Case	High	Low	Range	Mean	Error
37M	105	91	14	98.4	6.44
38F	131	108	23	120	7.3
40M	126	100	26	111	8.00
41F	122	105	17	113.1	6.45
41M	117	107	10	112.8	4.87
42F	98	89	9	91.8	3.16
42M	123	99	24	112.4	7.92
43F	105	95	10	100.5	4.50
44M	142	108	34	120.1	12.01
45F	138	117	21	129.6	6.73
45M	126	99	27	110.3	11.42
46M	123	104	19	114.8	6.65
48M	106.6	91.7	14.9	99.6	5.02
49M	151	114	37	129.4	15.35
50F	127	104	23	117.8	7.27
50M	104	45	59	90.1	17.56
51M	139	100	39	120.6	11.20
52F	119	91	28	108.3	6.83
52M	137	111	26	125.1	10.45
53F	135.6	93	42.6	111.2	15.40
55F	139	117	22	125.2	9.27
55M	114	97	17	104.3	6.85
58F	102	82	20	93.7	7.09
59F	120	93	27	105	9.5
60M	118	93	25	100.9	8.8
61M	113	84.5	18.5	100.5	11.54

Case	High	Low	Range	Mean	Error
62F	119	80	39	108.8	8.91
63F	180	134	46	155.8	13.96
63M	120	91	29	104.6	7.4
64F	119	102	17	108	7.5
65F	115	100	15	108	4.67
68F	116	101	15	107	8.7
70F	119	97	22	110.4	7.13
71F	128	100	28	111	9.5
74F	128	85	43	109.6	16.13
77M	114	93	21	104.3	9.97
78F	125	102	23	103.4	7.70
78M	146	106	40	122.2	19.94
80F	108	94	14	101	6.61
80M	113	96	17	103.5	8.35
82F	126	107	19	116.2	7.36
83M	95	77	18	85.7	11.05
84F	131	96	35	113.3	9.3
87M	140	100	40	119	15.0
90F	116	98	18	108	5.02
103F	104	83	21	95	7.40
106F	122	97	25	115	11
109M	73	59	14	66	4.88
112F	109	96	13	102.1	6.2
130M	124	104	20	113	13.25
131M	116	108	8	113	2.65
137F	132	101	31	109	8.2

Case	High	Low	Range	Mean	Error
137M	112	91	21	101.5	10.39
139M	104	81	23	94.3	7.67
145F	136	100	36	117.7	10.70
146M	108	91	17	97	6.25
157F	112	93	19	102.2	7.71
161F	159	125	34	146	12.25
163M	132	97	35	118.1	18.17
165F	109	92	17	102.1	6.0
170F	105	93	12	101	4.83
171M	119	95	24	108.8	10.38
176M	114	88	26	101	12
177F	137	101	36	112	17.1
180M	87	74	13	80.6	7.88
183M	102	88	14	94.6	6.60
184F	105	92	13	97.3	5.9
185M	127	105	22	115.1	8.80
190F	110	93	17	103.6	6.00
193M	118	105	13	114	3.9
205F	114	97	17	106.8	8.64
207F	128	99	29	115.3	14.50
208M	109	96	13	103.8	4.4
210F	109	73	36	97.3	12.31
217F	115	95	20	105.6	9.75

APPENDIX B



GROWTH CURVE
USING CORRECTION FORMULA
FOR REVISED STANFORD-BINET[1]

