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The process of learning as shown by the mirror-drawing experiment

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PROCESS OF LEARNING AS SHOWN BY THE MIRROR DRAWING EXPERIMENT

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BY

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Figure 1. Photograph of a boy using the mirror-drawing apparatus.

CHAPTER I

INTRODUCTION

What are we to understand by "learning", the process of which we are to study in this work? Nearly every text on psychology has its own peculiar definition of learning, dependent upon the psychological school to which the author belongs, and the type of learning which he has in mind. Professor Troland (30) says: "The conception of learning which predominates both in common sense discussion and in psychological research is that of the process by which particular kinds of motor reaction become connected with specific stimuli.....we assume in the beginning that there is an hereditary connection between a certain stimulus and a particular reaction. A purely afferent process can lay down a patterned record in the cerebral cortex which simultaneously involves or includes certain other stimulus factors. The pattern which is thus formed makes it possible for the new afferent or sensory component to set off the efferent reaction because it has become associated with an afferent element which already has this specific motor connection..... The simplest kind of learning would seem to consist in the mere recording of such patterned impressions upon the cortex. Such learning does not involve the formation of habits, and, in itself, cannot be detected by purely behavioristic obser-

vations.....Another aspect of learning which is emphasized in popular thought seems to be the acquisition of skill. Cert in kinds of skill very obviously involve the evolution of a close coordination between sensory and motor factors."

Watson stresses the importance of kinaesthetic impressions in learning, and in such case, it is not an exclusive motor acquisition.

Learning may take place either by practice, by imitation, or by some form of instruction or reasoning. Motor control is accomplished primarily by practice, commonly known as the "trial and error" method. This consists of the making of random attempts until, by chance, some of them are successful. These trials, may and usually are, supplemented by some attempts at reasoning.

In the beginning of the mirror-drawing test, the conditions prohibit imitation, and there is little opportunity for reasoning; improvement is due apparently to a process of trial and error. Although random movements seem to predominate at first, such a term appears inadequate to describe the complete learning process.

Statement of the Problem:

This study attempts to analyze the learning curve of the mirror-drawing test. Special attention is paid to a comparison of skill in mirror-drawing, and that in type-

writing and drawing, both motor abilities. It also attempts to discover any practical use to which mirror-drawing may be put, especially with reference to its possible use as an aptitude test.

History of the Problem:

Ages old and bred in us is the idea that certain tendencies peculiar to a few dominate many. The world was forced to accept as true, for example, that men are cleverer at mathematics than women, or that a skull of a certain shape proclaims the musician. After centuries of passive acceptance of these traditions, a scientific study into affairs of this nature began only comparatively recently--not more than seventy-five years ago. These investigations fall within the realm of experimental psychology and had their beginnings in the universities of Europe. A favorite theme was the process of learning, often demonstrated by the mirror-drawing experiment. More than with any other group this particular experiment seems to have been popular with the French. Interest was thriving from 1890 well into the new century, with the result that we have row after row of French books on this subject on our library shelves. In Germany, Dr. Lochte made the most exhaustive study of any one investigator. He examined 2804 school children and classified the results. In our country, the work of Miss June Downey, the character analyst, has been the most elaborate. Starch, Judd,

and Whipple have each included the mirror-drawing test in his manual. Dearborn devised the star which later, somewhat enlarged by Starch, became the almost-classic tracing pattern. No class of people has escaped experimentation--neither college men nor reformatory girls, epileptic boys nor scrub women. The subjects have practiced with their right hands and with their left hands, and even with their feet; they have made from one single copy to over two hundred, being timed for speed and accuracy. Vassar College, the Home for Epileptics at Vineland, New Jersey, and the Bedford Reformatory for Women, each in turn has been included in type of institution which has offered itself for the benefit of posterity.

To quote from Whipple (33) in regard to the delinquents: "Comparative study of the star-test in five successive trials with college girls, maids in college dormitories, and girls at Bedford Hills, N. Y., Reformatory conducted by Miss Jean Weidensall, reveals a number of interesting results....." I have selected data referring primarily to the time records only. The table shows that there exists a good correspondence between both the time and errors for the star-test and the classification made by the institution into three groups depending on outlook for reformation. The differences are more striking in the first than in the fifth tracing.

TABLE I

Scores in the Star Test for Three Groups of Bedford Reformatory Women

(Weidensall)

Institutional classification	FIRST STAR		FIFTH STAR	
	Time	Errors	Time	Errors
Most capable and promising	320	117.7	105	36
Women unable to take care of themselves in society	562	211	123	45
Backward and mentally feeble	610	264	127	55

In addition to these quantitative results, the star test proved to possess a value in a perhaps unexpected direction, viz.: as a device for sorting out "S"'s of the unstable and less tractable type.

On this point Dr. Heidensall writes: 'This test isolates better than any we have tried at Bedford those who are incapable of sustained effort under difficulties. It isolated, of course, the low-grade feeble-minded, for, no matter how hard they try, they do not succeed in tracing a star. The epileptics have a characteristically bad time and their stars are all knotted up with blind spots where they were caught and held indefinitely. Chiefly, however, is the test of interest in the case of those who are bright enough to trace the star well, but too unstable to do so. These are invariably the girls who are difficult to manage in the institution. The tracing goes well enough until suddenly the pencil at some hard point starts off in the wrong direction. The subject then tugs and pulls, grows more and more irritated, disturbed and excited, makes big black circles and finally throws down the pencil and gives up. When calmed, praised and urged to try again, she will continue and usually in the end draw a fairly good fifth star. This behavior in tracing the star is typical of their behavior in the institution when the pressure of discipline or responsibility becomes the least bit too exacting.'"

Whipple himself concentrated his attention upon the pattern to be traced. As well as enlarging the star devised by Dearborn, printing it in red ink, and tipping it somewhat away from the vertical position, in order to avoid the too easily drawn vertical lines, he experimented with still another modification, viz: the use of double concentric stars in the hope that this pattern would restrict the extent of permissible variation from the printed outline. No published results as to the differences in the conclusion which he drew from this modification can be found.

Miss Calfee's (33) tests of Texas freshmen included three tests previously used by Burt, viz.: card dealing, card sorting, and alphabet sorting. Correlations found by Burt between mirror-drawing and these three tests when applied to school children were .40, .34, and .29, respectively: those by Miss Calfee for school children were only .11, 126, and .06, for freshmen men .19, .11, and .22, and for freshmen women .37, .20, and .29 respectively. Save then, for the last mentioned correlation her figures are invariably lower than those of Burt. Other 'corrected' correlations reported by Burt for mirror-drawing (average correlations for various groups) are: tapping .74, dotting apparatus .92, spot-pattern test .75, immediate memory .38, discrimination of lifted weights .30. Off hand, one would not expect to find that factors which enter into the discrimination of pitch

would be the same as those which contribute to successful mirror-drawing. There appears to be no evident reason why some of the correlations should be so high.

She summarizes her findings as follows: (33)

"1. The analysis of the mirror-test presents distinctive learning types. Some subjects gain control of the situation by a fairly regular procedure, others temporarily lose control at some point in the series. The fourth or fifth trial in a series of six tests in the mirror drawing.

2. This examination further indicates that, where the time of each individual series is referred to the total time curve, fast, slow, and irregular, are fairly fundamental distinctions.

3. Finally, an accurate knowledge of the learning process, must, in the last analysis, be based on individual and small group curves."

In regard to sex differences, she writes: "with one exception where two places of difficulty occur for the girls, their records are always lower than the corresponding trials in the boys' records. Notwithstanding this superiority in absolute speed, they give the same variation as the boys from trial to trial."

Burt's experiment was to show that the effect of even a short period of time was persistent. He administered six tests in succession, and then twelve weeks later, two additional tests. The average speed developed was 34.5 seconds in the first, and 27.4 seconds in the second: in other words, the seventh tests surpassed the sixth, made twelve weeks previously--a condition found in the records of sixteen out of twenty-six boys.

Professor Starch, in an article in the Psychological Bulletin (28), presents a method of demonstrating the trial and error learning process, and gives a learning curve. "Learning by trial and error is undoubtedly the most fundamental method by which the child acquires motor control. The two other methods of learning, by imitation and by understanding, are chiefly supplementary to this primary method."

His experiment consisted chiefly of tracing a six-pointed star as seen in a mirror. "This activity (28) is particularly well adapted for demonstrating trial and error because it involves the establishment of new co-ordinations between motor and perceptual processes. The experiment was also used advantageously to investigate several problems in the psychology of learning; in particular, the genetic development of muscular co-ordinations, comparing children with adults, adaptation in acquiring a new motor habit, cross-education, transference

of training, and the effect of different intervals between records upon the rate of improvement.

The first attempts demonstrate in a convincing way the trial and error procedure. It is brought out particularly well by the several difficult places encountered. In those situations an effort to reason out the direction of movement is of little or no help. Apparently the only way to reach the line is to keep on trying until one succeeds."

He shows by graphic method the records made by himself with the right hand at the rate of one a day for one hundred consecutive days, without interruption except between the fortieth and forty-first (one day) and between the forty-sixth and forty-seventh records (two days). His curves for both time and errors represent the usual course of learning in that they indicate very rapid improvement at first, followed by slower progress later. The rapid improvement extends in the error curve over the first seven records, while in the time curve it extends over the first twenty records. Except for the first seven or eight records, the improvement in time and errors is at no time parallel. Either the error curve improves rapidly and the time curve remains stationary, or vice-versa. The error curve shows a gradual lowering after the first rapid drop until about the fiftieth record. This accompanied in the time curve by the first rapid drop and

then a continuous standstill and even loss until about the fiftieth record. After that the error curve reaches its dead level and the time curve again shows a gradual improvement until about the ninetieth record when both seem to have reached their limits.

He adds that the implication seems to be that the plateaus during which there is little or no improvement are an indication of more rapid development in some other aspect of the learning process which is not measured by that particular curve.

Starch found the transfer of practice to be as great as 90 percent. His method of determining transfer, however, has been challenged, and according to improved methods should be much lower.

Starch's study attracted the attention of David Spence Hill (12). During 1911 Hill reported tentatively upon a study of mirror-drawing undertaken by one subject during October, November, and December of 1910. The trials, one each day, were continued through fifty days. Nearly three years to a day after the first series, the subject completed (December 16, 1913) eight daily trials as before in 1910, when the practice or daily trials amounted to fifty. A comparison of the progress curves, both for speed and accuracy, for 1910 and for 1913 indicated that in about three or four

daily trials in 1913 the subject had attained her standard of 1910--that, in fact, at the beginning of the 1913 experiment her status was not considerably below that of 1910--the speed slightly less, the accuracy a fraction more. The curve for the 1910 record is markedly like that of Starch, and exhibits the usual daily variations.

In "Minor Studies in Learning and Re-learning" (12) Hill writes: "In our experiments with the mirror-drawing little of the previously-acquired skill had been lost in the interim. There was little re-learning to be accomplished, little had been forgotten, and it appears that after the warming-up the lost associations were quickly recovered. Our observations of the work of hundreds of trials of mirror-drawing lead to the opinion that there is very little of the trial and error method used in mirror-drawing after the first two or three trials. This accounts, in part, for the initial rapid improvement. Reasoning and even imitation of the attitude and movements of other experimenters very soon intervene. It is the usual happening for certain kinaesthetic sensations to appear plain, and these become associated with perceptions of direction and form and time. It is the recollection of these complexes which constitute re-learning of the act, modified by changes in maturity and in attitude of the subject at the time. These complexes of association constitute the fabric of the neuro-

muscular memory; and their impressions, retention, and recall may not be different from the usual aspects of the memory consciousness. In contrasting the first and last curves one must allow for possible ennui in the latter part of the first, and for renewed zest, curiosity or interest in the matter of re-learning. The performance seems no more remarkable than in the instantaneously picking-up of a neglected tune by an old pianist after years of indifference and forgetfulness. Aside from the danger of generalizing from an individual case we cannot see in this case any safe ground for assuming that the mind continued its activity for a time in the furtherance of a learning process after practice and study have ceased."

Judd used mirror-drawing to illustrate habit forming. "In order to modify a motor habit it will be necessary to begin with a process that is relatively little developed and repeat it a large number of times." (16) He used mirror-drawing as a means of discovering the various differences between movements, and the influences which affect these characteristics. In the case of mirror-drawing, he claims that the visual and motor factors involve nothing new or complex in themselves, but the normal relation is disturbed and must be readjusted. He suggests that the results may be treated quantitatively by counting the number of corrective movements in attempting to follow the pattern, and by measuring the time required to make a complete tracing. The intro-

spective record should show what the process of readjustment involves on the subjective side.

Miss Downey made exhaustive studies in mirror-reading and mirror-writing with special reference to (1) the extent to which individuals differ in their capacity to interpret mirror reversals; (2) explanation of such individual variation; (3) the extent to which reading mirror script (visual) is correlated with ability to write it (motor), and with ability to read and write inverted script; (4) the relative skill of the right and left hand in the production of mirror script; (5) the relation of capacity in mirror reading with capacity to interpret form in general.

Among other things, she sought to determine the range of variation in skill in mirror-writing among twenty-five college freshmen, and to determine how far such skill correlated with skill in mirror-writing. The results pointed to a correlation of a corresponding degree of handedness and efficiency in mirror-drawing.

Miss Louise E. Ordahl published in "Consciousness in Relation to Learning" (22) the results of a slightly different type of mirror-drawing experiment. She wrote most interestingly of her experiments in learning to write mirror script (that is, writing which begins at the right-hand side of the paper, and may be read by holding it up to a mirror or from

the reversed side of a sheet) which were carried on for a period of fourteen days with six observers. The subjects wrote an assigned sentence three times with the right hand and three times with the left, and vice-versa on alternate days, the writing of each sentence being timed, save in the case of two observers. As timing seemed to have no effect, untimed experiments were not made by the others.

The greatest difficulty was noticed by all observers in the first few trials, as noted by Starch and Hill, and consisted in knowing what the form of the letters should be. A certain amount of extraneous practice was allowed in order to meet this peculiar hindrance. Two observers began by writing on the blackboard with both hands at once, mirror-script with the left hand and normal script with the right. This was easier than the writing with the pen, which required smaller movements. The other observers seated at a desk with paper before them, were told to write the sentence in mirror-script, after it had been explained to them what mirror-script was, and were allowed to write the sentence, to hold the paper to the light and to correct mistakes.

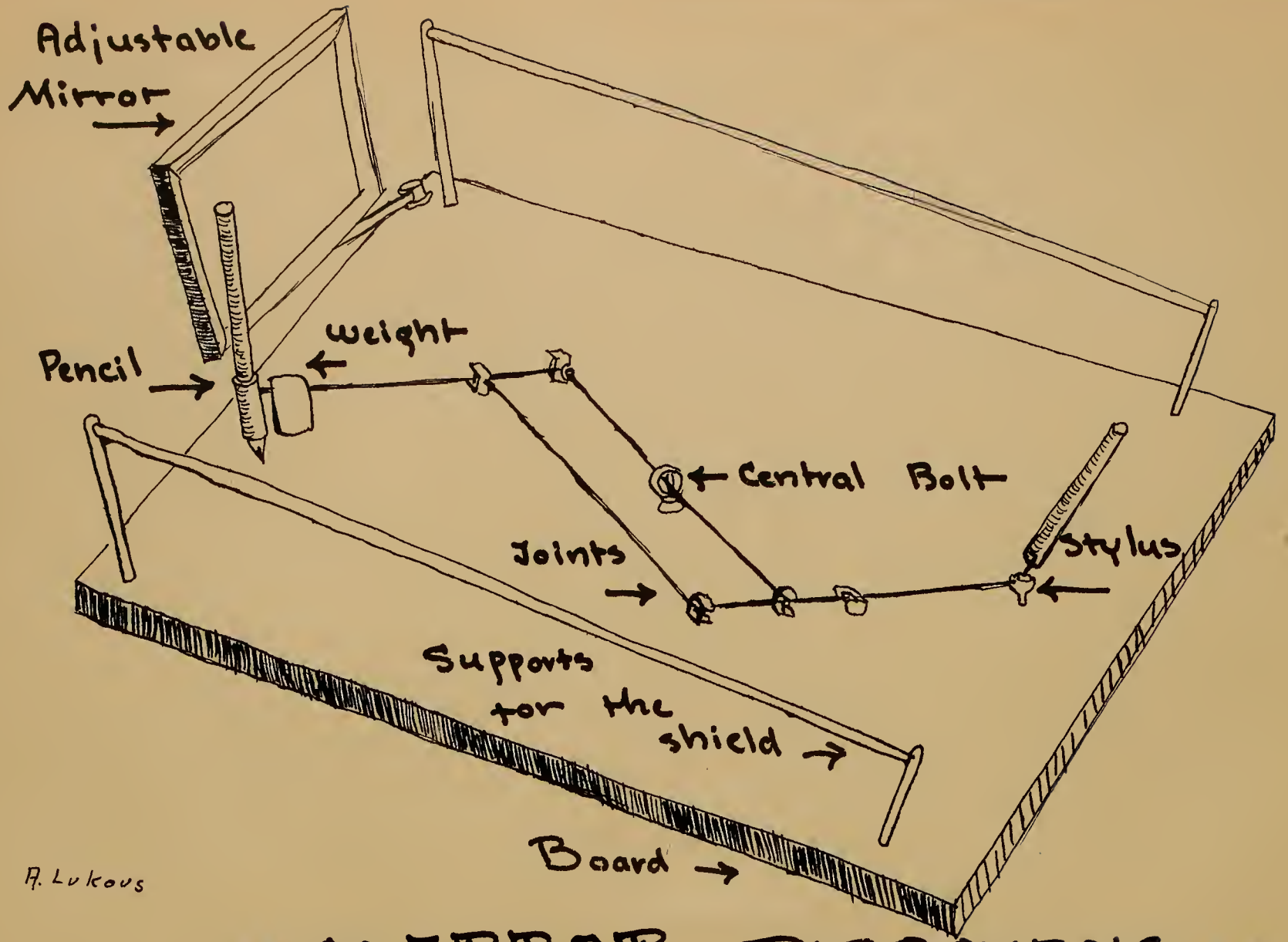
Attention at the start was confined to the writing as a whole, but soon general difficulties decreased and particular ones were attended to, since certain letter combinations were more difficult than others. Excessive muscular

tension was shown at first but later disappeared. She explained in detail how ease of writing and freedom from attention allowed difficulties to be anticipated and overcome before they were met only after considerable practice. "The function of learning is to improve the process by bringing errors to light and correcting them, and by adopting improved methods suggested by some habit fallen into, or by some idea as to better possibilities. The more purely muscular the process to be learned, the less conscious is the learning of it..... In the mirror-writing experiments, consciousness played a greater role (than in target throwing) in supervising and correcting the process, and for some observers, in starting an advantageous method.....In more complex processes like mirror-drawing, the learner is able to assume an objective attitude and direct and criticize his own activities and to shorten, by choosing new methods or avoiding observable mistakes, a process which would otherwise require much mechanical repetition.....We may say that in learning of any sort both conscious and unconscious factors exist. Unconscious factors are those involved in the fixing of the association by practice, and the cropping out of modifications of behavior subsequently utilized by consciousness. The more intellectual and highly conscious the material to be learned, the more immediate and direct the effect of conscious control. Practice results in a standing

out of common features of the process; these are focalized, and generalized into rules for new and better procedure, which immediately takes place. In complex processes involving both an intellectual and muscular side, the activity as a whole is conscious. Details are gradually mechanized, leaving the attention free to attack new difficulties. Factors of the activity which are at first only at the 'perceptual level' become clearly conscious, are then practiced and improved upon, and finally become mechanized and unconscious again."

Just at present the psychologists of renown are not actively concerning themselves with the mirror-drawing experiment, although vestiges of it remain in the newer manuals which they present to their students. Occasionally, however, some one of note will use it, or an adaptation of it, to show handedness or transfer. Miss Downey and Professor Judd are examples of such authorities.

Mirror-drawing, then, as an indication of learning, is not a novel experiment. Its variations are many; its adaptations, even greater.



••MIRROR DRAWING••

CHAPTER II

THE METHOD USED

Apparatus and Materials:

1. The mirror-drawing apparatus
2. Stars to trace
3. Thumb tacks
4. Stop watch

The apparatus used in this experiment is bolted to the center of an inch board about two feet long and more than half as wide. The bolt used to attach the apparatus is equipped with a special head so fashioned that it permits a wire, passed parallel to the board through the head of the bolt, to revolve completely around. This wire is one of four, always parallel in pairs, connected by joints. To the end of one wire a stylus is attached; to the opposite one, a pencil.

In the drawing of the apparatus on the opposite page can be seen the stylus manipulated by the student, although invisible to him because of a covering laid over the metal bars on the side. This stylus operates the pencil which travels with the stylus but in an opposite direction. The joints connecting the wires permit the perpendicular distance between the two sets of wires to vary, making it possible for the pencil to adjust itself to any change of direction.

The process is still further complicated by the fact that the pupil observes only in the mirror, never the hand directly. Of course, it was impossible to show in the drawing the cloth used as a screen to cut off the direct view of the hand and star. The photograph at the beginning shows a boy at work, with the screen in place.

The mirror is adjustable, to accommodate the writer in any position he may take and still make the copy visible.

Procedure:

A star was pinned to the board in such a position as to be visible in the mirror, but not directly so, because of the obstruction offered by the shield.

Instructions were as follows: "Trace the outline of the star, starting in the direction of the arrow. Work as rapidly as you can, but try to keep on the line. Time and accuracy both count--don't slight one for the other. Don't stop--but keep the pencil moving all the time."

After the pencil was placed in position on the paper, and the subject's attention called to the fact that he must observe only in the mirror, the "Ready" signal was given; the stop watch was then clicked.