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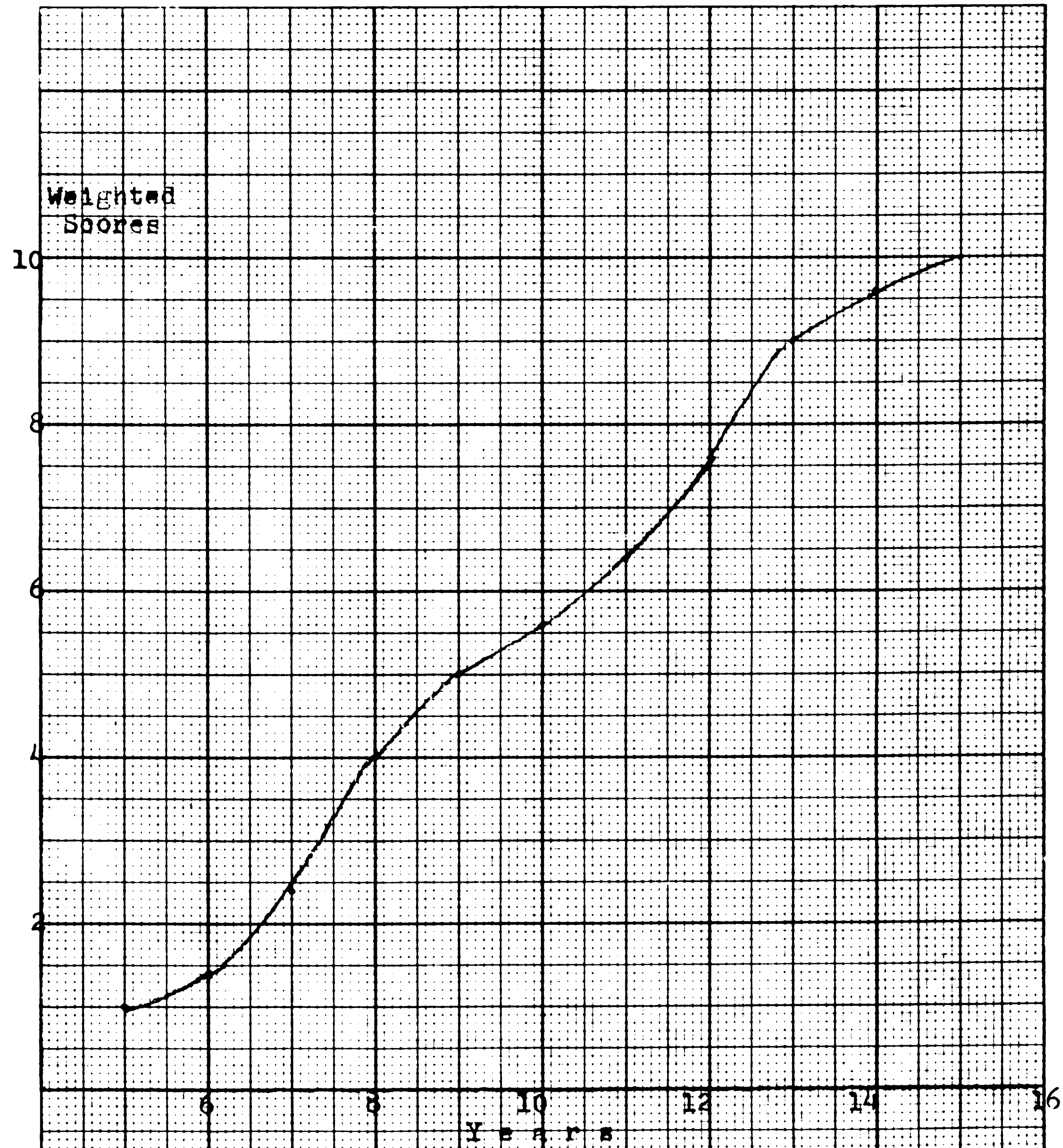
[1] Terman, Lewis and Maud Merrill, *Measuring Intelligence* (Boston: Houghton Mifflin Company, 1937), p. 31.



VOCABULARY GROWTH CURVE
(SAME SHAPE AS MOST INTELLECTUAL ABILITIES)[2]

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[2] Wechsler, David, "Intellectual Development and Psychological Maturity," *Child Development Monographs*, Vol. 21, No. 1 (March, 1950) pp. 45-50.