On the completion of each set of tracings a serial number was assigned to each pupil for identification purposes. This is the number, under the caption "pupil's number" found

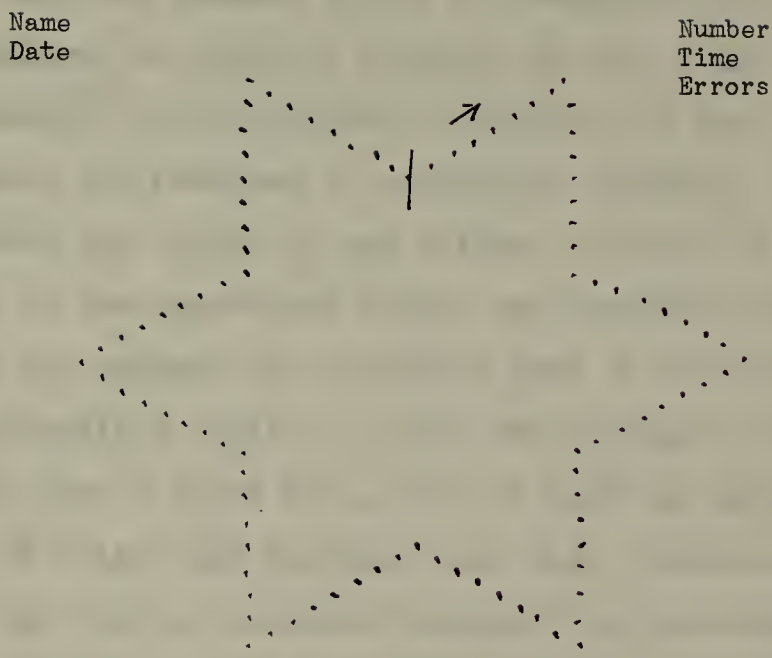


Figure 3. The Star used in the experiment.

A stencil was cut of the above star and from it 2500 stars were run off on a neostyle. Later 1200 additional ones were made. These were fastened to the drawing board of the apparatus by thumb tacks in such a position as to be visible in the mirror. A fresh one was used for each tracing.

at the extreme left of the tables.

The Subjects:

Over two hundred pupils in Greenfield High School volunteered to serve as subjects in this study. Of these one hundred and sixty-seven completed the task, the results of which are recorded in succeeding chapters. Failure to complete the series at one sitting, failure to trace the stars in the prescribed order, and previous practice were among the reasons for excluding some of the tracings. Occasionally a pupil was found who had been in the school system such a short time, that no tests of mental ability were on file; such tracings were also discarded.

The list of subjects includes boys and girls from all four classes. Since the first tests were made in January 1932 and were continued at intervals through February 1934 some of the pupils have been graduated and are now at work or are in college.

The range of intelligence, as determined by their I.Q.'s (obtained by the use of the Stanford tests) showed a considerable spread—from 70 to 150. Included in the list is a complete "A" group, and a corresponding "D" group, about twenty-five members in each. Any left-handed pupils who came to the author's attention were especially urged to participate. A cordial invitation was extended to those pupils

who had elected work in the Art Department; as a result, it was possible to correlate the school grades in drawing of seventy of the one hundred and sixty-seven with their mirror-drawing scores. Teachers of the manual arts--painting, free-hand and mechanical drawing, and wood-working, contributed a list of their most skilful pupils who formed another group for special consideration. Several were added from the author's own typewriting classes, considering that proficiency in typing may be due to manual dexterity, rather than to mental alertness. Five children from a "special" or "opportunity" class joined the ranks of those who "took the test". The ages of these children corresponded to those of first and second year high school boys and girls, but mentally they were unable to do the work required in the sixth grade. They are representative of the class of children found at the Belchertown State School for the Feeble Minded.

A group of graduate students at the Massachusetts State College, and a few older friends were persuaded to be subjects for the mirror-drawing test; they, however, made but few tracings.

In addition to the above, the author made over one hundred and fifty tracings of the star.

This study, however, is concerned chiefly with the one hundred sixty-seven pupils in the Greenfield High School who

made eighteen tracings each, in the following order:

1. 1 with the left hand
2. 16 with the right hand
3. 1 with the left hand.

These tests by necessity were given individually as only one person could use the apparatus at a time. Each pupil required about one hour to complete the eighteen tracings although less than half of that time was spent in the actual tracing of the outlines. At the beginning of the hour several minutes were consumed in explaining the procedure. Fastening eighteen papers to the board, removing them, and recording the time for the tracing took about as much more time as the explanation. The subjects did their work with earnestness and interest, and experienced considerable strain and fatigue at the beginning of the series. As they became more familiar with the reversing effect of the mirror, it was customary for them to deliberate between tracings as to the proper method of procedure and technique. This was particularly true in the case of the brighter pupils and seemed to be a repetition of the saving in mechanical practice, which was observed by Miss Ordahl, and mentioned in her writings.

Altogether, nearly two hundred and fifty persons tried the test, each experimenting approximately an hour.

Name	114	Number	1 L
Date	January 18, 1934	Time	78"
		Errors	100
		Score	89

Figure 4. A star traced by a pupil very inexpert at mirror-drawing.

Name	119	Number	3 R
Date	February 15, 1934	Time	28"
		Errors	5
		Score	17

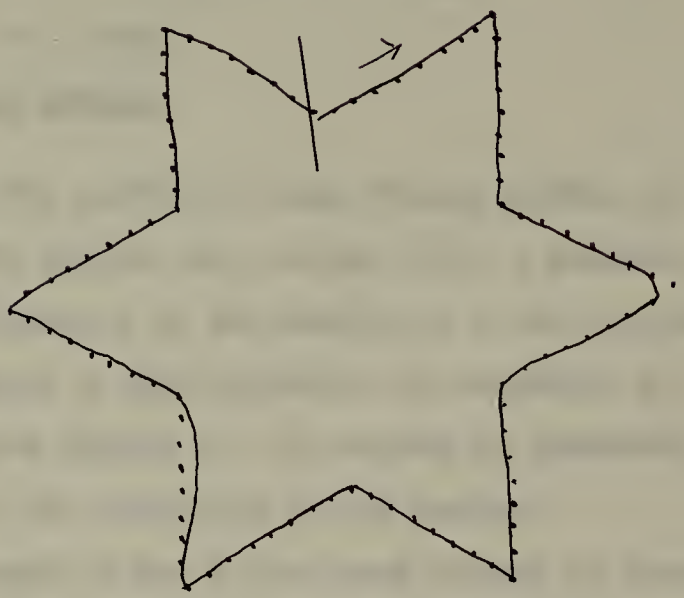


Figure 5. A Star traced with great accuracy

The criteria of successful accomplishment in this experiment were three:

1. Not missing a dot
2. The extent of missing
3. Speed

Marking the errors:

When the pupil had been totally unable to follow the outline the errors were scored 100. A perfect star had 0 errors. Figure 4 is an example of a star scored 100. Star tracings show a wide variation in accuracy, as evidenced by Figure 4 and Figure 5. The amount of inaccuracy was much greater at the beginning of the series.

Although it was a very easy matter to record the time, as the watch was accurate to a split second, a more thoroughly standardized method for checking errors would be desirable. It was very difficult to keep the ratings uniform, and frequent comparisons were necessary. It must be remembered that there are all degrees of missing a dot and that no two tracings were exactly alike, and that the amount of error, as well as the number of errors was taken into consideration.

The scheme followed here was very unsatisfactory because of certain inevitable discrepancies, such as the margin of subjective error; but no more accurate method could be devised.

The following extract from an article entitled, "An Improved Technique in the Mirror-Tracing Experiment", by C. E. Lauterbach of West Virginia Wesleyan College, appeared in a recent edition of the "Journal of Experimental Psychology": "The tracing of a star, or other figure, by its reflection in a mirror has been widely used in the laboratory as an experiment in trial and error learning. Scoring the performance has always offered considerable difficulty. Two scores have been necessary, a time score and an error score. This in itself has been a disadvantage but an additional criticism is found in the fact that it is frequently impossible to determine accurately just what constitutes an error.

The illustration (Figure 6) shows the figure to be traced divided into units so that the number of units traced per minute may be computed and a single rate score secured. The total number of units in the star is 132. The requirement is that the line traced by the subject must cut through, or run tangent to, each circle constituting the star. In the illustration the subject has failed to meet this requirement in 34 instances. Her unit score, as secured with a stop watch, is 93 seconds. Her rate per minute becomes (98 + 93) x 60 or 63.2.

By this method a single score is secured and when successive tracings are made a single learning curve may be con-

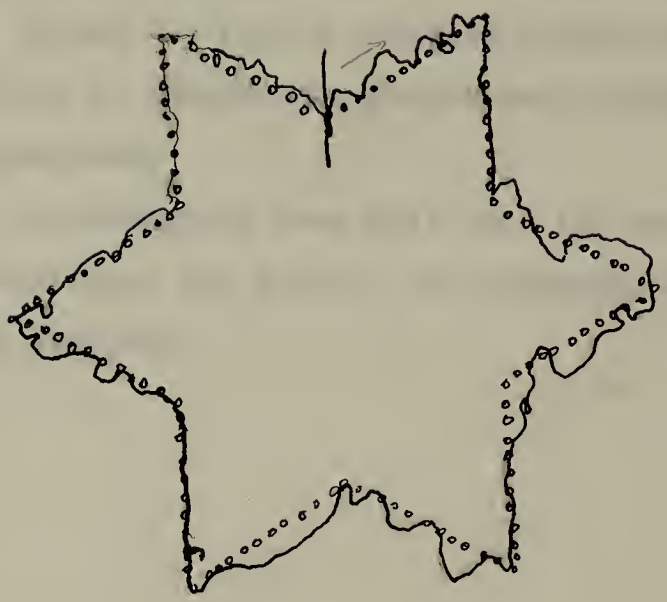


Figure 6. The eleventh trial of a ten-year-old girl (grade 5, I.Q. 108) in the mirror-tracing experiment. The record shows that she made 34 errors in a total number of 132 points. Her time score is 1 min. 33 sec.

structed."

If this study had not been so nearly completed at the time the above suggestion appeared in print, part of the scheme might have been adopted. The use of the circle instead of the dot in the outline of the star would make correcting easier for fairly accurate tracings, but would be of little help in judging the poorer ones which are much harder to evaluate.

Other investigators have felt that the greater the number of measures, the greater the opportunity for discriminating analysis.

Name	W. J.	Number	8 R
Date	January 11, 1934	Time	48"
		Errors	55
		Score	54

Figure 7. A copy of a tracing in which more time was spent on the right side than on the left.

Name	P. M.	Number	12 R
Date	January 11, 1934	Time	19"
		Errors	11
		Score	15

Figure 8. A copy of a tracing made by a girl who is mentally defective.

Name	F. Y.	Number	1 L
Date	February 7, 1932	Time	90"
		Errors	38
		Score	64

Figure 9. Copy of a star traced by a left-handed girl. This is the first of the series.

Name	A. B.	Number	1 L
Date	June 8, 1932	Time	2' 6"
		Errors	85
		Score	106

Figure 10. A copy of a tracing made with the left hand.

Name	S. B.	Number	14 R
Date	January 22, 1934	Time	40"
		Errors	10
		Score	25

Figure 11. Copy of a star traced accurately but in a little longer than the average time.

Name	S. D.	Number	5 R
Date	January 5, 1934	Time	50"
		Errors	45
		Score	48

Figure 12. Copy of a star showing a large amount of variation from the dotted line. Apparently, there is little effort toward greater accuracy.

Name	R. S.	Number	7 R
Date	January 23, 1934	Time	45"
		Errors	80
		Score	63

Figure 13. Copy of a star traced by a boy with an extremely nervous temperament.

Name	R. H.	Number	15 R
Date	February 1, 1934	Time	11"
		Errors	40
		Score	26

Figure 14. Copy of a star, near the end of the series, traced quickly but with no degree of accuracy.

CHAPTER III

ARRANGEMENT OF SCORES

The first part of CHAPTER III consists of an arrangement of scores, showing first the number of errors and then time measurement. The tables are complete in that they show the result of sixteen trials with the right hand, and the total; followed by the result of two trials with the left hand, and the final total, complete for all tracings.

Table 2 shows the number of errors; Table 3 is a time record.

These two tables are followed by the mirror-drawing scores.

TABLE II -- ERRORS

Pupil's Number	Right Hand Trials																Right Hand Total	Left Hand Trials		Grand Total
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16		1	2	
131	15	10	6	15	12	10	15	18	4	15	15	6	3	7	5	25	181	50	20	251
46	40	35	30	35	15	30	25	15	25	8	20	10	6	20	12	40	306	70	50	486
91	25	30	20	30	12	10	10	10	6	8	15	10	15	7	9	5	232	40	12	274
10	100	100	100	100	100	90	90	90	48	25	20	15	60	70	18	40	1066	100	50	1216
47	20	25	30	35	32	10	15	6	20	10	15	12	15	18	21	12	296	12	25	333
8	30	30	5	10	10	15	8	15	20	25	8	10	12	10	35	3	246	20	12	278
28	30	18	20	20	25	20	13	33	25	24	20	18	6	8	10	2	300	40	12	352
102	18	12	3	12	5	5	10	15	12	6	6	45	55	30	30	25	276	12	20	308
120	8	5	30	10	10	15	20	10	5	4	15	12	8	10	6	30	198	7	40	245
121	70	60	50	40	45	40	30	35	30	30	30	20	30	24	30	30	564	80	45	709
117	12	12	4	30	10	12	12	15	5	7	6	30	11	5	8	10	188	15	12	216
5	30	35	35	12	14	21	20	15	12	10	12	15	4	10	7	28	280	42	20	342
82	60	55	55	45	35	45	25	30	30	40	35	40	40	35	30	30	630	70	15	715
57	20	10	8	15	15	12	15	10	9	22	25	11	9	12	18	30	241	30	20	291
123	65	65	60	45	40	40	30	35	30	30	24	15	11	5	10	7	512	14	20	546
19	35	30	30	25	15	30	15	15	12	25	12	10	15	18	20	20	327	50	20	397
22	5	6	8	10	15	25	10	20	10	10	12	8	8	12	10	12	191	15	15	221
20	5	5	3	8	15	10	6	5	5	10	4	5	10	8	35	35	169	10	24	203
24	20	8	5	10	8	15	10	8	5	15	15	12	6	8	12	10	167	10	8	185
105	30	25	20	12	20	35	40	35	30	25	25	20	25	20	20	15	397	30	10	437
108	15	15	12	4	8	5	12	4	10	8	10	9	12	15	6	6	151	15	8	174
106	15	20	20	12	12	5	5	4	4	4	8	10	2	2	3	8	136	12	15	163
110	70	40	35	30	20	25	20	18	15	18	20	25	20	18	15	15	404	80	10	494
100	20	30	30	24	21	20	20	12	20	25	24	30	14	8	8	15	321	28	12	361
107	65	35	30	25	25	20	15	15	20	15	15	25	25	20	20	20	390	45	70	505
37	90	70	80	60	50	60	60	40	20	10	10	8	5	8	5	35	611	90	48	749
30	15	12	20	10	6	10	10	10	7	5	6	15	4	6	3	3	136	25	3	164
69	40	45	45	32	30	18	21	12	20	10	8	8	5	8	6	5	313	30	25	368
50	35	35	25	25	25	15	12	12	8	5	10	6	15	15	20	20	285	40	30	355
112	10	5	10	10	8	2	3	3	3	3	5	2	4	8	5	8	80	15	5	100

TABLE II--ERRORS

Pupil's Number	Right Hand Trials																Right Hand Total	Left Hand Trials		Grand Total
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16		1	2	
127	40	21	18	28	8	11	6	5	6	5	11	4	3	6	8	4	184	65	7	256
80	40	25	25	15	7	25	8	10	25	20	20	25	20	30	11	10	306	65	12	383
26	25	25	8	20	10	8	20	5	8	12	18	25	20	20	15	15	254	50	12	316
84	40	35	35	25	21	35	30	20	30	30	22	15	18	12	30	15	415	45	20	478
29	20	20	20	12	8	5	10	8	4	4	9	8	8	10	15	10	171	90	8	269
86	20	40	30	35	35	35	35	30	28	35	35	30	25	25	22	20	430	50	10	540
71	50	40	40	40	30	35	30	25	25	20	28	30	30	22	22	20	407	75	50	612
12	25	15	35	35	45	32	28	15	30	30	22	35	15	21	12	25	420	25	18	463
115	60	45	60	40	35	50	60	18	15	25	15	25	15	30	40	50	583	75	50	708
114	80	70	40	30	30	20	25	15	18	15	15	18	30	30	20	15	471	100	30	610
25	18	20	20	15	15	12	10	18	25	15	12	20	12	15	22	20	269	20	10	299
78	60	30	70	65	75	70	70	70	60	60	55	45	40	40	50	60	920	60	70	1050
16	65	65	65	60	60	60	60	40	40	35	35	30	25	18	18	15	691	70	12	773
17	40	40	20	30	30	25	30	30	40	30	30	25	25	20	18	12	445	50	10	505
18	60	65	70	50	30	24	35	25	35	45	30	30	50	30	30	30	659	80	35	774
146	18	28	25	24	41	40	60	50	25	35	30	30	35	40	50	40	571	20	60	651
147	40	60	60	50	35	30	25	15	25	21	30	30	15	30	12	20	498	70	15	583
150	60	50	30	45	15	6	8	10	30	25	20	25	25	15	25	20	409	50	50	509
98	35	40	50	50	50	60	60	50	45	40	40	40	30	20	20	20	650	50	30	730
134	75	70	60	40	35	25	25	18	18	21	30	21	30	18	30	25	541	90	15	646
135	18	10	6	4	10	4	8	3	4	7	8	4	7	10	5	3	111	20	9	140
51	50	40	35	25	15	25	15	25	30	22	25	20	15	15	6	12	375	90	10	475
113	90	50	35	40	50	70	70	30	18	55	55	40	65	85	45	80	878	69	29	976
34	45	35	35	30	25	25	15	20	5	15	18	12	12	6	12	12	320	40	10	370
126	40	90	70	80	70	70	75	70	70	80	70	50	90	85	90	90	1190	90	100	1380
151	30	35	60	60	50	50	60	90	90	95	90	90	90	90	90	90	1160	25	25	1210
153	95	80	80	80	60	40	40	50	35	30	35	35	30	25	25	25	765	80	20	865
152	25	20	20	15	20	30	25	20	60	90	90	90	100	95	60	85	845	25	60	930
32	90	50	50	50	50	40	20	15	12	25	80	60	59	70	30	25	732	100	25	857
101	30	30	15	25	10	12	8	8	8	40	40	40	40	25	40	15	386	40	30	456

Pupil's Number	Right Hand Trials																Right Hand Total	Left Hand Trials		Grand Total
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16		1	2	
153	25	35	50	35	30	15	20	30	20	11	15	25	15	35	30	25	419	40	35	496
157	25	25	20	20	25	12	15	10	10	6	6	5	10	3	10	1	227	20	10	247
159	40	40	20	15	24	35	35	25	30	30	15	20	15	25	15	20	419	50	30	500
154	25	20	20	25	5	30	12	15	25	25	25	12	20	25	20	30	351	35	25	411
155	25	30	25	10	15	12	3	6	12	10	4	12	5	12	10	6	305	40	20	205
156	50	40	45	40	40	35	50	35	35	25	25	25	25	10	35	35	500	30	25	515
97	75	75	60	25	30	30	25	10	25	30	25	10	25	15	20	20	513	50	20	563
99	35	25	15	15	35	12	25	20	25	25	15	40	25	15	35	35	400	10	10	400
95	50	45	45	35	30	35	5	35	10	15	25	25	25	25	25	10	425	50	20	500
94	30	35	35	35	40	40	40	30	40	40	45	45	5	45	30	10	550	25	20	601
55	25	20	10	15	12	20	12	10	30	25	25	25	25	25	25	15	307	35	30	332
85	10	6	25	20	35	35	35	35	10	20	20	12	25	12	10	20	320	40	20	300
76	35	30	30	20	30	30	20	20	25	25	15	15	30	10	6	6	329	30	25	354
75	30	30	12	35	30	22	25	25	25	20	25	25	35	30	15	12	401	40	30	471
96	40	35	35	30	25	15	15	12	12	5	10	12	6	10	8	4	277	60	10	347
1	30	45	22	35	30	30	30	35	20	15	12	15	20	15	20	20	307	30	20	447
77	50	60	35	45	30	35	25	20	15	25	20	15	20	12	8	10	425	60	35	520
68	40	35	40	45	40	35	50	30	30	30	30	20	20	35	30	20	530	40	10	588
67	20	30	40	15	12	15	15	12	10	10	10	8	9	10	5	10	221	60	25	306
110	3	5	1	3	1	2	5	2	1	1	1	3	5	3	2	3	42	5	4	51
21	12	10	6	3	12	12	4	12	10	12	6	10	12	8	12	12	175	8	12	195
144	8	15	15	10	8	7	6	15	12	15	10	12	8	10	8	8	171	10	10	191
70	30	15	20	30	15	12	15	10	12	12	10	10	15	12	10	30	265	15	25	305
145	35	25	21	15	20	32	12	30	21	24	12	15	12	12	6	10	334	42	4	370
14	35	25	30	20	12	15	12	10	5	7	12	6	5	3	4	4	207	35	5	247
7	45	40	15	20	15	15	5	10	40	30	25	25	25	25	30	30	405	60	28	493
89	75	60	50	50	42	30	25	20	15	15	15	12	10	10	10	10	450	80	12	542
153	8	32	40	40	30	30	30	30	20	20	20	25	25	40	35	8	503	30	60	593
38	45	50	65	60	40	50	40	40	35	40	30	30	40	35	11	21	609	40	20	749
74	40	45	50	45	45	50	40	50	50	50	50	40	50	40	20	25	710	50	30	770

TABLE II -- ERRORS

Pupil's Number	Right Hand Trials																Right Hand	Left Hand		Grand
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	Total	1	2	Total
90	22	25	25	20	25	30	21	20	45	20	20	15	12	15	12	12	330	100	15	454
11	40	40	35	35	30	35	35	20	25	25	15	15	12	10	10	10	400	50	20	470
139	38	22	35	30	25	20	20	18	15	20	12	20	30	25	15	10	356	92	35	482
140	12	30	20	20	25	85	60	70	80	60	50	55	45	45	40	40	737	6	40	783
142	45	60	45	35	30	25	25	15	22	10	20	20	15	10	12	15	419	55	15	492
143	60	70	80	50	70	80	90	90	90	90	90	90	60	75	85	50	1210	60	50	1320
23	12	25	15	20	25	25	15	25	20	21	23	18	22	20	12	20	320	23	18	366
111	38	40	35	35	35	30	22	20	18	15	15	13	18	15	18	12	373	50	12	435
85	90	80	25	20	60	60	50	60	50	70	60	60	50	50	60	50	885	80	50	1025
15	70	70	60	60	60	60	65	60	60	50	50	50	90	30	50	40	885	80	30	995
166	90	70	65	45	40	20	30	25	10	10	3	20	10	5	20	20	403	100	15	598
163	50	40	30	30	15	8	18	3	10	6	25	20	10	5	10	25	307	38	25	370
162	25	40	65	25	30	20	30	40	15	10	15	15	10	20	8	20	388	40	15	443
164	90	30	10	6	4	10	5	3	8	6	10	6	8	12	12	20	239	70	10	319
167	45	40	25	25	20	10	5	6	5	6	12	6	6	5	5	6	228	50	6	285
65	85	80	90	20	70	70	75	80	35	35	45	35	45	35	32	20	812	85	15	912
93	5	3	5	10	4	2	1	10	7	4	2	3	2	5	4	2	69	80	7	156
81	5	12	4	4	3	4	4	5	8	4	5	4	1	4	12	3	80	10	8	98
128	20	20	40	40	8	35	30	25	25	6	3	3	5	18	12	5	294	8	2	304
118	75	25	12	30	20	8	18	15	20	25	12	15	12	5	12	5	300	70	8	397
64	50	40	60	25	30	20	35	25	7	10	8	10	10	8	25	8	371	55	15	421
130	90	50	60	45	45	40	35	25	10	30	30	20	15	25	12	10	542	80	42	664
125	15	20	10	8	10	15	15	8	5	5	3	4	10	8	8	8	152	10	20	182
122	8	5	4	12	30	25	8	40	45	60	60	70	50	60	50	50	567	40	50	657
35	65	40	12	15	18	30	20	8	15	20	12	8	15	12	18	5	313	60	12	385
4	90	50	35	40	28	12	12	15	8	20	25	35	50	15	5	7	427	100	5	532
66	25	85	75	60	30	20	18	12	7	10	5	10	12	15	11	2	397	42	15	454
3	65	25	60	55	50	40	32	20	40	55	45	32	45	70	45	60	807	42	38	887
87	15	12	8	10	5	7	12	2	10	5	5	5	4	5	8	9	118	20	6	144
124	90	90	90	90	85	90	85	95	90	100	90	100	100	100	90	80	1465	95	85	1645

Pupil's Number	Right Hand Trials																Right Hand Total	Left Hand		Grand Total
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16		1	2	
88	8	10	5	5	2	5	5	4	5	1	0	2	1	2	2	1	56	8	0	64
116	10	15	8	7	6	8	5	6	5	5	9	8	10	8	4	5	115	20	20	155
132	45	35	40	30	25	30	22	21	12	12	18	15	35	19	15	12	335	35	35	455
100	35	50	32	30	40	90	80	80	70	10	15	25	90	70	45	62	694	45	25	804
79	20	5	8	10	15	20	6	10	8	8	7	5	5	5	3	6	132	10	8	157
103	50	15	15	5	20	20	10	10	5	2	8	10	40	35	30	25	300	50	25	375
41	8	12	8	4	5	15	25	20	6	20	13	18	15	6	30	12	222	20	20	262
129	20	15	35	15	40	35	40	12	10	5	35	30	15	4	10	5	304	40	20	384
36	30	8	10	5	5	12	10	35	30	25	25	10	8	10	8	30	261	40	20	321
42	70	50	50	35	30	30	20	10	12	5	4	3	7	5	8	5	344	60	12	416
52	20	10	10	15	5	15	20	8	8	4	6	7	6	4	8	10	164	12	10	186
27	60	20	30	35	25	36	35	25	20	18	22	20	20	11	20	12	409	60	15	483
9	55	40	50	45	18	10	20	12	20	10	12	8	30	10	20	35	375	20	30	425
33	95	90	90	90	60	65	60	50	60	50	50	50	45	45	45	50	935	65	60	1140
92	10	24	20	8	7	15	12	20	25	6	7	5	3	2	4	8	170	30	6	215
104	50	20	15	15	10	30	35	25	12	40	40	25	30	30	25	12	414	45	8	467
148	50	62	50	40	35	35	30	18	25	25	15	10	18	12	15	21	459	40	20	523
149	30	25	25	30	23	22	21	20	18	15	12	10	11	13	11	7	268	12	6	316
137	35	35	32	21	6	21	4	7	11	25	12	10	10	4	9	8	250	15	15	280
44	32	5	8	12	10	18	40	35	10	45	35	18	21	12	10	12	503	20	35	578
31	80	78	60	75	58	30	25	21	12	12	16	25	30	25	30	25	593	80	40	711
58	70	62	55	60	20	15	15	21	12	10	24	20	25	12	24	12	405	40	15	528
45	6	8	10	3	5	15	8	2	3	5	3	3	5	8	3	6	93	8	5	106
141	50	50	50	45	50	50	50	50	50	60	60	60	50	50	50	50	805	95	70	980
136	48	42	35	35	30	28	12	12	15	4	21	5	21	12	8	5	333	50	10	393
138	62	48	34	40	38	45	30	20	10	15	12	10	18	11	10	8	410	65	30	505
72	35	15	12	15	15	18	10	30	12	25	20	19	30	18	18	12	304	50	8	362
80	25	12	15	5	12	8	3	15	5	3	8	4	8	4	15	20	157	30	15	212
43	15	25	25	12	10	20	12	5	2	3	5	1	10	8	4	12	177	12	8	197
56	65	75	70	75	60	67	60	60	35	25	40	38	42	36	34	30	820	80	6	906

TABLE II -- ERRORS

Pupil's Number	Right Hand Trials																Right Hand Total	Left Hand Trials		Grand Total
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16		1	2	
61	27	18	8	11	18	23	16	17	15	13	20	12	19	13	10	19	254	27	21	307
39	33	50	50	50	40	35	40	35	30	30	30	35	32	26	29	27	500	50	28	659
50	50	45	30	37	33	42	25	30	33	38	36	26	17	32	19	18	510	50	17	577
6	20	21	30	25	25	20	20	16	20	22	22	18	11	18	17	13	313	16	50	379
73	36	20	18	30	40	40	40	35	35	32	32	30	28	30	30	27	502	40	26	568
23	35	27	18	24	24	24	18	28	23	20	20	25	23	25	30	40	414	33	30	477
40	25	30	37	40	40	34	37	42	26	30	26	25	28	2.	22	30	492	35	40	567
2	35	35	35	24	22	20	22	30	22	18	21	15	22	19	25	27	393	100	33	526
40	30	30	35	25	30	30	30	28	30	25	23	23	17	17	20	30	443	40	20	503
54	14	11	11	20	22	17	11	16	18	17	14	18	14	9	12	22	240	17	19	276
13	20	18	20	26	23	18	20	18	19	17	23	18	17	18	20	23	328	20	21	369
63	20	32	27	21	13	27	23	16	17	14	16	15	25	22	34	24	346	50	27	423
62	35	25	22	25	25	25	18	18	21	28	36	22	21	21	21	19	382	35	25	442
48	20	34	27	20	25	30	18	20	24	29	11	15	20	11	18	16	358	40	18	396

TABLE III

TIME IN SECONDS

Pupil's Number	Right Hand Trials																Right Hand Total	Left Hand Trials		Grand Total
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16		1	2	
11	28	34	31	35	25	38	34	31	27	21	25	21	26	30	20	32	453	50	30	533
80	110	40	26	20	15	46	25	25	25	15	15	17	16	21	21	17	472	86	21	579
26	25	20	25	25	19	18	19	19	10	15	14	17	15	14	15	15	294	180	20	494
57	120	75	40	54	55	41	35	54	34	35	25	20	20	20	25	20	671	150	35	856
37	180	65	115	32	70	103	76	58	64	59	47	42	39	38	45	25	1103	200	48	1356
28	51	34	40	35	46	28	35	38	30	51	46	60	57	45	55	80	740	68	57	865
58	86	73	61	50	37	24	15	16	21	32	19	16	20	28	17	25	540	60	83	663
30	50	55	60	40	50	50	50	47	50	51	60	45	45	35	45	50	793	120	55	968
31	60	37	30	30	35	27	40	30	24	30	35	45	34	25	31	37	558	92	37	687
33	80	81	75	155	60	54	40	51	44	34	32	27	27	30	27	30	827	92	77	991
76	73	56	56	37	58	40	52	36	48	35	35	35	40	38	39	61	746	95	56	897
32	58	64	49	50	43	37	45	38	50	46	52	40	59	41	33	30	734	100	35	869
24	99	68	49	69	37	38	30	25	32	35	32	28	31	33	33	28	655	125	47	827
25	38	40	45	28	31	24	25	25	25	21	23	20	26	22	21	22	436	47	23	506
75	117	50	45	42	38	44	30	28	22	20	18	18	23	19	21	20	564	117	30	711
65	146	104	50	23	20	20	25	16	18	16	16	17	17	19	14	18	539	173	18	730
83	47	46	40	30	25	16	14	17	30	18	10	19	15	16	26	20	388	29	25	442
47	24	34	45	25	32	30	25	25	30	30	35	27	25	37	25	37	486	30	53	569
82	178	96	63	26	54	45	39	36	36	36	36	30	28	40	21	23	787	90	34	911
84	76	42	44	35	26	38	26	26	20	28	25	17	20	21	26	28	500	96	20	616
51	35	29	26	29	31	34	25	23	27	17	21	21	19	22	18	20	397	75	24	496
124	90	58	45	35	35	35	45	35	30	20	10	20	12	16	10	25	541	60	25	626
126	56	35	40	30	35	23	24	28	17	37	19	30	24	16	17	26	447	60	32	539
50	15	50	50	55	55	37	42	41	36	34	26	24	17	18	16	16	582	132	21	735
80	54	34	30	26	20	22	22	30	20	24	28	22	34	15	17	35	439	64	25	528
44	148	114	76	82	78	54	53	45	40	53	42	35	25	23	25	23	916	213	33	1162

TABLE III

TIME IN SECONDS

Pupil's Number	Right Hand Trials																Right Hand Total	Left Hand Trials		Grand Total
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16		1	2	
45	78	58	51	51	45	45	49	36	40	41	36	31	36	19	23	19	657	104	31	792
120	78	28	27	15	21	20	35	34	14	20	29	17	15	15	11	12	391	103	31	525
212	78	110	30	40	41	22	17	18	18	16	10	18	15	17	13	16	492	101	21	694
147	124	90	99	93	65	59	65	108	44	42	40	60	50	56	60	57	1112	160	56	1328
148	190	196	100	65	60	44	33	43	64	53	47	53	60	40	35	45	1128	100	50	1278
146	38	27	25	20	21	21	19	22	20	20	20	17	17	18	16	13	334	25	16	375
88	112	71	60	70	65	58	50	65	43	[illegible]	50	46	52	45	45	101	977	115	40	1132
113	26	18	22	25	19	19	14	22	30	17	8	12	9	8	13	6	208	31	20	519
114	60	50	30	40	40	65	50	50	50	50	45	60	62	35	32	50	769	78	50	897
9	120	40	46	30	20	14	35	30	10	35	31	18	12	16	25	5	524	60	20	604
116	80	67	61	55	54	53	36	36	33	24	27	25	30	45	29	21	594	81	28	803
1	42	53	29	60	38	16	40	47	20	35	17	32	24	30	27	28	544	155	46	745
3	167	195	96	78	82	90	48	45	30	28	23	27	29	20	21	19	991	120	27	1138
4	51	30	30	45	30	32	28	26	27	32	21	24	24	21	23	23	471	120	33	624
123	105	75	60	60	70	45	35	40	30	25	35	40	25	35	30	25	735	60	25	820
117	38	17	17	13	14	17	14	16	16	13	13	25	20	13	11	11	268	119	51	402
115	110	41	39	53	30	24	25	21	16	19	19	20	16	15	15	14	477	19	12	508
77	62	47	35	32	36	19	24	27	25	22	20	25	23	23	30	25	475	120	35	638
93	45	45	50	45	35	41	18	25	15	17	15	15	15	12	9	13	415	105	11	531
92	60	52	32	45	42	55	40	50	51	54	40	41	30	35	33	20	600	115	28	823
91	145	100	56	85	63	56	47	50	45	42	31	29	29	29	25	29	861	68	52	971
95	210	135	130	67	38	24	20	29	20	24	20	18	21	29	15	14	943	102	22	1047
94	87	46	37	29	53	38	31	29	20	10	17	15	14	19	17	14	484	62	19	565
130	240	251	205	106	105	117	50	45	32	45	40	37	32	33	26	25	1370	295	42	1707
35	115	44	41	38	40	38	41	41	27	26	34	42	37	36	42	41	683	97	40	820
87	78	70	66	50	43	35	37	33	26	29	28	28	26	25	26	23	623	82	33	738

TABLE III

TIME IN SECONDS

Pupil's Number	Right Hand Trials																Right Hand Total	Left Hand Trials		Grand Total
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16		1	2	
108	81	153	102	100	120	99	70	51	68	67	54	46	50	45	46	40	1201	124	52	1380
109	52	60	50	48	45	52	38	52	37	28	23	22	31	21	22	25	573	68	25	665
110	61	42	29	26	18	18	18	19	12	16	16	16	14	18	13	30	354	150	22	535
111	180	200	68	45	66	30	41	31	44	31	30	25	20	27	27	25	911	145	27	1083
112	128	154	126	178	104	81	60	70	65	70	65	70	55	50	48	40	1309	108	50	1457
5	31	38	33	32	28	22	25	28	20	14	28	27	34	20	27	43	451	62	23	536
156	40	20	25	25	20	20	15	15	35	35	35	35	25	25	30	20	420	30	30	480
154	36	31	32	29	24	27	24	20	20	22	22	23	27	24	20	19	400	56	29	485
159	305	204	126	70	65	155	70	40	72	66	60	65	95	65	40	30	1593	120	65	1778
158	61	42	33	28	24	19	15	15	13	15	12	8	24	25	24	20	379	90	26	495
157	20	25	15	20	20	20	25	20	20	20	20	20	22	19	25	21	330	20	17	367
163	90	82	65	60	28	43	34	52	40	52	50	20	35	50	65	50	796	98	40	924
166	122	120	113	142	91	90	74	81	64	85	90	55	60	40	40	40	1254	100	60	1414
162	79	140	82	40	55	54	55	54	62	75	45	62	73	45	53	50	1039	100	58	1196
134	155	120	62	54	45	42	27	21	16	16	18	15	17	14	13	13	628	255	20	903
132	60	35	40	41	55	22	25	23	17	31	27	18	27	32	27	18	515	46	20	579
101	55	27	34	35	27	30	27	35	30	30	25	27	20	20	20	20	442	35	20	495
131	22	25	20	24	27	31	32	23	32	26	28	30	25	30	31	22	443	37	28	508
96	115	82	80	65	30	50	32	32	35	32	30	32	30	25	25	25	690	167	40	897
98	135	145	112	97	95	75	80	70	47	53	40	38	45	40	38	45	1207	160	64	1431
97	125	105	80	55	30	28	27	38	23	20	13	21	21	17	18	18	625	37	13	675
99	43	54	26	26	34	24	20	17	16	12	11	10	12	14	15	17	351	60	15	426
133	420	120	77	61	35	36	28	39	35	31	30	37	22	25	29	25	1051	140	27	1227
127	56	38	39	36	30	34	41	35	31	29	32	27	34	32	31	25	548	85	24	657
78	49	42	23	39	25	31	21	21	20	21	20	20	18	16	18	17	406	95	24	525
129	44	40	45	30	22	34	41	30	29	29	50	22	22	17	25	25	505	42	25	572
41	48	46	34	41	39	28	23	16	22	17	15	17	15	25	20	15	419	45	33	497
36	47	35	45	40	40	30	32	30	25	30	25	25	20	25	20	20	492	60	22	574
100	29	52	18	17	17	10	20	19	16	18	13	19	11	10	10	10	293	26	17	336

TABLE III

TIME IN SECONDS

Pupil's Number	Right Hand Trials																Right Hand Total	Left Hand Trials		Grand Total
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16		1	2	
144	13	11	9	14	21	26	21	15	55	9	26	19	25	20	22	10	324	18	19	361
146	32	22	16	16	18	18	12	23	13	13	13	13	19	11	11	12	262	43	14	319
136	40	20	20	22	15	14	15	15	12	17	14	13	19	21	20	23	306	18		324
7	26	31	32	31	34	35	22	24	24	24	24	21	18	25	20	21	412	28	24	464
89	63	39	62	64	68	50	52	40	40	40	35	32	32	35	28	30	710	59	40	809
14	95	55	70	45	65	40	53	56	43	40	39	36	48	34	30	31	784	64	48	896
56	107	158	135	157	126	89	52	60	53	49	38	44	41	40	44	34	1247	155	50	1452
43	40	32	31	44	24	37	33	22	33	23	100	48	20	18	70	23	598	66	38	702
59	95	63	59	60	72	54	34	27	29	25	22	20	15	14	20	16	625	77	20	722
72	50	55	41	54	31	27	40	55	27	20	22	25	15	15	15	18	510	86	23	619
150	200	100	85	90	75	70	62	70	75	68	28	28	45	45	35	35	1111	140	46	1297
149	50	59	61	71	101	54	54	50	36	42	38	36	41	46	26	29	706	90	55	941
151	14	17	13	14	15	16	14	11	12	13	13	17	18	17	13	15	252	19	21	292
152	13	14	14	12	11	12	14	10	8	9	11	10	19	17	15	15	206	19	15	240
153	25	30	18	28	19	43	35	25	18	25	20	19	39	32	30	35	441	60	42	543
86	35	33	30	30	30	28	26	42	32	37	35	23	24	27	31	21	504	56	43	601
12	63	40	35	36	46	33	35	28	29	23	41	19	22	26	30	26	532	75	20	627
52	90	60	45	45	40	43	21	34	29	25	26	25	25	23	22	20	573	60	27	660
55	122	103	111	91	71	78	54	43	93	47	30	27	37	35	39	27	1006	100	50	1243
90	115	122	78	52	55	43	50	45	40	40	40	40	35	30	30	30	845	295	15	1155
46	73	67	60	55	50	22	20	22	27	23	27	23	25	21	19	16	540	60	154	754
10	48	63	76	31	31	40	45	28	60	30	30	24	22	31	23	33	623	44	14	681
74	45	35	23	18	17	18	10	17	14	12	11	10	10	10	8	7	259	92	13	364
70	85	60	41	45	36	46	35	29	24	29	25	20	21	18	16	28	558	80	26	644
27	180	60	23	30	30	28	28	26	24	25	23	18	21	19	20	30	575	245	25	845
42	160	116	70	68	45	45	40	33	32	29	29	25	33	33	32	29	817	162	40	1019
71	44	37	34	39	19	19	17	18	18	24	18	21	19	19	11	15	370	81	45	496
8	65	60	34	30	32	32	21	20	20	20	20	20	19	19	21	20	453	85	40	578
85	90	90	90	30	120	45	45	30	28	18	17	15	19	17	22	17	693	80	30	803
38	38	32	40	34	40	21	21	21	16	20	17	23	16	18	18	18	387	31	23	441