HEINIS MENTAL GROWTH CURVE[3]

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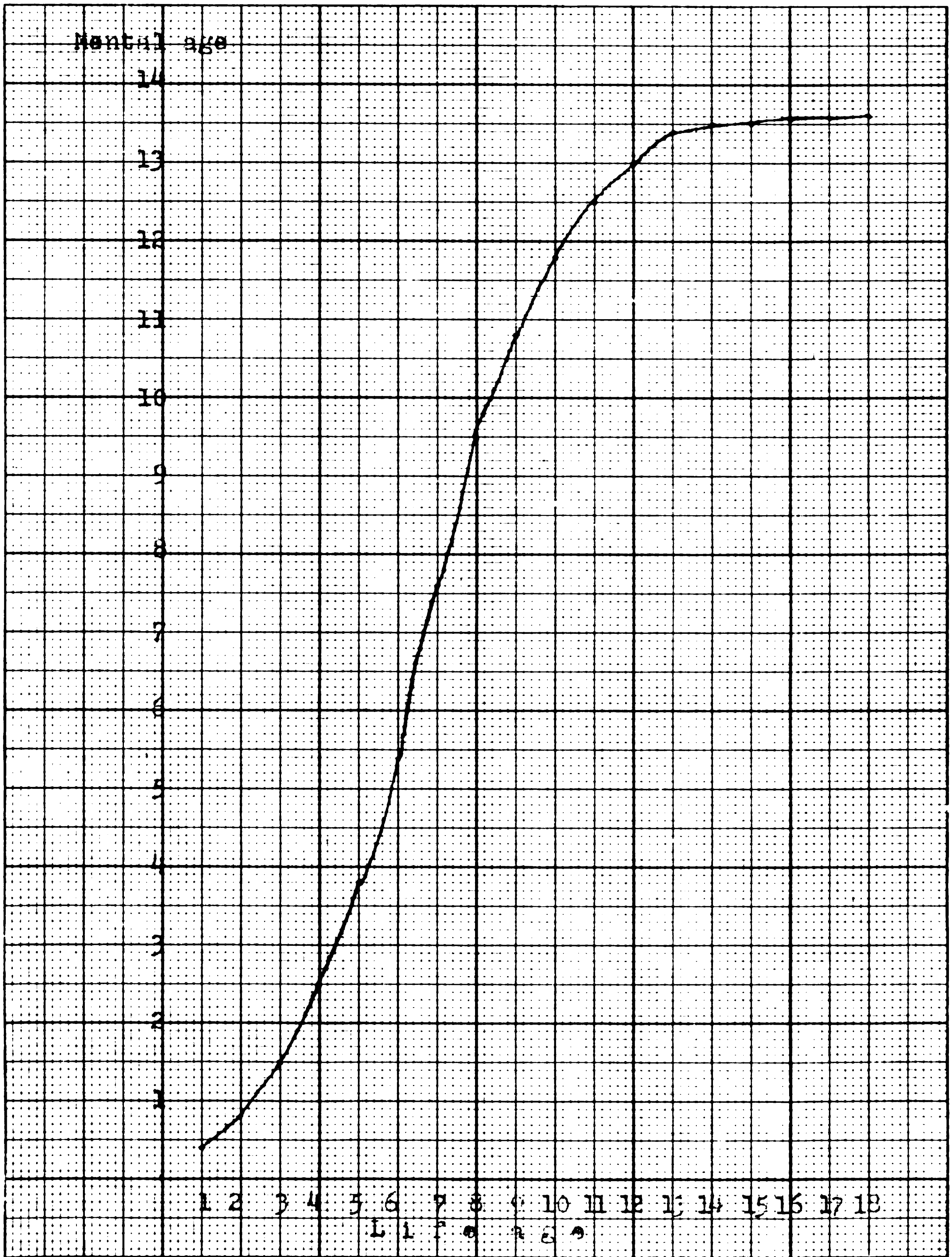