TABLE III

TIME IN SECONDS

Pupil's Number	Right Hand Trials 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	Right Hand Total	Left Hand Trials 1	2	Grand Total
116	68	92	68	90	50	47	49	33	40	43	34	25	27	30	29	23	748	162	34	944
22	170	117	135	88	49	51	37	47	43	40	40	39	41	41	41	40	1019	100	45	1164
119	50	31	21	18	19	22	20	21	26	29	32	25	23	24	25	27	413	37	27	477
20	42	33	22	20	20	16	22	25	23	33	37	32	36	26	67	47	501	44	38	583
19	65	40	52	47	40	50	41	29	30	27	28	26	22	27	21	18	563	66	28	657
18	97	90	124	79	82	54	72	55	54	64	45	44	41	30	30	53	1014	122	53	1189
77	60	30	18	16	13	30	18	39	28	21	22	31	25	26	17	19	413	54	31	498
16	80	67	90	60	43	67	60	37	32	32	32	27	28	33	52	26	766	100	27	893
15	54	58	45	30	35	35	33	36	39	28	28	22	23	20	17	20	523	82	15	620
102	35	25	25	15	15	15	10	25	10	30	20	24	22	35	22	20	348	20	26	394
103	30	30	20	15	15	15	15	15	10	15	20	25	26	28	27	21	327	30	24	381
104	59	18	18	18	27	25	25	17	20	31	15	18	25	31	19	20	386	62	22	470
105	13	12	13	13	13	12	37	11	11	10	14	11	12	12	13	16	223	15	15	253
106	84	56	48	32	31	24	24	25	21	21	20	16	19	22	21	20	484	104	33	621
107	43	23	12	13	14	10	14	35	23	22	33	34	16	21	16	17	346	40	22	408
73	120	56	53	35	44	62	75	41	50	28	35	39	35	27	120	44	874	240	29	1143
69	40	45	57	45	40	36	27	48	30	25	31	32	29	26	26	20	557	37	35	629
40	366	96	80	54	71	45	51	50	40	42	31	30	30	30	25	40	1081	160	42	1283
119	36	55	28	40	50	29	30	25	23	32	35	27	24	24	24	38	520	55	34	609
137	102	93	127	55	66	102	51	34	40	30	24	20	20	20	22	30	836	60	30	926
141	37	37	26	20	27	19	15	21	20	12	10	12	10	11	10	9	296	39	20	355
139	90	48	63	95	56	63	39	38	37	42	41	26	56	54	40	27	815	120	44	979
140	75	95	75	75	60	120	100	145	146	72	96	80	77	62	56	58	1392	139	47	1578
142	80	45	45	45	45	30	40	60	40	30	20	25	25	25	25	20	600	55	20	685
143	32	27	24	27	14	17	21	14	12	9	55	25	22	22	20	16	357	47	22	426
78	40	30	35	35	31	25	25	28	31	21	24	24	19	18	18	23	427	50	28	505
135	78	72	85	70	55	45	36	55	39	41	44	40	40	40	40	37	817	19	51	887
67	113	65	80	53	42	33	32	30	27	31	27	31	26	19	18	19	646	115	21	782
68	82	35	37	50	34	26	35	25	21	19	26	15	19	23	16	20	483	61	23	567
138	45	49	50	35	35	52	31	35	43	38	24	25	41	26	25	28	582	53	20	655

TABLE III

TIME IN SECONDS

Pupil's Number	Right Hand Trials																Right Hand Total	Left Hand Trials		Grand Total
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16		1	2	
81	55	44	37	36	31	33	37	33	32	27	26	26	26	26	30	30	520	64	41	634
64	31	25	20	20	17	13	12	20	32	21	22	18	20	18	15	15	325	43	20	388
128	41	41	50	40	30	21	22	24	30	25	20	28	20	24	30	24	476	49	32	557
29	58	54	50	39	28	36	35	35	33	33	34	42	33	29	45	35	641	125	45	811
118	69	48	45	73	34	37	42	42	50	39	55	45	30	37	26	62	754	63	29	826
122	74	59	34	31	35	32	24	39	39	16	13	24	21	18	18	18	495	83	27	615
125	80	59	44	45	44	34	30	32	45	35	30	30	25	25	25	25	608	81	25	714
104	251	110	110	90	70	82	55	55	55	62	56	60	50	60	60	60	1206	160	48	1494
107	132	90	95	66	61	65	50	49	47	45	55	42	41	40	40	30	949	96	40	1085
100	31	28	30	35	38	30	33	27	34	30	31	32	29	44	29	27	508	40	41	589
106	191	95	65	60	50	40	35	35	35	33	33	30	32	30	26	22	817	65	27	909
101	55	50	50	20	15	12	31	20	24	20	26	23	15	14	14	20	418	120	20	558
61	140	175	175	120	67	95	90	90	70	73	71	65	61	59	50	42	1419	65	42	1526
59	137	154	164	202	120	90	62	57	60	67	62	45	70	45	42	38	1325	30	40	1395
60	302	120	70	115	65	75	75	70	70	78	75	51	51	61	42	40	1355	193	60	1605
6	104	60	55	53	53	65	55	35	21	58	33	53	19	31	32	35	714	53	35	853
78	120	65	120	56	42	55	44	62	75	41	60	16	55	39	35	27	1074	240	29	1143
55	180	120	100	100	115	120	90	62	71	70	78	70	65	52	45	50	1411	195	60	1666
49	84	90	70	55	55	45	45	45	45	30	30	30	40	40	26	30	760	90	42	892
2	152	122	90	70	54	46	55	62	51	56	56	61	44	65	61	59	1115	400	100	1615
40	366	96	80	65	62	45	51	50	40	42	31	30	30	30	25	40	1081	160	42	1283
55	90	90	55	60	35	28	60	55	41	36	37	28	42	37	28	35	757	120	52	929
15	77	47	28	75	40	61	75	55	40	56	66	40	55	45	49	61	869	72	61	1023
63	60	65	78	70	34	75	49	65	46	46	46	46	46	36	43	42	1087	78	46	1021
62	142	80	56	61	59	52	65	42	35	47	33	33	35	35	35	32	841	90	49	980
48	33	32	35	34	32	35	37	34	32	40	45	42	40	40	40	40	501	70	42	703

The Mirror-Drawing Score:

The Mirror-drawing Score is a more or less arbitrary arrangement for the sake of convenience in handling the data, and for comparison with other scores. It was derived by taking the average between time and errors. For the sake of the convenience afforded by the smaller numbers, average time and average errors were used. The left-hand trials were discarded and only the sixteen trials with the right hand were included in computing the mirror-drawing score.

The mirror-drawing scores range from 14 to 67. It is evident that the smaller the score (fewest errors and shortest time), the higher it is.

In the same manner as the component factors, time and errors, the mirror-drawing scores show greatest improvement at the beginning.

TABLE IV

SCORES SHOWING THE MIRROR-DRAWING RANKS

AND THEIR COMPONENT FACTORS

TIME AND ERRORS

Pupil's Number.	Mirror Drawing Rank	Average Time.	Average Errors.	Pupil's Number.	Mirror Drawing Rank	Average Time.	Average Errors.
115	35	33	36	88	33	61	4
66	31	32	30	46	28	34	23
55	42	63	20	23	33	47	20
18	52	63	41	110	24	22	25
136	20	19	21	148	50	71	29
161	20	19	21	119	16	33	3
56	65	78	51	34	36	49	20
17	27	26	28	106	19	30	8
51	24	25	24	63	39	56	22
13	38	56	17	124	62	34	92
19	28	35	20	108	42	75	9
127	23	34	12	105	19	14	25
11	27	28	25	66	26	27	25
36	24	31	16	31	36	35	37
2	47	70	25	129	26	32	20
96	30	43	17	134	45	57	34
62	38	43	34	141	49	19	51
160	27	32	22	164	25	29	22
49	39	48	31	167	37	59	14
74	30	16	44	153	57	66	48
163	34	50	19	128	24	30	19
126	24	30	19	81	19	33	5
132	17	21	14	139	37	51	22
20	21	31	11	163	34	50	19
25	22	25	17				

TABLE IV

SCORES SHOWING THE MIRROR-DRAWING RANKS

AND THEIR COMPONENT FACTORS

TIME AND ERRORS

Pupil's Number	Mirror Drawing Rank	Average Time	Average Errors	Pupil's Number	Mirror Drawing Rank	Average Time	Average Errors
41	20	26	14	79	17	25	9
113	36	17	55	93	15	26	4
143	49	22	76	140	67	67	46
155	19	25	13	12	30	33	26
124	26	42	10	39	60	83	36
114	39	46	29	131	20	28	11
89	36	44	28	103	20	20	19
14	31	49	13	1	29	34	25
65	42	34	51	40	48	68	28
33	57	52	62	30	29	50	8
28	32	46	17	26	17	18	16
77	28	30	27	76	34	47	21
43	24	37	11	107	23	22	24
157	34	52	16	59	25	39	10
70	26	37	16	68	32	30	33
109	28	36	20	111	34	57	23
112	44	82	6	152	33	13	53
67	27	40	14	38	34	24	43
95	50	43	56	71	27	23	31
130	60	86	34	27	31	36	25
22	38	64	12	101	26	28	24
58	31	34	29	4	44	61	27
120	16	19	12	102	20	22	17
97	36	39	32	147	50	70	31
159	62	100	26	121	34	31	37
82	44	49	39	48	29	37	21
146	26	16	36	75	30	35	25
144	15	20	11	151	44	16	66
32	46	46	46	78	42	27	58
47	24	30	19	7	26	26	25

TABLE IV

SCORES SHOWING THE MIRROR-DRAWING RANKS AND THEIR COMPONENT FACTORS TIME AND ERRORS

Pupil's Number	Mirror Drawing Rank	Average Time	Average Errors	Pupil's Number	Mirror Drawing Rank	Average Time	Average Errors
118	33	46	19	122	33	31	35
125	24	38	10	69	24	35	20
166	54	78	30	29	25	40	11
64	22	20	23	35	31	43	20
87	23	39	7	54	31	47	15
132	28	32	24	153	30	28	31
98	53	75	41	91	34	54	14
94	33	30	35	145	21	21	20
158	25	24	26	72	25	32	19
156	30	26	34	60	58	85	32
53	57	78	26	8	22	28	44
100	35	18	52	6	32	45	20
42	36	51	22	104	25	24	26
10	53	39	66	150	47	69	26
44	39	57	20	149	34	50	19
164	46	60	15	57	29	42	15
123	39	46	32	9	26	30	24
99	23	22	25	142	32	38	26
90	34	53	21	52	23	36	10
61	52	78	16	21	18	26	11
16	48	48	44	135	29	51	7
138	31	37	26	162	45	65	24
165	38	51	26	45	23	41	6
84	20	31	26	92	27	43	11
95	40	53	27	126	51	28	74
3	56	62	50	5	23	28	18
15	44	33	55	73	43	55	31
117	14	16	12	116	27	43	10
80	24	30	19	83	22	24	21
50	27	35	20	37	54	69	38

CHAPTER IV

ANALYSIS OF SCORES ACCORDING TO TIME AND ERRORS

In this chapter an explanation and interpretation of scores will be made; first, an explanation centering around the element of time, secondly, in regard to the errors; and lastly, an analysis of the mirror-drawing scores, involving both time and errors.

Time:

The time consumed for the entire eighteen tracings varied from 240 seconds to 1778 seconds.

The shortest time needed for tracing the first star was 15 seconds; the longest, 420 seconds. In the final tracing two boys finished in 11 seconds; the longest time, in the final tracing for the right hand was 70 seconds.

The average time for the eighteen tracings was 45 seconds; the median, 36. Ninety-eight finished their work in less than average time. The ranks of ninety students fell within the small range between 20 and 40.

According to the evidence in Table 5, the individual differences are striking. The results of the scores of no one person appear more than once in the table. In other words, it did not follow that because a subject made the first tracing in the shortest time, he would also finish the series

TABLE 5

Time in seconds for Mirror-drawing

Trial	First Left	First Right	16th Right	Second Left
Fastest	15	13 (1)	6 (2)	11
Slowest	420	366	70	100
Average	97	90	27	21
Median	65	69	25	30
Mode	60(3)	60 (4)	20	40

Figure 5

1. 3 pupils--all girls
2. 2 pupils--both boys
3. 11 60's
4. 8 60's

first, nor, in like manner, because he was very slow at first that he would continue to be slow. The greatest gain in time, from first to final tracings was 395 seconds--cutting the time to 25 seconds from 420. Three increased the time by one, two, and three seconds, respectively.

In Figure 15 we have a "typical" learning curve. There is a high initial error, which decreases fairly rapidly in the first trials, but with slow improvement later. This curve was computed for sixteen trials, and since there are no "plateaux" we infer that the practice has not been continued long enough to register the complete learning process, where lack of improvement would be indicated by the flatness in the curve.

Figure 16 shows the learning curve for one particular boy. Notice that rapid improvement is often followed by periods of loss. It indicates the attempt that was made to reduce the number of errors by extending the time.

Figures 17, 18, 19, and 20 were included as graphic proof of individual differences. They are interesting in that they vary from the norm (Figure 15) so strikingly. Other graphs could have been added indefinitely. An idea of the extent of the individual differences can be realized only by taking into consideration the differences of scale to which the graphs were drawn.

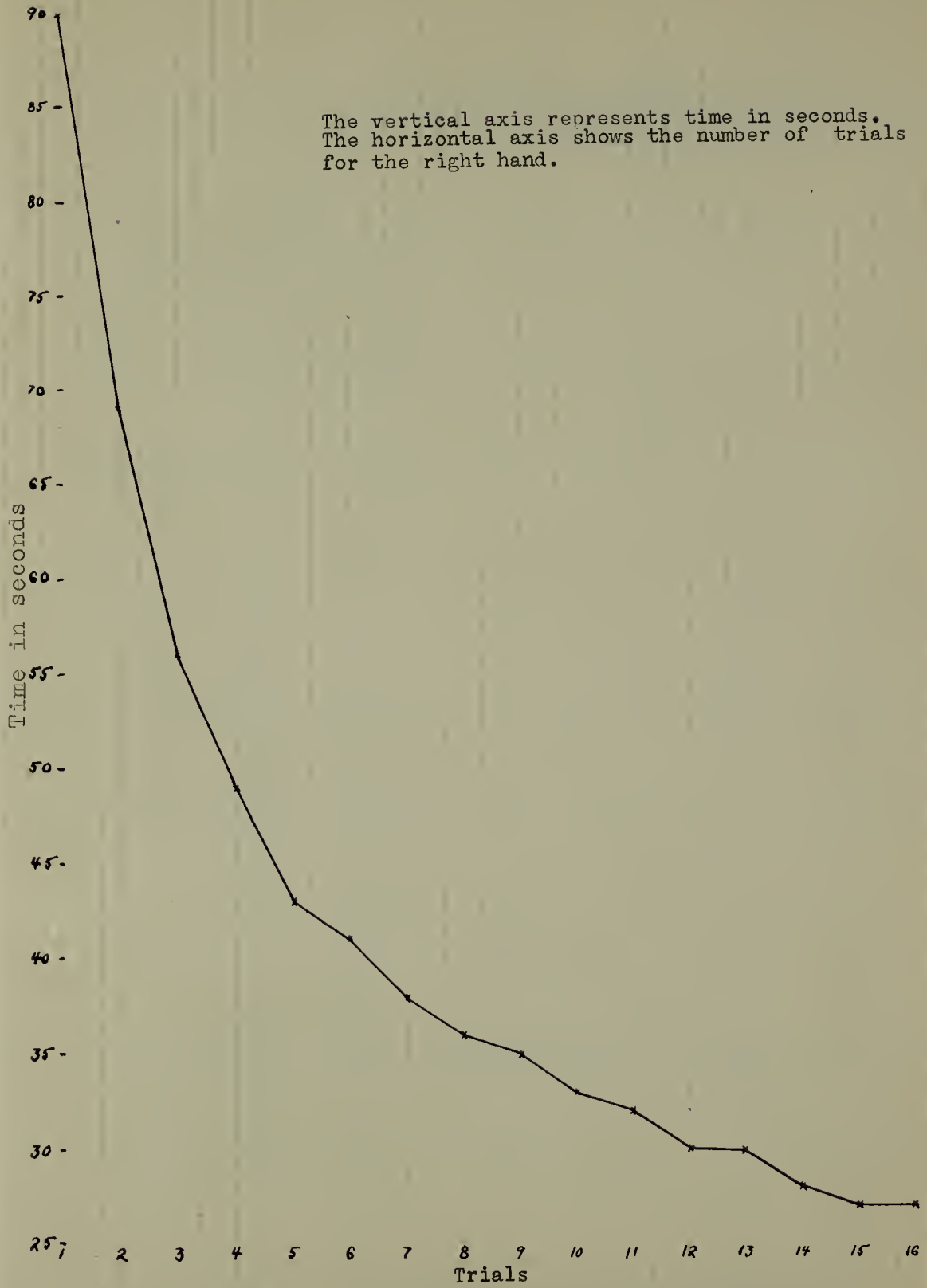


Figure 15. The effect of practice upon the average speed for 167 boys and girls.

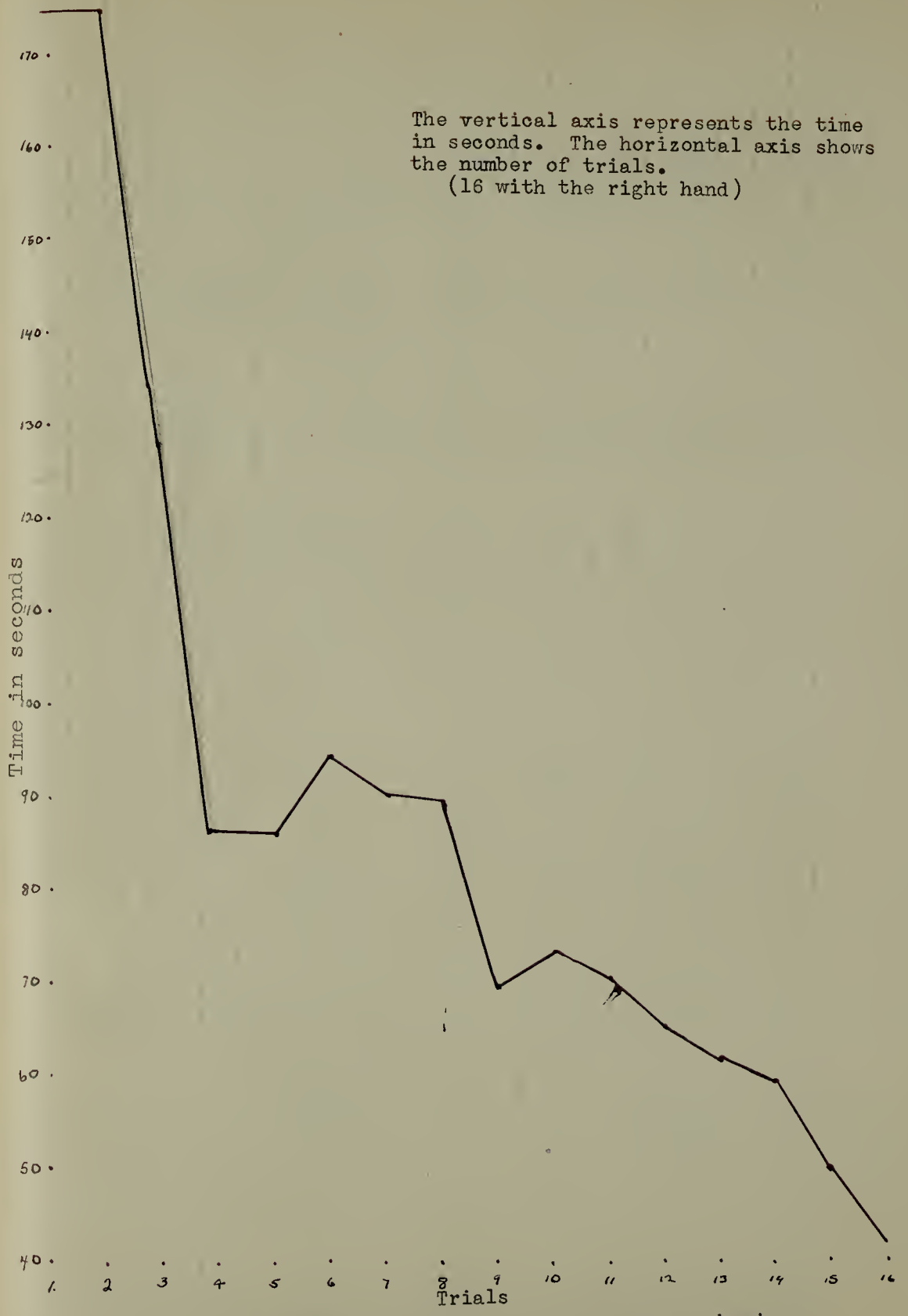


Figure 16. A typical individual practice curve, showing periods of rapid improvement followed by periods of loss.

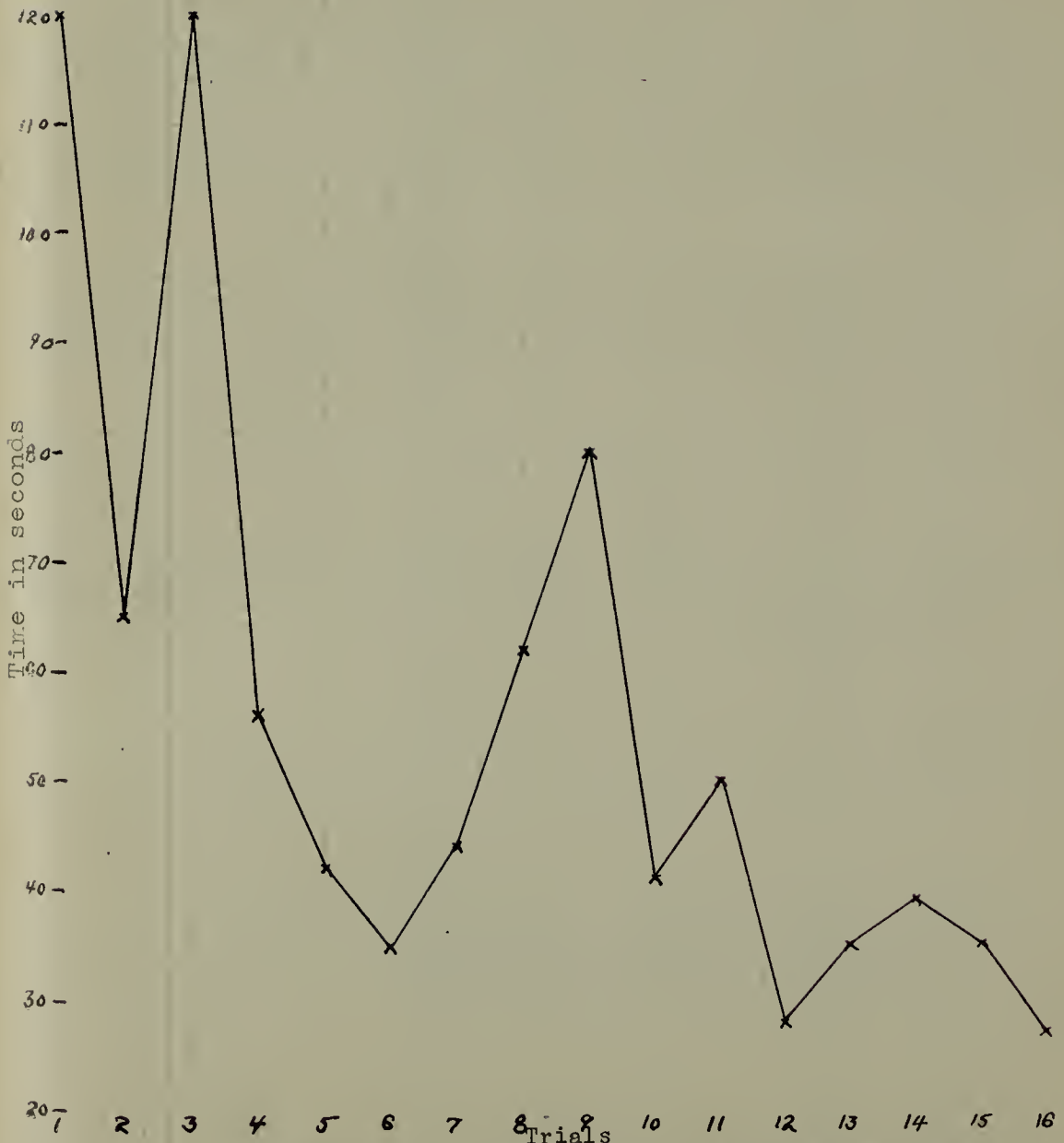


Figure 17. Time curve of a boy with epileptic tendencies. The curve gives an indication of his unstable nature.

Figure 18. Time Curve of a girl now an inmate of a reformatory. The cause of the long period of time used in Trial 1 was an uncontrolled fit of bad temper.

Figure 19. Time Curve of the boy who made the best Mirror-drawing score. This boy ranks high in scholastic achievement; his I.Q. is 149.

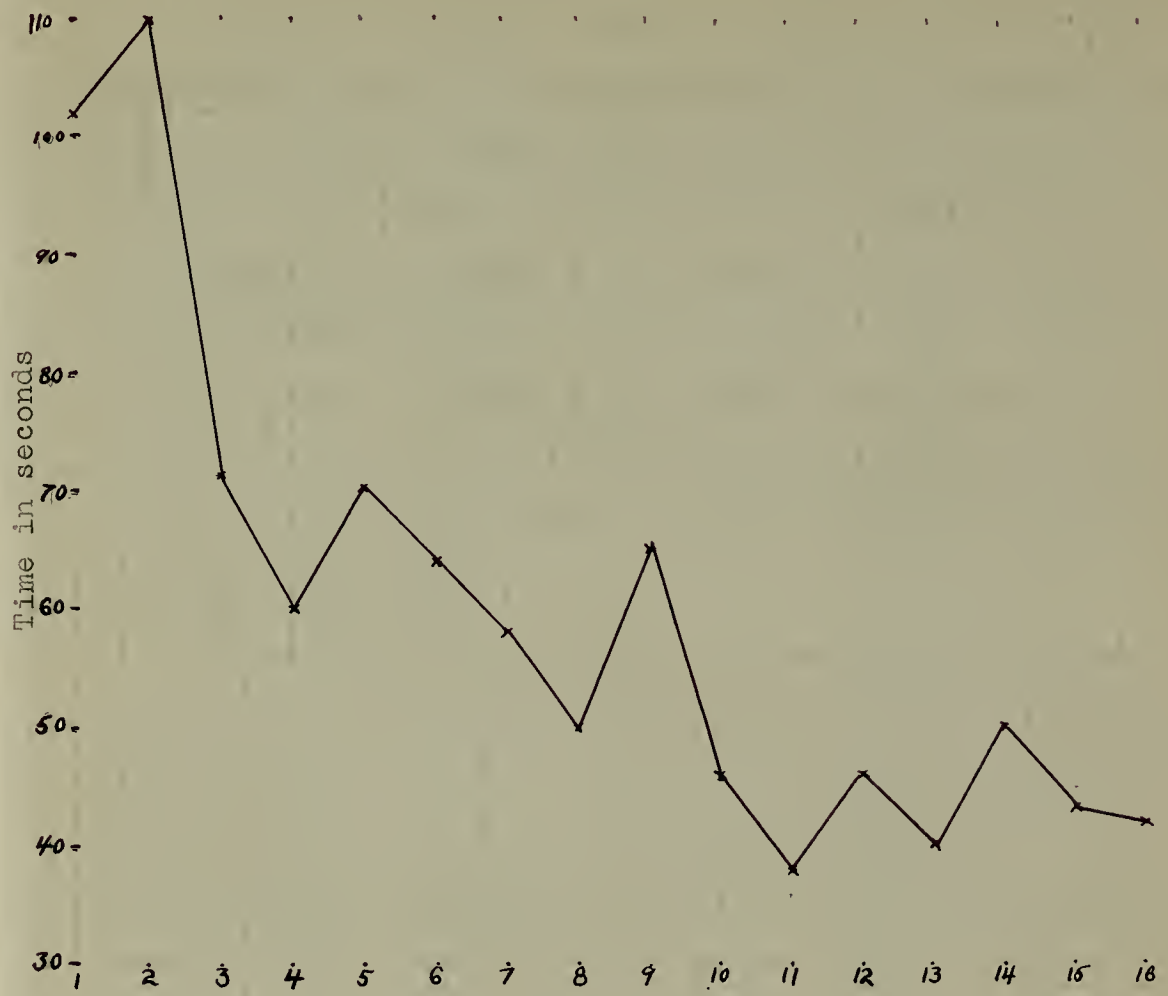


Figure 20. The Time Curve of the girl who made the fewest errors. In trial 11 (smallest number of seconds) there were no errors.

Ninety-two pupils traced the right side of the star in less than one-half the time required for the complete tracing. Of the remaining seventy-five, eighteen used exactly the same time for both sides, and thirty spent a longer time on the left side. The records of the remainder were lost. The mid-point proved a difficult spot for many. When considerable time was spent in turning the angle which marked the dividing point between the two sides the delay was charged against the second half, on the grounds that the right-hand half was already completed.

At no point in the tracing of the star did progress advance with clock-like regularity. The greatest amount of time was consumed at the inside and outside points, and even among these there was a considerable difference. Point No. 5 was considered the most difficult by the greatest number of pupils; others vehemently proclaimed point No. 3 to be "a bad one". No point escaped mention at some time by some pupil. Figure 21 shows the effect of a long period of time spent at some difficult point. It would have been interesting to have compared the time used in the tracing of each of the twelve lines, or for each of the twelve angles, but it was impossible to do so with the data available.

Some pupils remarked upon the varying degrees of difficulty without solicitation; very few, when the question was

Name	60	Number	1 R
Date	June 3, 1932	Time	302"
		Errors	90
		Score	196

Figure 21. Copy of a star showing very clearly that the points were the most difficult, and that the degree of difficulty varied among them.

put to them, failed to observe that differences existed.

Errors:

For the entire eighteen tracings, the fewest errors recorded were 51--made by a pupil (No. 119) whose mirror-drawing score ranks 5. Another pupil made two tracings absolutely without error as far as I could see.

In repetition, according to the scheme used for marking errors, the greatest possible number was 100, for any one trial; 1800 for eighteen trials. A close examination of the tracings of one pupil revealed 1645 errors. It might be well, perhaps, to disregard this case because of the fact that, although she took the test of her own accord, she appeared bored and uninterested, and apparently did not care to exert herself to make any effort. A further examination of Table 3 reveals that pupil No. 126 made 1380 errors. This pupil (a boy) is hard-working and trustworthy--a friend to all he meets. His attempt was an honest endeavor. While the number of errors made by the first is appreciably more than that by the second, the latter was decidedly inexpert. His last star, in respect to errors (100 errors) was not so good as the first one (90 errors). For him, the whole problem was still unsolved.

The average number of errors for the entire eighteen trials was 26.83; the median, 26.

TABLE 6

Errors in Mirror-drawing

(18 Trials for 167 pupils)

	First Left	First Right	16th Right	Second Left
Greatest Number	100	100	90	100
Smallest Number	5	3	1	0

In a great many cases, the fifteenth tracing was better than the sixteenth. Usually, merely the remark, "This is the last one," would cause a noticeable increase in the length of time and the number of errors. No amount of good intention would overcome the paralyzing effect of the nervousness experienced. Consequently, it may have been a mistake to have made any suggestion at all.

Figure 21 is a copy of a star traced by a boy (No. 131) now in the Naval Academy at Annapolis. He experienced a tremendous amount of difficulty at first, as evidenced here. Not to be conquered by anything which he attempted, he repeatedly returned for practice, and finally became very expert.

Figure 21 shows very clearly that a greater amount of difficulty was experienced at different spots, and that the points were the most difficult of all. Of the six points, point No. 4 was completed in the longest time and with the greatest number of errors.

Table 7 may be interpreted to show, in a little different way than any hitherto described, that pupils vary individually in the number of errors made. In other words 73% of the pupils made fewer errors than the median; 27% made more. The greatest number of pupils, in regard to number of errors, fall in quartile II.

To overcome the making of errors, it was necessary that

TABLE 7

Quartile	Average Errors	Number of Pupils*
I	3--24	54
II	25--46	68
III	47--68	30
IV	69--92	15

*Total number of pupils, 167

the pupils become adjusted to the reversing effect of the mirror. In the beginning the adjustment was haphazard. Errors in the general direction dropped out rapidly after the first few trials, persisting longer at the points of the stars. In adjusting themselves to the reversing effect of the mirror several methods were reported. For example, when the pencil was moving in a direction away from the outline, the subject tried to reverse the direction of the movement, and go in the opposite direction--this direction being determined kinaesthetically. Visual perception played but little part in this process, being used only to determine the existence of errors, but not their direction.

Another method used by a few subjects, was to try to go further in the apparent direction of an error just previously made. Because of the reversing effect of the mirror, this, they reasoned, should bring the pencil back toward the line.

They found, too, in trying to correct an error that there was a tendency to overcorrect. As a result many avoided correcting small errors--that is, they would continue to the point of the star, even though they "just missed" several dots.

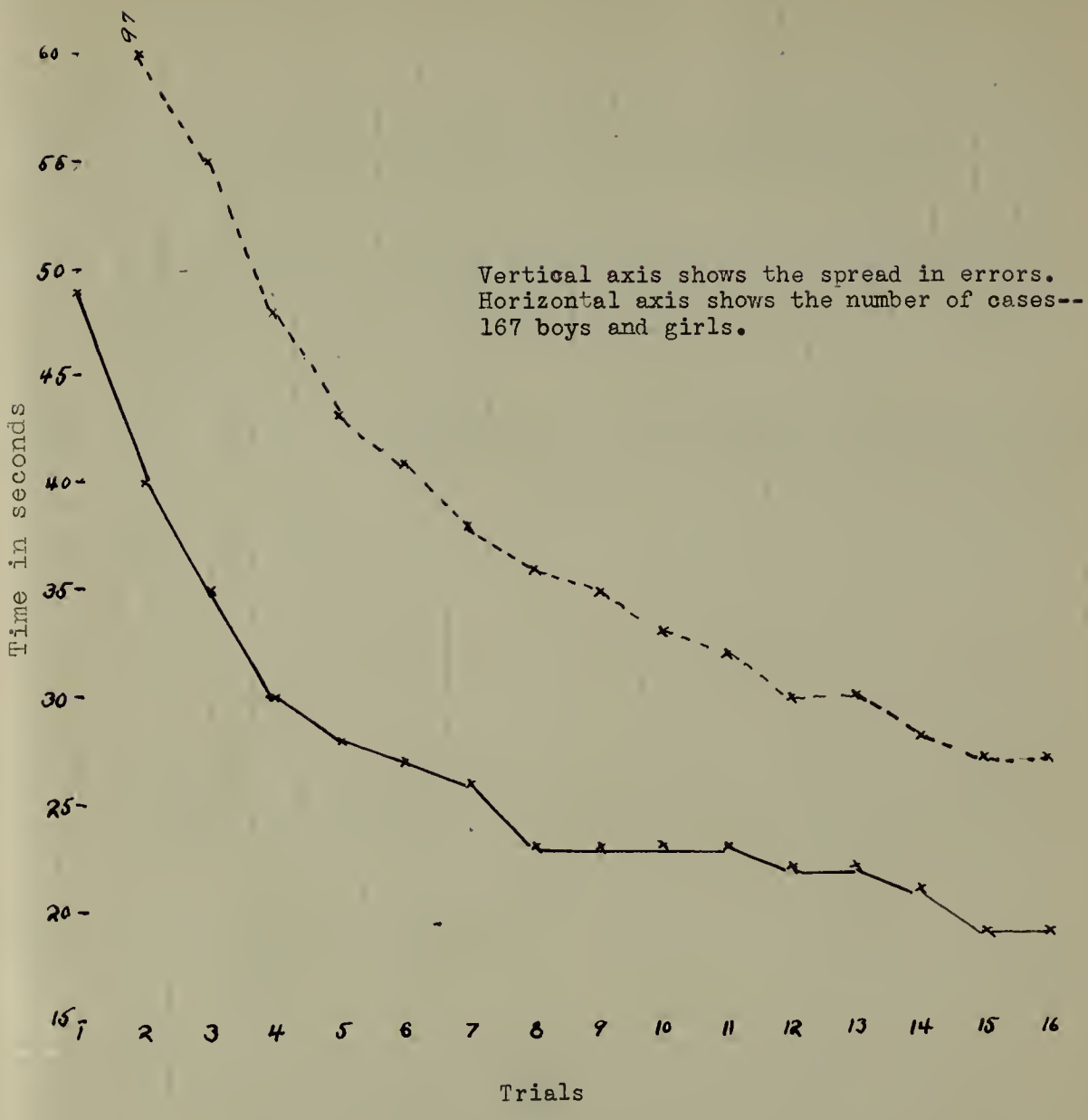


Figure 22. The Effect of practice upon Errors. (Average number for 16 trials)

Improvement in errors travels apace with that in time. Starch found that the error curve continued to improve after the time curve had reached its dead level. 16 trials were not enough to show this.

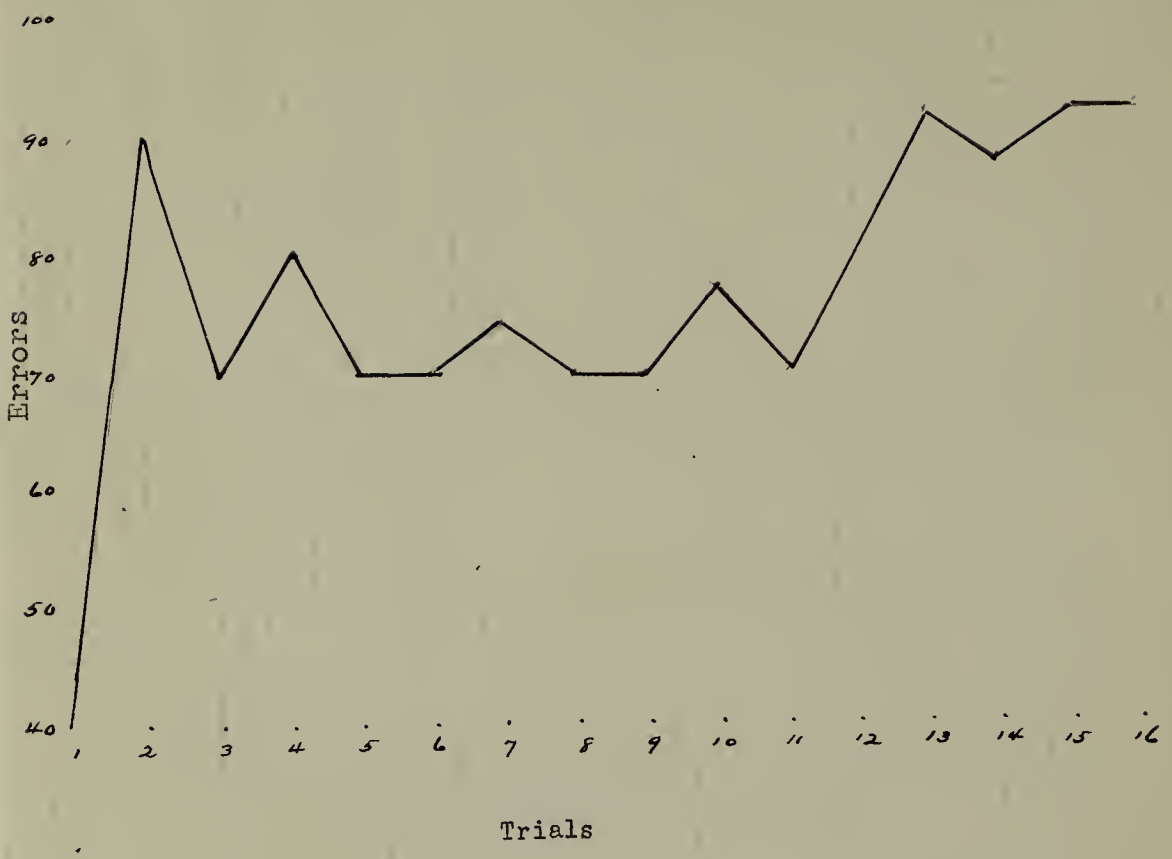


Figure 23. Graphic representation of Errors of the boy (No. 126) who made the greatest number.

It would appear that sixteen trials had scarcely commenced to overcome the reversing effect of the mirror.

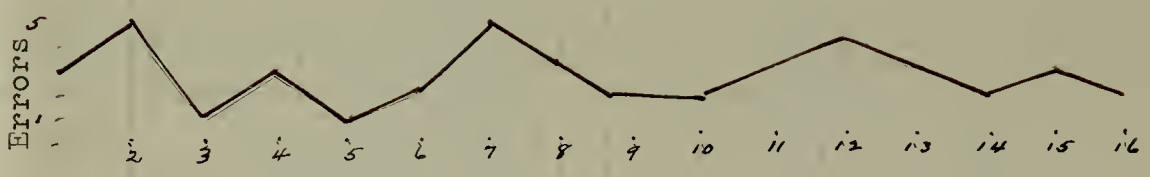


Figure 24. Graphic representation of Errors, made by the pupil who made the fewest.
In Mirror-drawing Score she ranks 5.

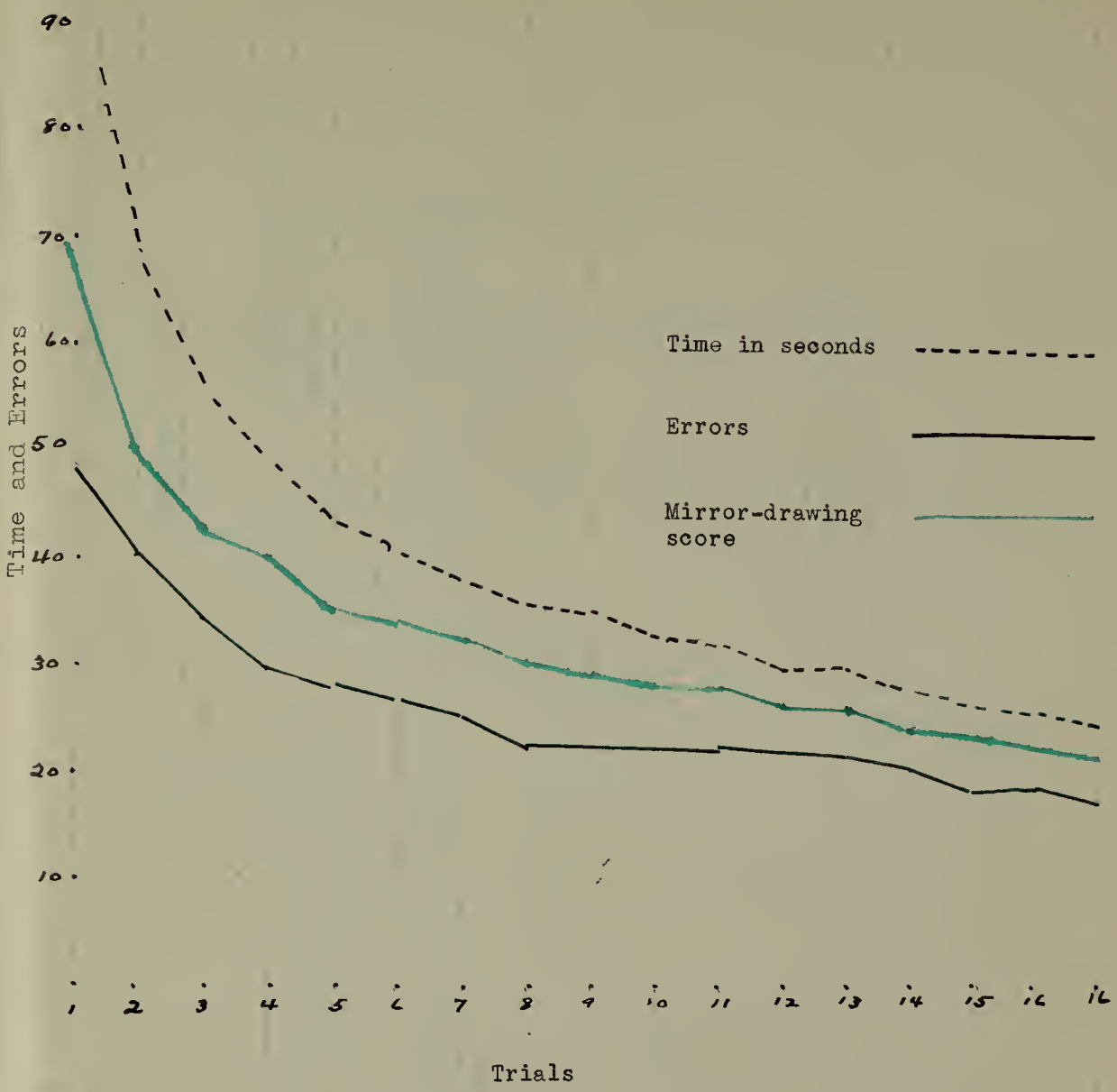


Figure 25. The Effect of practice on the Mirror-drawing Rank. (Average scores for 167 boys and girls.)