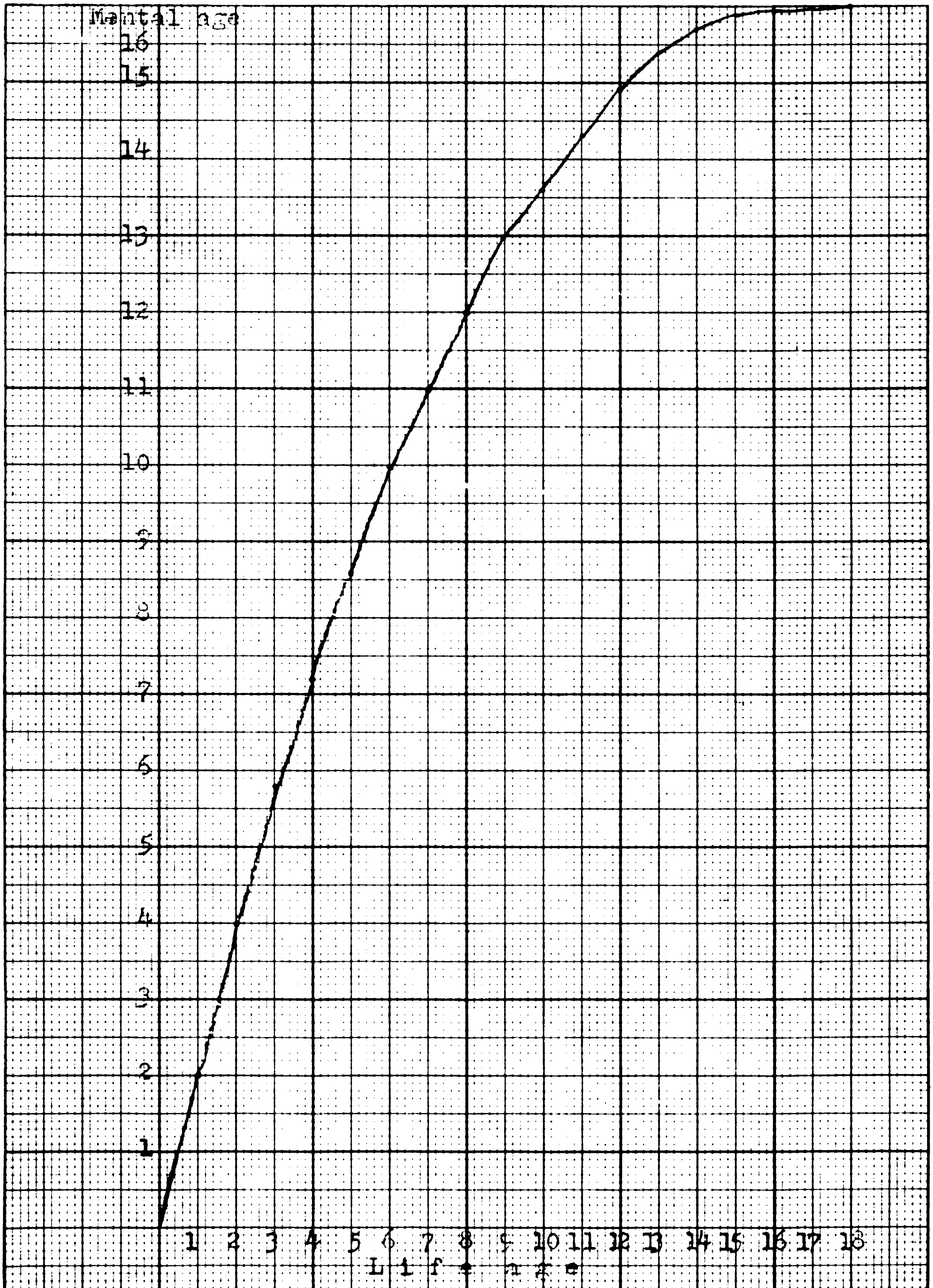
[3]Kuhlmann, Frank, *Tests of Mental Development* (Minneapolis: Educational Publishers, Inc., 1917).