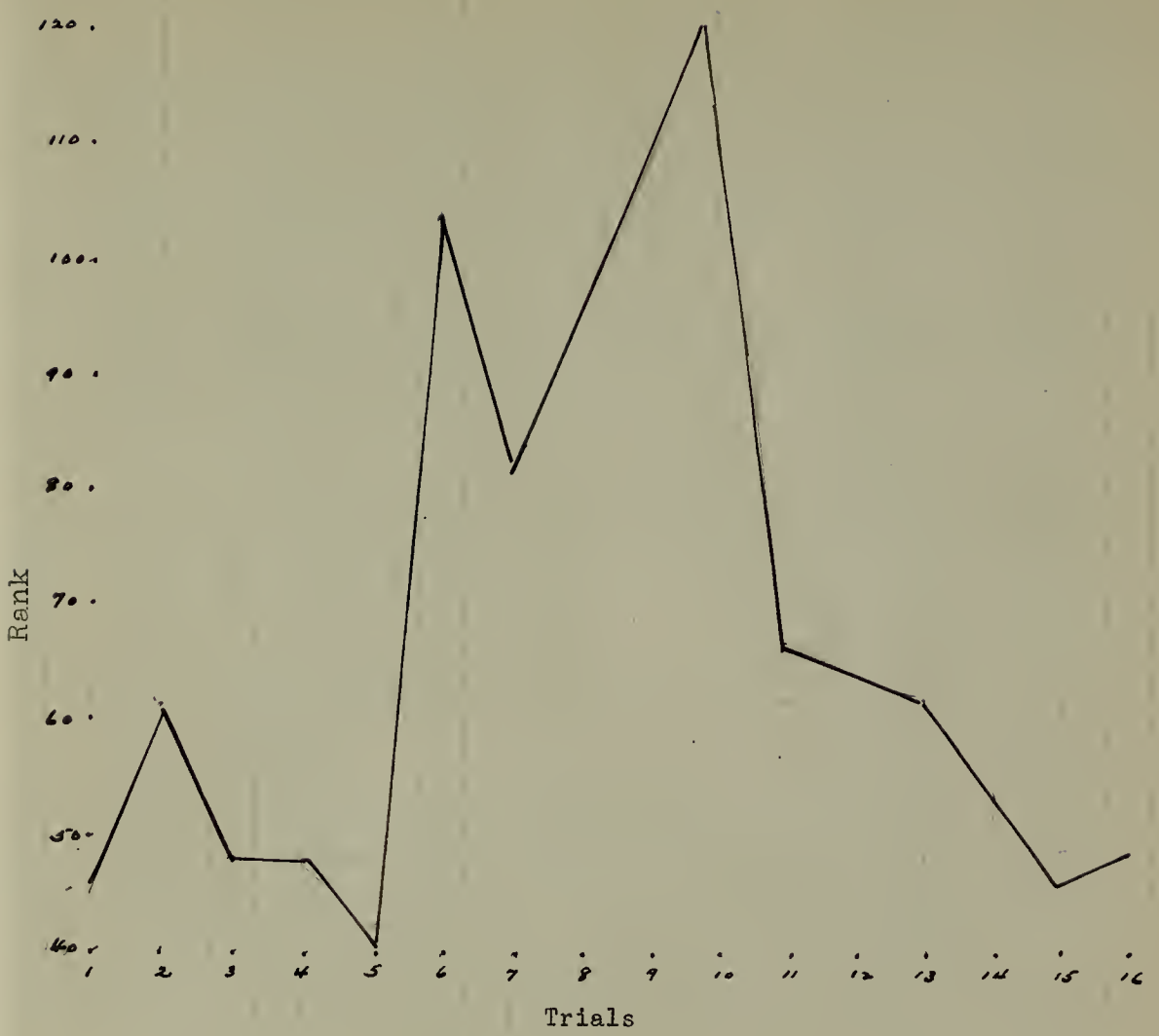


Figure 26. The Effect of practice on the Mirror-drawing Rank.
Pupil No. 140--the boy who made the poorest rank,67.

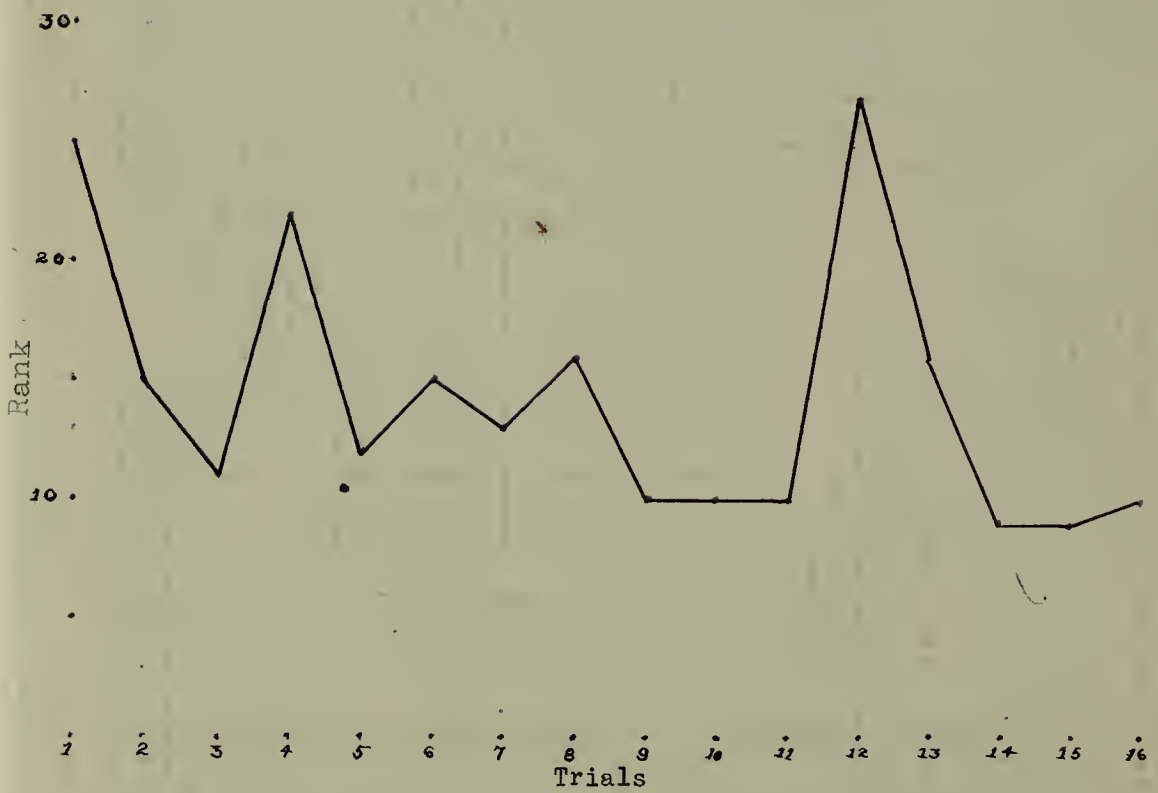


Figure 27. Graph showing the effect of practice on the Mirror-drawing Scores

Pupil No. 117--the boy whose mirror-drawing score was best--14

Greatest number of errors	30
Longest time (per trial)	38 sec.

CHAPTER V

VARIOUS COMPARISONS

Boys and Girls:

In this group of ninety-seven girls and seventy boys, the mirror-drawing ranks failed to reveal any real differences which could be attributed to sex. This is in direct violation to Whipple's assertion: "That girls decidedly surpass boys and that women decidedly surpass men is shown in all the published results of mirror-drawing, with the exception of two groups reported by Burt and Moore, and in them certain divergencies in method and in other test conditions offer a sufficient explanation of the apparent exception. Miss Calfee's averages, for six trials, give for the freshmen women 64.4 sec., P.E. 22.3, for the freshmen men 101 sec., P.E. 28.5. She finds that only 6 percent of the men reach the women's median, while 90.4 percent of the women reach the men's median. It is not only possible, but probable, that this sex-difference, is in some part due to greater familiarity of women with the use of the mirror. Burt believes there is also an innate sex difference at work." (33)

In this study, the average score for boys was 34, for girls, 33; average time in seconds, for boys and girls was the same, 41; the average errors, for girls, 26, for boys, 27. The above results do not include the two left-hand

tracings. In the matter of averages, the relationship could hardly have been closer.

The best score, and the poorest one as well, were each made by boys. But the record for fewest errors, forty-two errors in eighteen tracings, belongs to a girl. There were two tracings without errors, both by the same girl, but not the girl who made the fewest errors. No boy made a tracing free from errors; but more than twice as many boys as girls made one only. The average score for errors, per tracing, almost matched--3 for girls, and 4 for boys. For a single tracing, the greatest spread in time lies with the boys--six seconds, the shortest, to four hundred and twenty, the longest.

Briefly, in the comparison of the two factors--speed and accuracy--we find that honors do not stay with either sex for long. If we consider errors, the girls made the fewest errors, but they made the most, too. If it is with speed that we concern ourselves, we find boys at both ends of the scale. We have the boy who neatly traced a star in six seconds, and with him is the boy who in great bewilderment took seven full minutes for his. Whatever the angle of consideration, there is no factor that can be singled out that is peculiar to either side.

Individual cases are always of interest, but the actual relationship existing between two sets of scores is most

accurately shown by their coefficient of correlation. "The coefficient of correlation is useful whenever each member of a group of individuals has been measured in two or more traits. It expresses in one figure the average degree of resemblance or mutual implication of the two traits. This measure has been abundantly useful in expressing the relation between mental and physical traits, and in foretelling the probable standing on test from the scores of another. Its reliability depends upon the number of cases included and the closeness of the correlation."

Perfect correlation is +1, chance correlation between relationships is 0, and perfect negative correlation is -1. Furthermore, Rugg's general principles of r (coefficient of correlation) being negligible or indifferent when it is .15 or .20; present but low, from .20--35; marked, from .35--60; and high when above .60 or .70, give us a rough measure of the closeness of relationship.

To be significant r must be at least four times the possible error. (15)

From any of the evidence shown in this study, there is nothing to indicate that the relationship between mirror-drawing ability of boys and girls would be either close or substantial. Nor do we find that such a relationship, either positive or negative, exists. Between the mirror-drawing ratings of the boys and the girls the coefficient is only .04.

The group in this study was nearly twice as large, and the number of tracings three times that of Miss Calfee's. If her records are reliable, these should be too. Hers were published over twenty years ago. Can it be that the findings in this more recent study justify the present trend of modern education, similar training for both sexes?

The boys showed themselves more mechanically-minded than the girls. When the apparatus failed to operate satisfactorily, they were greatly concerned. They not only recognized the fact that a difficulty existed, but they proceeded to produce a remedy. One boy took the apparatus to the manual-arts department and lined up the wires; another filled a pencil-cap with molten lead, to help the pencil make a heavier impression. Still another, perhaps to avoid giving offense, reported to a shop instructor of unquestionable mechanical skill, that he felt that he could do a better job if certain adjustments were made on the apparatus. The boys appeared to be more interested in the results, too. They discussed the problem of mirror-drawing all over the building with any one who would listen--and many and varied were the theories they formulated. Not a single girl came back to find out her score; about twenty-five boys returned to inquire about their rating.

Figure 28 shows the effect of practice on the time curve,

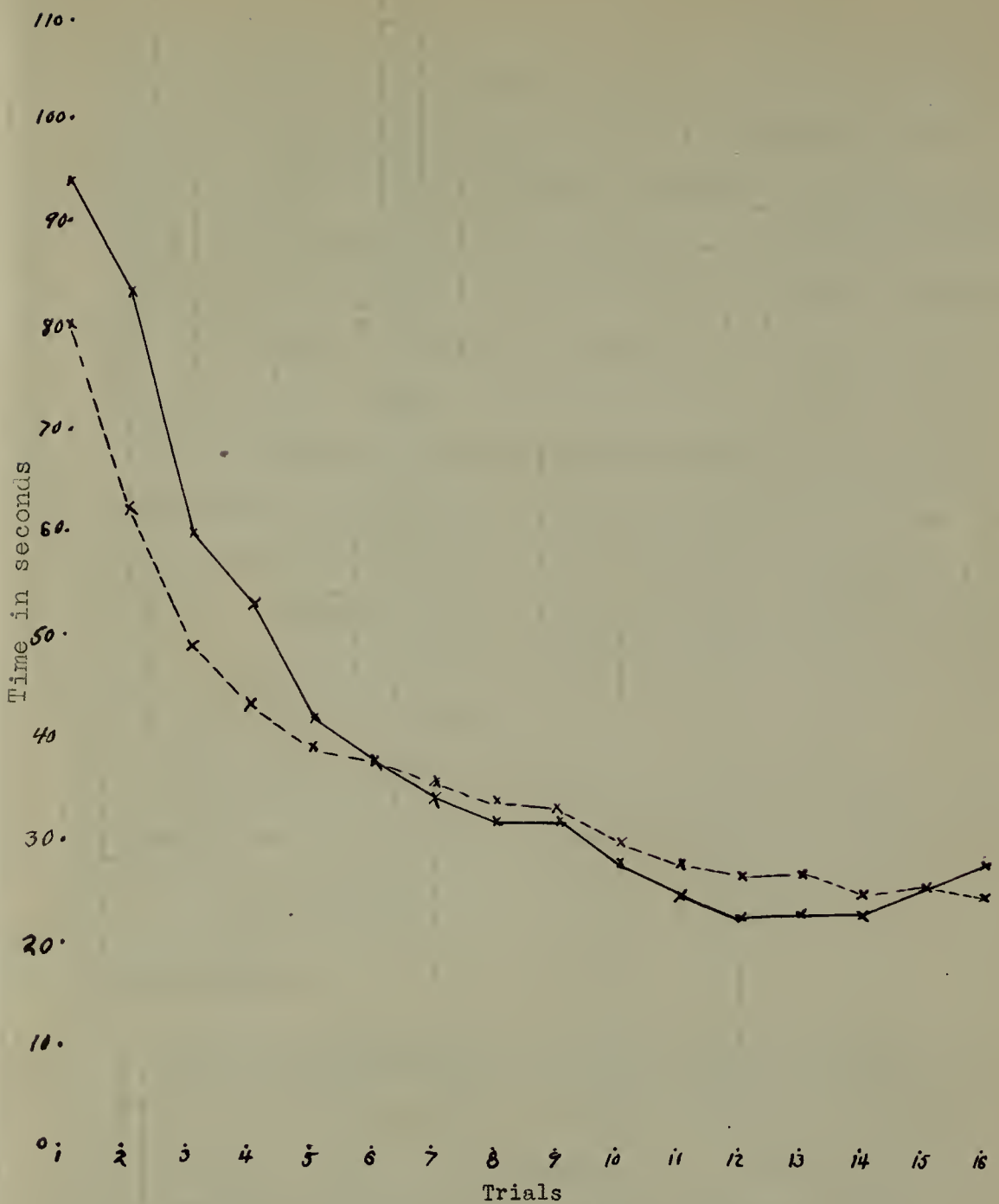


Figure 28. Graphic representation showing the effect of practice upon the Time curve.
(Boys and girls separately)

for boys and girls, computed for the sixteen right-hand trials. The average length of time is practically the same; the spread for the girls is somewhat greater. The girls were slower getting started, but they overtook the boys on the sixth tracing. Toward the end they tried harder than the boys to do better, which had no other effect than to retard their speed. This brought the boys for final placing better than the girls. There were no reliable quantitative differences apparent for boys and girls. There is, however, some evidence of a qualitative difference that is more consistent than reliable. Notice that the curve for boys is steadier, and steadier in spite of the fact that there were fewer boys than girls.

Figure 29, similar to Figure 28, except that it tells the story of the errors, reveals nothing new either in form or in interpretation.

Intelligence:

Intelligence, in this investigation, represents that type of ability which can be measured by school grades and psychological tests. McDougall says: "The capacity to acquire knowledge and skill we call vaguely 'memory'—the capacity to apply them effectively we call intelligence." (18)

The first part of this chapter failed to reveal anything

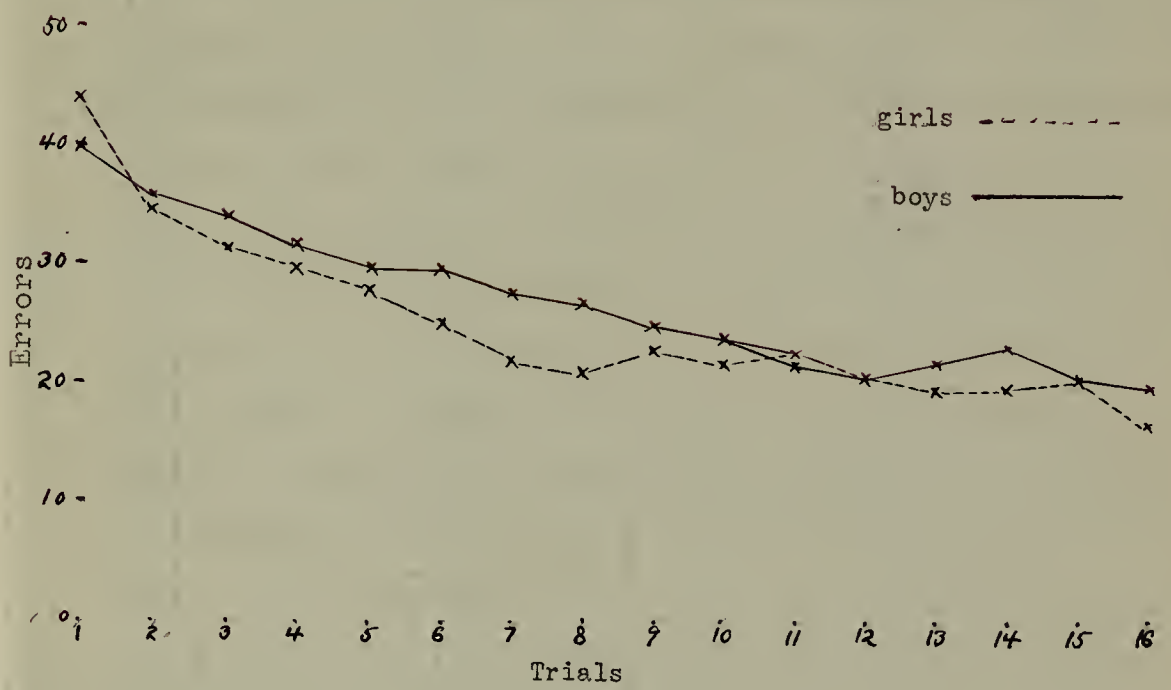


Figure 29. Graphic representation showing the effect of practice upon the Error curve.
(Boys and girls separately)

very distinctive in the difference between girls' scores and those of boys. Nor is there anything very striking when it is intelligence that is being considered. Exactly the same subjects were used here as in the first part of this chapter. Between intelligence, as shown by the I.Q.'s the coefficient of correlation is slightly negative. This correlation does not prove, of course, that general intelligence is of no value in adaptation to the test. It is a common occurrence to find surprising expertness or inexpertness in unexpected quarters. It is interesting to cite here, that while the coefficient of correlation between intelligence and mirror-drawing is negative in this study, the boy with the best mirror-drawing rank stands high in both scholastic achievement, and in psychological testing (I.Q. 149); and that the boy with the poorest mirror-drawing rank is the school's most skilled worker in wood-working. (I.Q. 110) Interesting examples may be contradictory, but the trend is unmistakable. With a group of this size such a coefficient is indecisive, but at least it weighs against the possibility of a very high positive correlation.

There is evidence that students seldom work to capacity. In many cases only the effort necessary to satisfy requirements is expended. It has often been noted that the very intelligent do not seem to achieve school success in any

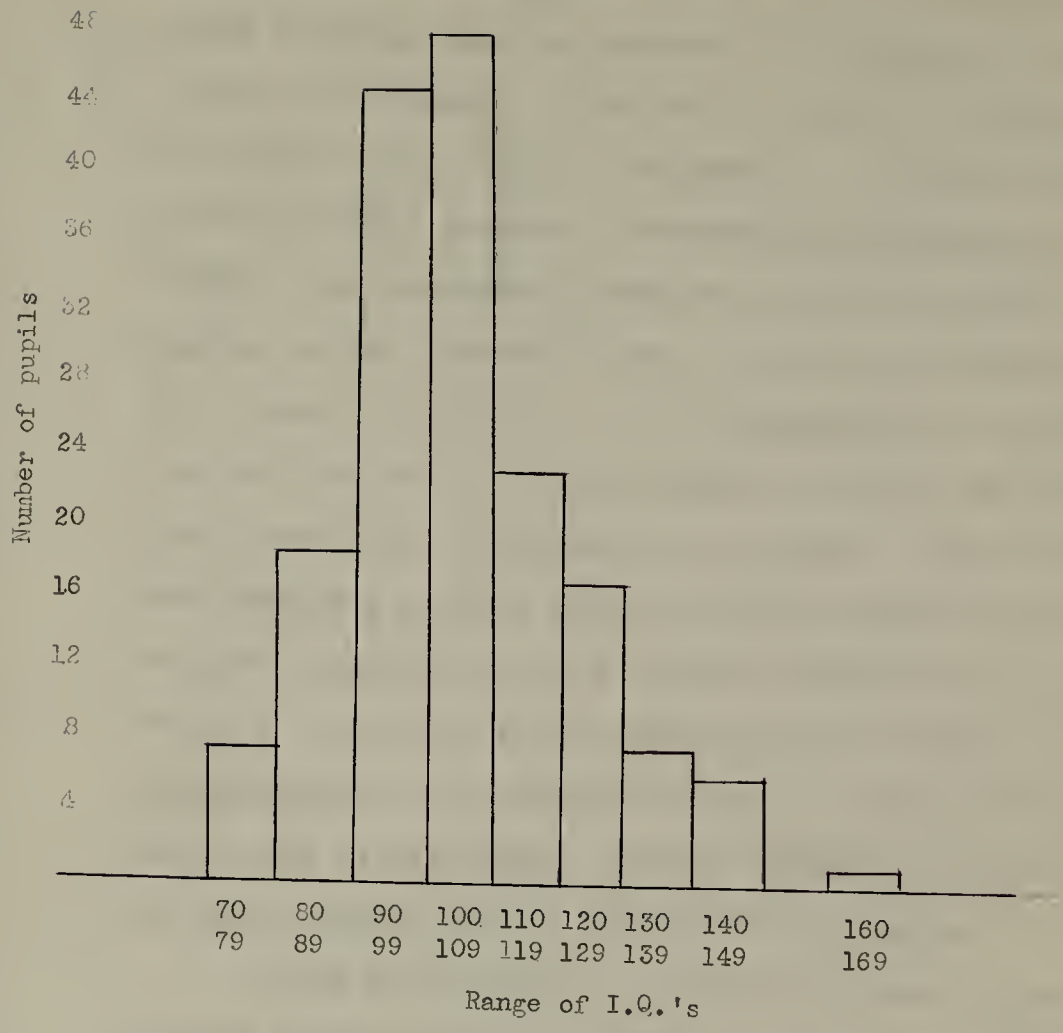


Figure 30. Bar Graph showing the relative frequency of the I.Q.'s. The skewness may be charged up in part to the fact that there was a relatively small number of people in the group, and that there was considerable selection.

corresponding proportion. Noticeably wide is the difference found between those of superior intelligence and their scholastic achievement. Conversely, inferior intelligence does not necessarily imply a completely unsatisfactory accomplishment in school success. Patience, persistence, painstaking effort, and stick-to-itiveness overtake capacity. The pupils in the Greenfield High School are divided into sections on a basis of ability. It so happened that the time of writing this paper, an A group, and a D group, in the same subject, were both included in my classes. Since there were two sections between these two, and since these two intermediate sections met with another instructor, the difference between them as superior and inferior groups, was most marked. Comparisons of the results of the two groups in mirror-drawing were used as additional data in connection with the influence of intelligence on the mirror-drawing score.

Figure 31 and Figure 32 show that the A group took a little longer time, and made a few less errors. This is quite in accordance with the sentiment that superior students, as a group, show persistence, initiative, courage, and control to be common characteristics, while the inferior group is marked by timidity, impatience, and carelessness, which in a measure, account for their failure. The most striking difference, however, between the superior and the inferior

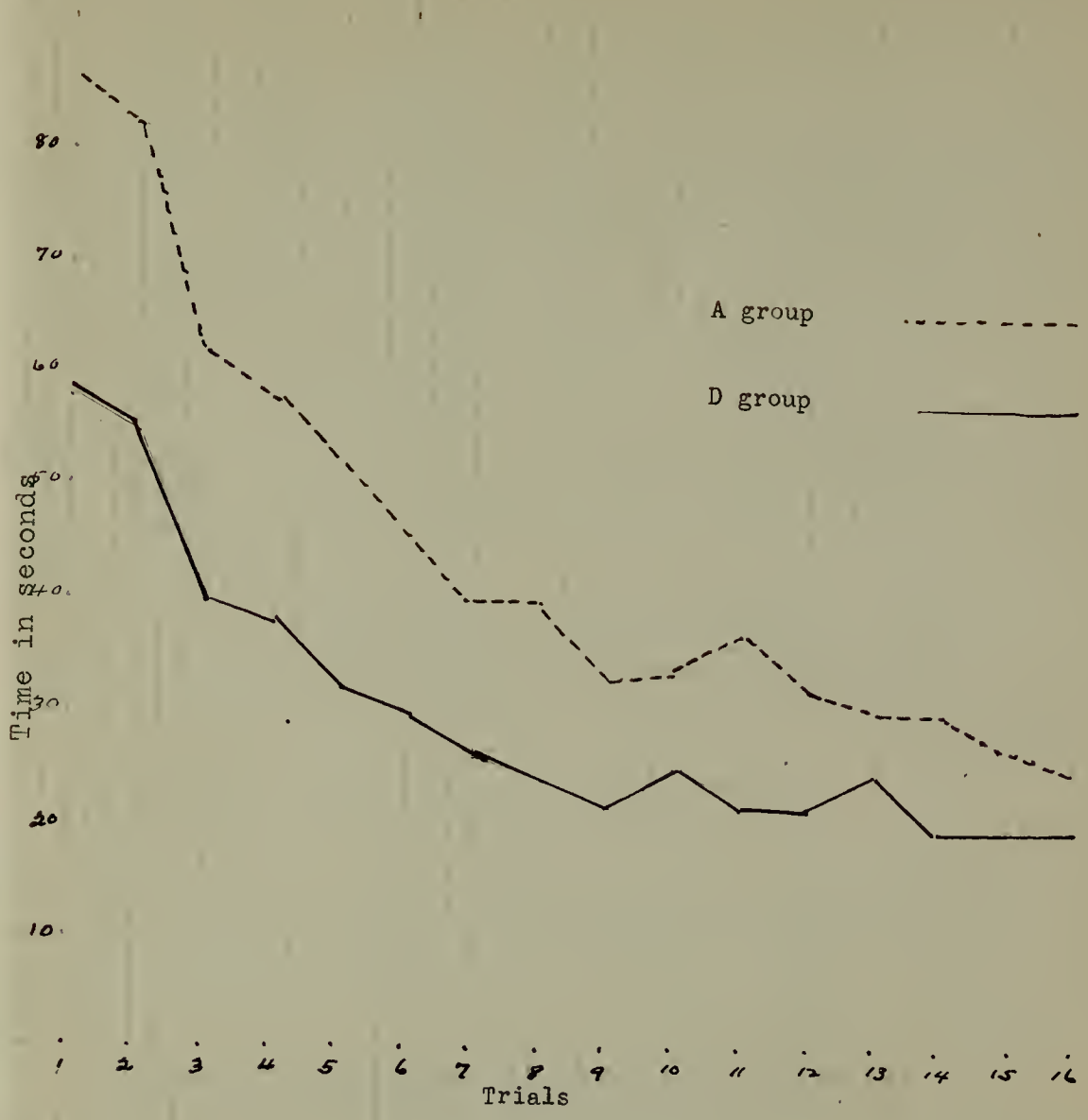


Figure 31. Graphic Representation showing the Effect of Practice upon the Time Curve.
(An A group and a D group)

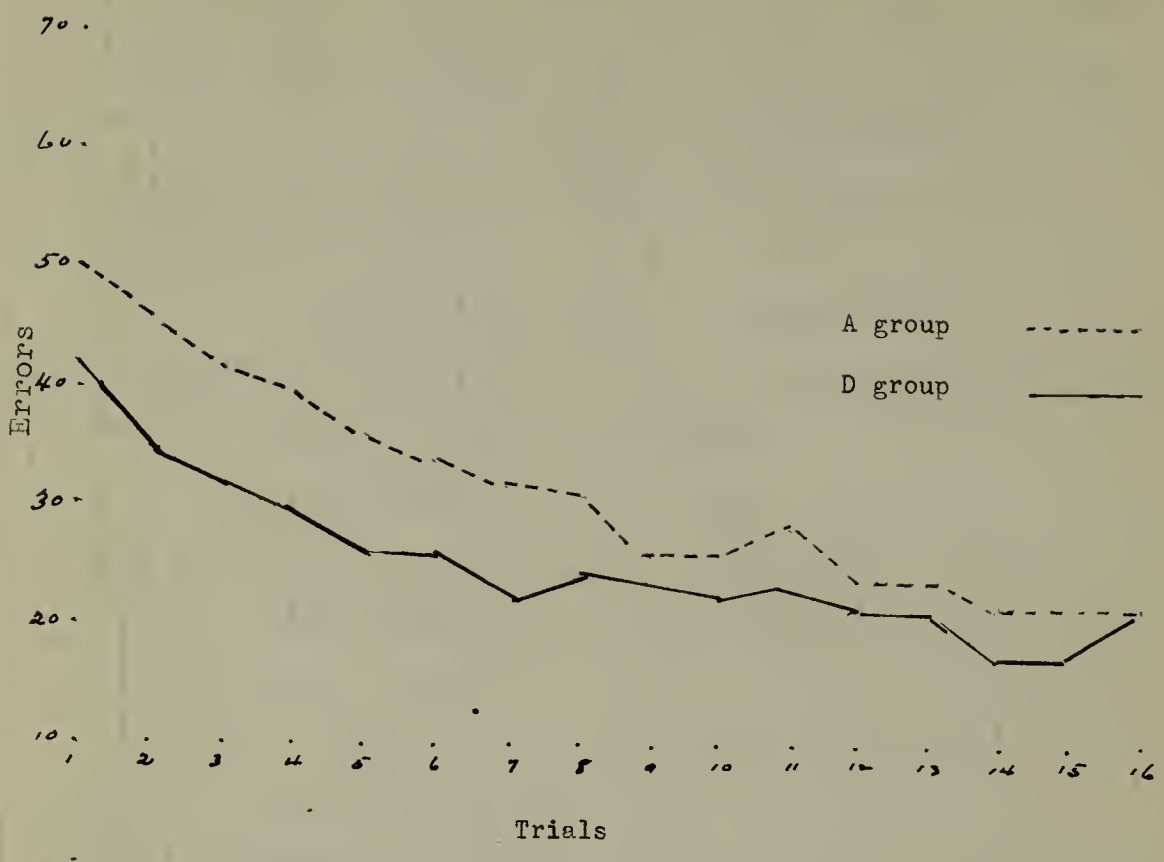


Figure 32. Graphic Representation showing the Effect of Practice upon the Error Curve.
(An A group and a D group)

group lay not in achievement, but in the concern which they manifested in the process. The inferior group, calloused from attempting problems which over-tax their capacities, made little effort to overcome the difficulties. The superior group, on the other hand, offered many apologies for their lack of skill, as they wiped away the perspiration. There were some in both groups who rejoiced in their success; of these the rejoicing was greatest with the D group, since with them success comes less often.

Another group of factors closely allied with intelligence are those of the emotional and temperamental variety. The nervous child, regardless of intelligence, became panicky at the outset. If he was especially nervous he seldom fully recovered. One particularly conceited girl burst into tears when a friend, supposedly duller, exulted at his own superior accomplishment. Inferiority complexes, and shifting states of embarrassment and elation were only too evident.

Typewriting and Drawing:

Assuming, then, that mirror-drawing is a motor accomplishment, we will proceed further in this investigation by comparing the mirror-scores with other scores likewise motor by nature. First, it may be said that no learning process is purely mental and that relatively few on the human side at

least, are purely motor by nature. The terms "purely motor" and "purely mental" simply refer to the extreme points on the behavior scale, with most human learning actually falling somewhere in between.

Typewriting and drawing were chosen as types of motor abilities. Typewriting was selected for no more logical reason than familiarity. Since typewriting is included in the commercial curriculum, these ranks were easily available to the author as a teacher of commercial subjects. Furthermore, it is well known that success in typewriting does not wholly depend on intelligence.

It had been observed before actual statistical work had been begun, that as a rule those pupils who were skilful in typing showed mirror-drawing ability as well. With this in mind a correlation between school grades in typewriting and ranks in mirror-drawing was begun. In our school 60 is a passing grade in all subjects. The average mirror-drawing score, which includes both time and errors, for all right-hand trials, was taken on a basis of judgment for mirror-drawing. The average score was 36.23; for the sake of convenience 36 was used. It must still be remembered that the smaller the mirror-drawing score, the greater the ability. It is also true that in normal distribution the "average" rank is somewhat better than what is just "passing".

This would advance the score 36 toward 40; how far it is hard to say.

Typewriting:

There were eighty cases included in the comparison of typewriting and mirror-drawing.

Interpretation of Figure 33:

The scatter diagram is shown divided into four sections on a basis of ability in typewriting and mirror-drawing.

The upper left section shows the cases with inferior grades in both typewriting and mirror-drawing, the upper right shows superior typewriting but inferior mirror-drawing, the lower right shows superior typewriting as well as superior mirror-drawing, and the lower left the cases that excel in mirror-drawing but with inferior typewriting.

A glance at Figure 33 shows that the majority of cases fall in such a position as to indicate that ability in mirror-drawing carries with it the ability to do typewriting, and that lack of ability in one is accompanied by lack of ability in the other. This accounts for 70 percent of all cases. These results were disappointing, if not surprising. Perhaps, after all, seven out of ten cases, as the diagram shows, is all that should be expected, since we have never been led to

Typewriting

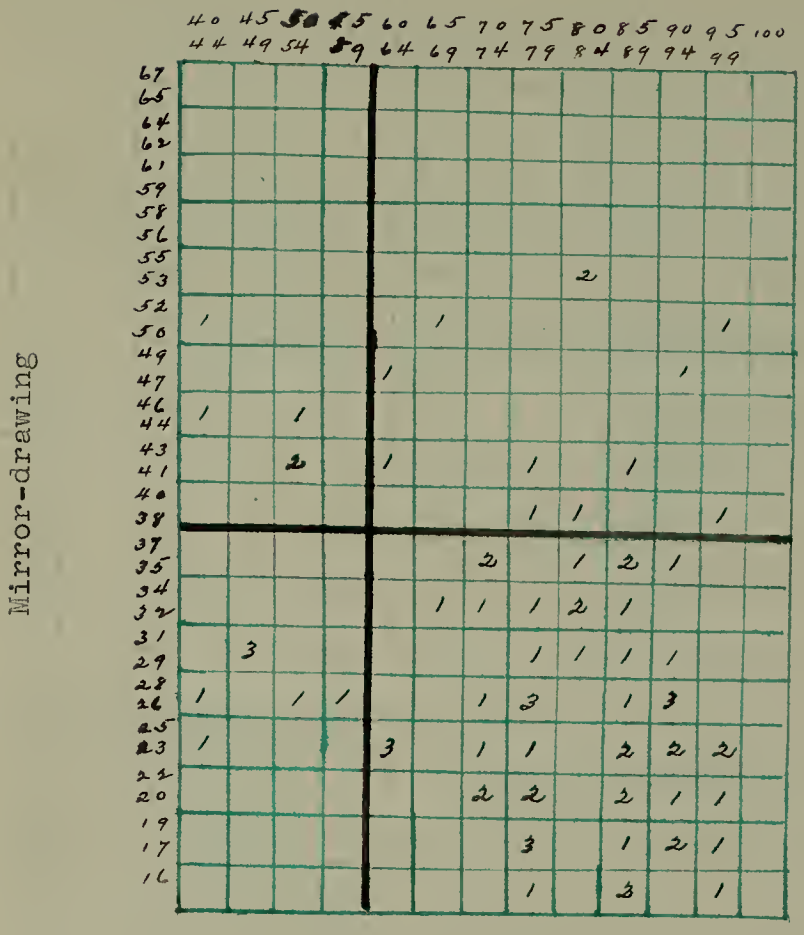


Figure 33, Scatter-diagram showing the relation between Typewriting and Mirror-drawing.

believe that superiority in one form of motor ability necessarily signifies equal success in every other.

The coefficient of correlation is .279, positive, but not very high. There are too many whose typewriting is satisfactory but whose mirror-drawing score is very poor.

Perhaps the most striking point to observe is that while the lowest score for the entire group of one hundred sixty-seven pupils is 67, there is no one taking typewriting with a mirror-drawing score below 55, and only sixteen with a mirror-drawing score below the average. If the factors that govern mirror-drawing are the same as those for typing, then either of two things might be true--either the practice in typing has been transferred to mirror-drawing, or some of the poorest have already been elimimted from the typewriting group. Without a control group it would be impossible to prove the transfer; in regard to the latter possibility, the best students rarely drop out, and in a sense those pupils who continue in any subject over a considerable period of time become a "survival of the fittest".

The group in the upper right section is the hardest to understand. It is a sizeable group, too large to be ignored, consisting of those who are skilful typists, but with little ability in mirror-drawing. The most satisfactory explanation there is to offer is that there is a possibility that for them

skill in typing came only as the result of greater effort and practice.

Drawing:

When the results of the comparison of mirror-drawing with typewriting scores failed to disclose anything of unusual interest or importance, the comparison with mirror-drawing and drawing was attempted in similar manner, and with more pertinent results.

It was possible to compare the scores in mirror-drawing with those in drawing, for ninety pupils.

Interpretation of Figure 34:

The scatter diagram for drawing and mirror-drawing bears a strong resemblance to the preceding one for typewriting and mirror-drawing. It also is shown divided into four sections. The upper left section, containing no extreme cases, indicates that superior art does not exist with very poor mirror-drawing. The upper right shows superior drawing with superior mirror-drawing. The lower right shows superior mirror-drawing with poor grades in drawing. The number of cases is sufficient to warrant investigation. The lower left section signifies lack of ability in both drawing and mirror-drawing.

The upper right and lower left sections indicate the cases where excellence in mirror-drawing and drawing exist

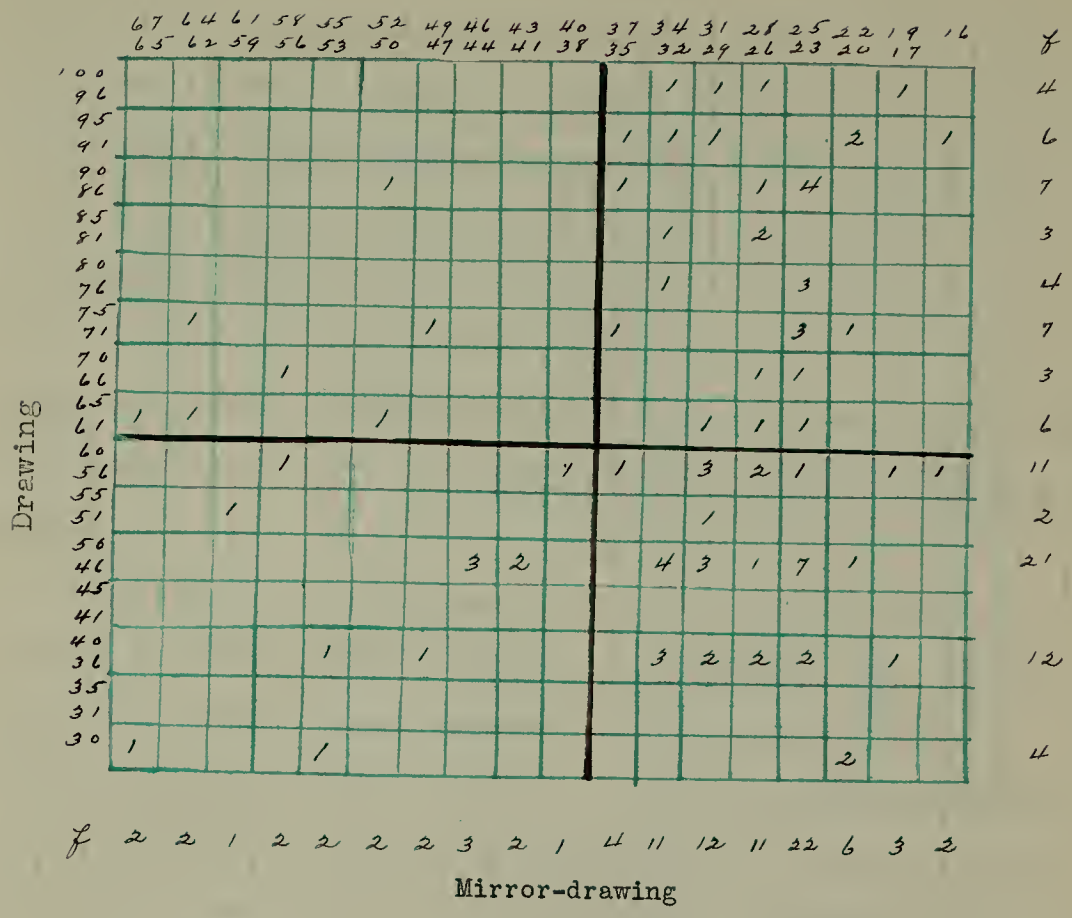


Figure 34. Scatter-diagram, showing the relation between Drawing and Mirror-drawing.

together, or conversely, where absence in skill in one is accompanied by absence of skill in the other. Although these two sections include more than half of all cases, the coefficient of correlation for drawing and mirror-drawing is not large, .293. Nevertheless, it is the highest found in this study. Other correlations have been with time and errors, boys and girls, mirror-drawing scores with intelligence quotients, and mirror-drawing scores with school grades in typewriting. None of them is large enough to be significant.