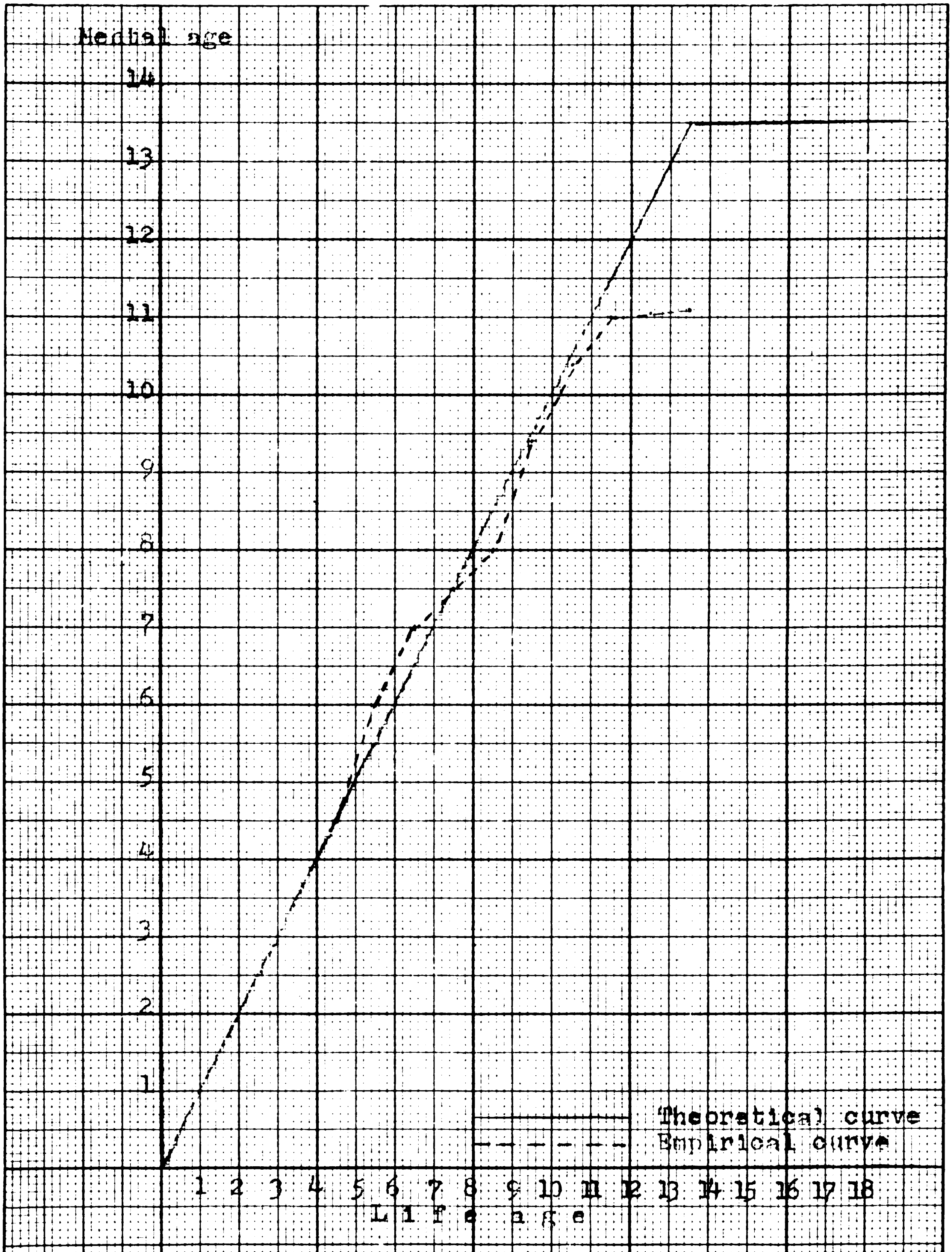


DOLL'S CONCEPT OF MENTAL GROWTH[1]

[1]Edgar Doll, "The Growth of Intelligence," *Psychological Monographs*, Vol. 29, No. 2 (1920) pp. 9 - 10.



TRADITIONAL THEORETICAL GROWTH CURVE
OF AVERAGE NORMAL INTELLIGENCE



MEDIAN MENTAL AGE GROWTH
BY THE GODDARD-BINET SCALE