The lower right section, with thirty-six cases, is perhaps the hardest to understand. These are the pupils with good mirror-drawing ranks, but who are failing in drawing, although they elected it. In our school drawing or "art" as it is called, is elective, but credits earned count toward graduation. An "artistic temperament" has been the traditional explanation for many lapses from expected behavior in the past. May it not be used here to explain the unaccounted-for cases in the lower right of the diagram? We do not wish to strain the data to show that these pupils who have the ability to excel in drawing are unable to resist the opportunity to waste their time which the freedom from discipline offered in the atmosphere of the drawing department. The novelty of the mirror-drawing experiment, complete in one short sitting, overcomes their usual boredom, and permits their

natural ability to assert itself.

Having observed that pupils who were working in the drawing department, as a class, were slower than the average, and that they regarded the experiment more as a problem to be worked out than as a "stunt", it was decided to drop for the time being the time factor and consider only accuracy. As a further investigation into the comparison between mirror-drawing and art, a scatter diagram between drawing and errors in mirror-drawing was prepared. (Figure 35) The results found compare very favorably with the upper left section of the preceding diagram—that ability in drawing rarely exists without ability in mirror-drawing, or conversely, accuracy in mirror-drawing might be used as an index for ability in art. It shows but three cases with more than fifty-five errors in mirror-drawing, and only eleven cases with more than the average errors. (The average used is for the original one hundred and sixty-seven cases.) In other words, success in art seems to go hand in hand with accuracy in mirror-drawing. It is at this point that the author offers whatever evidence this study may contain, to show that the real value of the mirror-drawing experiment is not value in its own right, but value that might be used in some form of orientation.

Persistence of the Effects of Mirror-drawing:

Mirror-drawing provides no exception to the general

Grades in Drawing

Errors in Mirror-drawing (average)

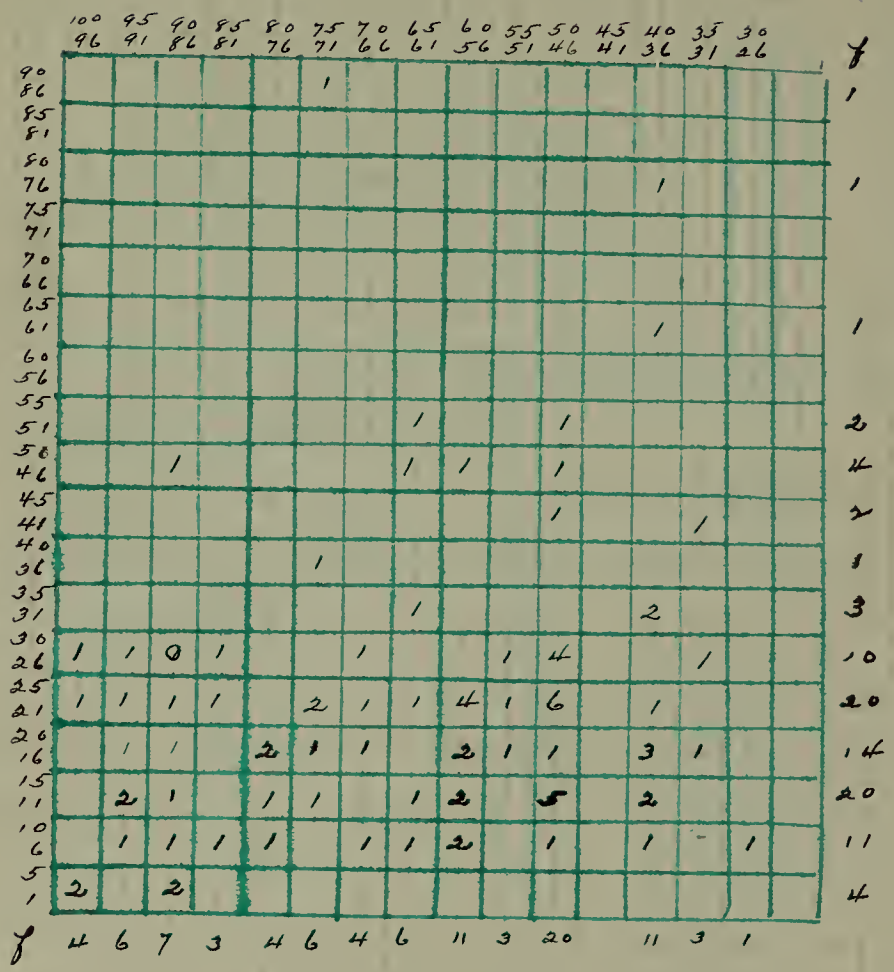


Figure 35. Scatter-diagram showing the relation between Errors in Mirror-drawing and Drawing.

principle that motor learning is lasting. One does not have to learn to skate each winter; the loss in speed in typewriting due to long intervals without practice may be regained in a comparatively short time. So it is with mirror-drawing.

It was possible to make some retests after a lapse of two years. Without exception the first of the second series showed some improvement over the initial tracing; usually there was marked improvement. Of course, the opportunity for showing the persistence was greatest when the first tracings were unusually poor.

In this experiment, the average time for the first tracing was 90 seconds, two years later it was 32 seconds. (The second group did not contain all those students of the first group.) On an average, the re-learning was so rapid that after five trials, accuracy had been regained that was equal to the final records of the original series.

Figure 36 shows the first tracing in the original series of pupil No. 2. Figure 37 is a copy of the first tracing in a series made after an interval of two years. This was an unusual case, in that the beginning of the second series was decidedly better than where the first left off two years before. This may be explained by the fact that she was one of the first to try the experiment when everything was new and strange. Figure 36 is mute testimony of her initial nervousness and marked self-consciousness. Although she did

Name	2	Number	1 R
Date	January 17, 1932	Time	6' 40"
		Errors	100
		Score	250

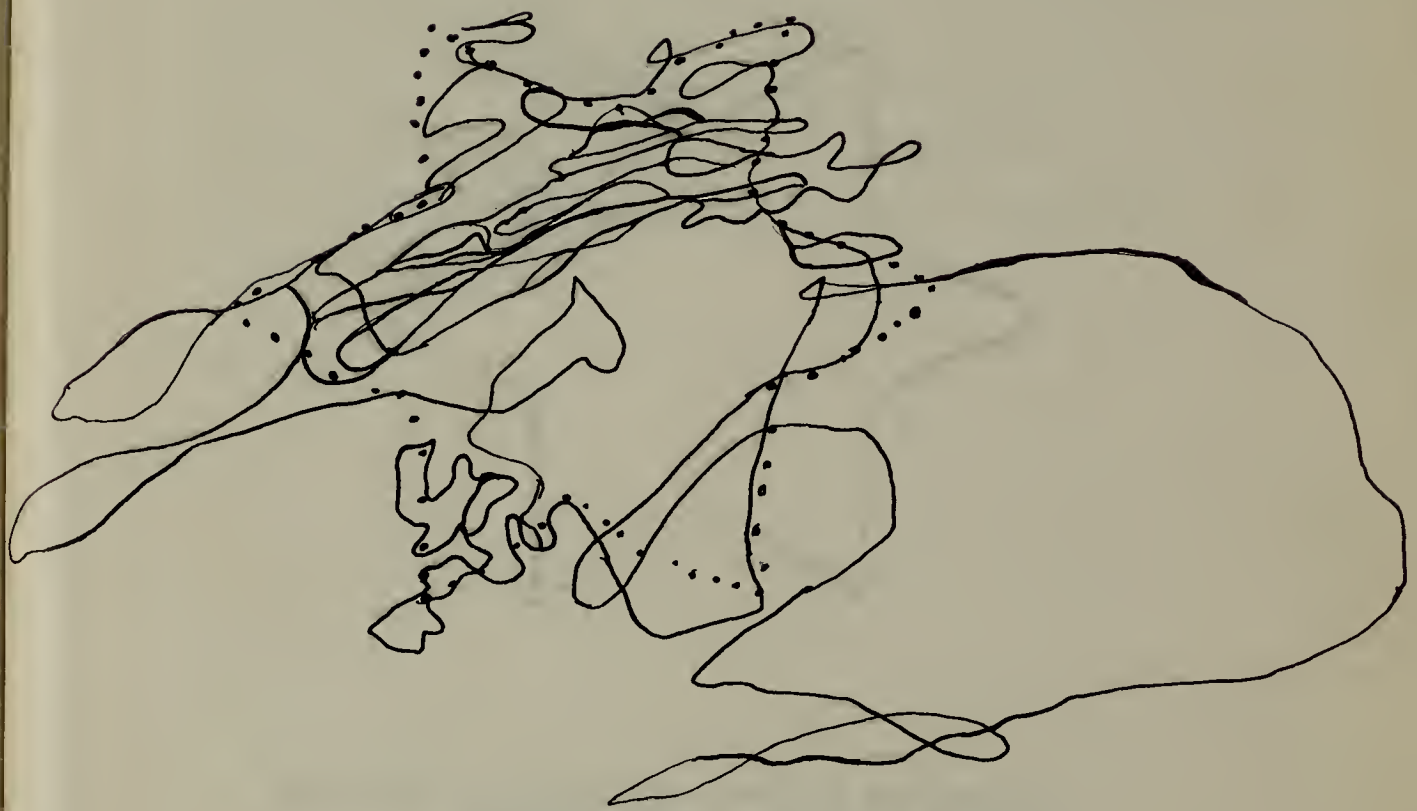


Figure 36. Copy of a star, the first of a series, traced by the girl who experienced the greatest difficulty in adjusting herself to the reversing effect of the mirror.

Name	2	Number	1 R
Date	February 13, 1934		(second series)
		Time	48"
		Errors	9
		Score	27

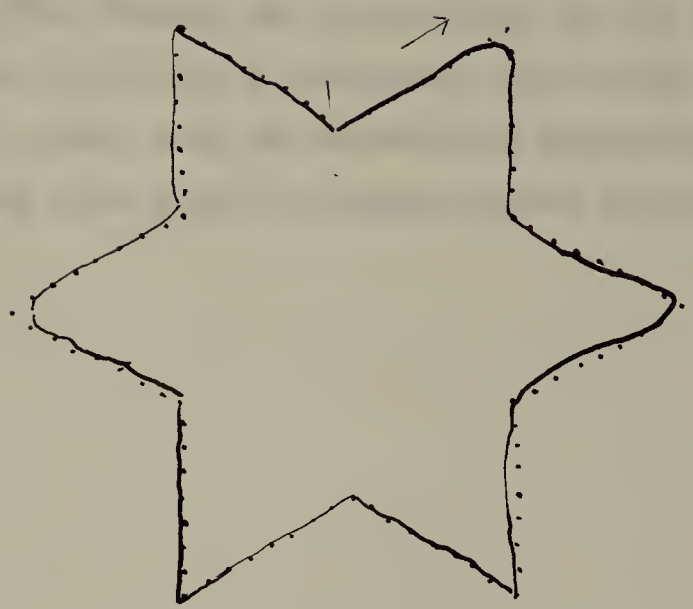


Figure 37. Copy of a star traced by the same girl two years later, and without practice during the interval. It shows the persistence of mirror-drawing.

not attempt a tracing during the interval she grew very much accustomed to the apparatus and procedure. The nervous attitude disappeared and the subject demonstrated her ability in the phenomenal improvement.

Mirror-drawing seems, therefore, to resemble muscular habits, like skating and typewriting, in the manner in which skill once developed is retained, with little loss over long periods, rather than the associative connections of mental activities with their relatively lesser persistence.

CHAPTER VI

THE LEFT-HANDED

Miss June Downey, in her findings in the various fields of handwriting analysis, has made valuable contributions over a long period of years to the study of left-handedness. "About four out of a hundred are born left-handed, but three of them are using the minor hand. Among the one hundred supposedly right-handed persons whom we measured, we found three who gave constantly, for the four measures, an excess in favor of the right side. One of the subjects reported himself as ambidexdrous, and in fact the difference in favor of the left is very slight. He is very inexpert at mirror-writing. The other two belong in our best quartile. One of them admitted that he was left-handed. He calls himself right-handed because of writing with the right hand; he does, however, a number of things with the left hand. No particular pressure was exerted to make him write with the minor hand. As a matter of fact the difference between the two hands is not extreme. The third case shows an extreme difference between the two arms and hands. Questioned in detail this pupil does many things with his left hand. He supposed this was due to accident in forming certain habits." (10) In this same report, "Unidextrality and Mirror-Writing,

the result of a comprehensive research, she finds little difference as to hand, provided the subjects are not "shift-overs". The detection of the shift-overs already referred to, by arm and hand measurements, is a contribution of Ernest Jones, of the University of Wyoming, who worked contemporaneously with Miss Downey. "Some left-handers," writes Professor Jones, "are transfers, since their right side measurements are considerably larger than the left-side ones. A parent is left-handed; the left-handedness of a child may be explained by imitation". (10)

In this study eleven of the one hundred sixty-seven people were left-handed. Since not more than four left-handers to the hundred are anticipated, this is rather more than the average, due to the fact that every available one was included. It had been hoped that special attention might be given here to the relationship of left-handedness to skill in mirror-drawing, but data were too meagre.

We would like to pass the matter by, however, with the statement that the left-handed people in this group revealed an expertness quite above the average. They were careful, accurate workers, although individual differences were as apparent here as elsewhere. The small number observed, of course, make the results mere speculation.

CHAPTER VII

CROSS-EDUCATION

It is well known that training given to one muscle group will carry over to other muscle groups, and that a considerable amount of practice gained with one hand is transferred to the other unpracticed hand. Beginning with Weber a long line of investigators have noted this phenomenon, usually called cross-education. Outstanding experiments in the field have been performed by Scripture, Smith, and Brown on steadiness of hand, Woodworth on ability to hit a target, and Starch, Ewert, and Bray on mirror-drawing. K. S. Lashley, of the University of Chicago, has also noted transfer effects in the course of work on cerebral function in learning. He taught monkeys to open a problem box with the right hand. He then destroyed the motor area of the left cortex, thus paralyzing the right hand. When the animals were again placed in front of the box they used the left hand, the feet, and even the head to open it. The animals are said to have shown little or no random movement.

In 1928 Professor Charles W. Bray, in the Psychology Laboratory of Princeton University, undertook an experiment to study transfer from one part of the body to other parts, mirror-drawing being chosen as the task. The procedure followed that described by Dearborn and used by Starch and

Ewert. The subject traced a star which he could see only through a mirror, similar to the method used here. An effort was made, so to adapt the experiment that the task could be performed by the feet as well as by the hands. Technical difficulties as well as the difficulties of the task prevented the attempt to obtain data from hands to feet; but the impression of the experimenter and that of the subjects as well was that the feet gained considerably from the practice of the hands. Transfer from right to left was shown by the results; but because of certain errors in the procedure this work was unsatisfactory. The results confirmed, in general, those of Ewert (11) on transfer from preferred to non-preferred hand. Professor Bray (2) found that varying the amount of hand practice from ten to sixty trials had no effect on transfer of learning to the foot. He interprets this to mean that the slight improvement characteristic of the hand practice after the first few trials is not transferred.

T. W. Cook (6) (7) of Acadia University is at present expending all his energy in a modification of this same task of tracing a six-pointed star seen in a mirror. He found, using himself as a subject, that one hundred trials practice tracing a six-pointed star with the left foot, resulted in a marked gain at the same task with the right hand. The superiority of hand over foot, however, again made

comparison difficult. He is at present at work on the same task, with new subjects, three groups of ten each (one is a control group), with new apparatus which emphasizes the direction component.

Several types of explanation have been proposed to account for transfer from one part of the body to others. The early investigators found an explanation in terms of the improvement of some faculty. Explanation by faculties is no longer acceptable, being regarded purely verbal. Other explanations of cross-education and transfer from one part of the body to another have been drawn from the related field of transfer from one situation to another. This has led to two theories, that of identical elements, and that of generalization. The theory of identical elements would say that transfer from one part of the body to another takes place when the subject learns part activities involved in the performance of both members. Thus Woodworth suggests (34) that common head or eye movements may be involved in the performance of an act of skill by either hand. "L'exercise d'une main n'est pas entierement separe de celui d'autre; les mains sont souvent innervees ensemble et donc entrainees specifequement en meme temps." The theory of generalization does not differ greatly from that of identical elements except

that it emphasizes conscious rather than behavior factors. It suggests that transfer is due to the generalization of methods, attitudes, or ideals learned in practice by one part of the body and applied by a performance of the act to another part.

The two theories are more or less complementary. They can therefore be combined and called the theory of "common elements."

One further possibility has been advanced to explain transfer. From W. W. Davis, of Yale, we learn of the theory that assumes some sort of practice of the unused member. Mere familiarity with the set-up of the experiment and the overcoming of nervousness is probably important in transfer.

Of the existence of transfer there is no doubt; the amount of transfer is not so easy to determine. By the old method two tests were made on some part of the body, interposing a period of practice with some other part. The difference between the first and the last tests is assumed to show the transferred improvement. Unfortunately the method fails to consider the effect of the first test upon the second. Acts of skill are known to improve greatly in the first few trials; so it is only to be expected that the second test will show an improvement over the first. For this reason the method described gives no adequate measure

of transfer. This defect was pointed out by P. H. Ewert, who has shown that early estimates of the amount of transfer must be discounted, and a different method followed.

Ewert used two groups of subjects, one of which followed the usual procedure. The other group acted as controls, receiving only the end-tests of the unpracticed part. Comparison of the relative improvement of the two groups gives an adequate amount of transfer. Ewert found that the non-preferred hand improved 36 percent in time, and 21 percent in errors in fifty-trials practice with the preferred hand. Measured in the old way the transfer would have been 82 percent in time, and 76 percent in errors. This shows that previous estimates of transfer have been too high, but that some transfer actually occurs. Starch, one of the first in the field, reported 90 percent. Ewert was also able to show that transfer is greater from the preferred hand than in the opposite direction.

This experiment attempted nothing more ambitious than the transfer of learning from the preferred to the non-preferred hand. In the absence of a control group, it would be safer not to say how much--except, perhaps, that the amount was so considerable that it surprised and astonished all concerned. A glance at the tables on pages 40 - 51 confirms this.

CHAPTER VIII

THE SPECIAL OR OPPORTUNITY GROUP

Perhaps the group of greatest interest, and surely the one which produced the most unexpected results were five pupils, two girls and three boys, from a special or "opportunity" class, enrolled in the public schools of Greenfield. The programs of these pupils are so arranged that they come to the High School a scheduled number of periods each week that they may take advantage of the greater opportunities for shop and laboratory work which a school of twelve hundred pupils offers, and where it was hoped they might mingle socially with others of equal age. But the responsibility of protecting them from bodily harm was more than the teachers of printing and carpentry cared to assume, so eventually they found places only in the placid atmosphere of the drawing room where there were neither presses nor saws. It was there that the author found them, and from where they were gladly loaned out as many and as often as the author wanted. In chronological age they varied from fourteen to sixteen years. But their mental ages were so low that it had been impossible for them to take the tests which purpose to measure intelligence. As several pupils' records are on file with I.Q.'s in the 60's, the inference is that theirs was below that. In drawing, however, they showed considerable native ability.

All five that I met were in every sense of the word perfect examples of the "under-privileged" child. The first boy to come to the author was a state ward, with parents "unknown", according to the school records. Not only did he have the misfortune of being mentally defective and homeless, he was the blackest little urchin imaginable, on whom some one with a perverted sense of humor had bestowed the name "Golden"! He arrived wearing a pair of patent-leather dancing slippers several sizes too large, from which the soles had been almost completely worn away. He watched me inquiringly while I explained what it was I wanted him to do, but showed no inclination to start until assured that this had no connection (for him at least) with school work. From that point on all my remarks were interspersed with many "Yes ma'am's" in true negro style. Then I saw that his suspicions were calmed and that he was ready to start. His procedure was calm and deliberate; there was an air of confidence in his manner. Although we have every reason to believe that every thing was new to him, he worked as if with a practiced hand. Nor did he appear in any way different from other boys. He made sixteen tracings with his right hand and a final one with his left. His work was outstanding in that it was so free from errors. In both time and errors, it fell in the best quartile; his mirror-drawing rank is 19.

All the pupils from this group were under-size and underweight. Indeed, lack of vitality has been made a feature of a diagnostic scheme for detecting intellectually subnormal children. The next boy to come was no larger than a ten-year old, although there was something that stamped him as being older. He was quicker than the first boy, and while not so accurate, still kept his score in the first quartile. He seemed very much pleased with himself when he found that he could do what was expected. The encouraging remark, "You're a prize pupil!" brought back the response, "Oh, is there a prize?" This gives an idea of the immaturity of his mind; no regular pupil would so have construed the author's meaning.

And then there was a subject named Sophie. She was the thinnest of them all, a particularly frail looking little girl, with big blue veins that stood out on her temples. The mirror-drawing apparatus was on a table in a small room opening off the typewriting room. Through the open door she watched the pupils operating typewriters at top speed, a group busily engaged running off copies on a neostyle, fifty a minute, and it just happened that over in the corner still others were cleaning stencils and hanging them up to dry on an improvised clothes line. Sophie was fascinated. Although her record shows her to be one of the slowest in mirror-drawing, her time was not spent in making random movements as was the case of

other pupils who spent longer than the average. She would draw a few lines and look around. Then realizing she wasn't doing what she came to do, would work steadily on a little longer, only to lose herself again in her unaccustomed surroundings. Perhaps it would have been wise to have closed the door when the adjoining room was in use, but other pupils had not found it distracting. As for errors, they were surprisingly few. And so it was with the other two. In general, the pupils of this class took less time than the average; but the greatest difference lay in the fact that they made such few errors.

There may be a significance in this which we cannot afford to overlook. Mental defectives are a very real worry; any substitute for intelligent self-direction would lighten the burden. This investigation suggests that mental defectives show striking variations on the manual side that might possibly serve to place them into groups. Mirror-drawing is a complex process. If these pupils are capable of success in mirror-drawing, why would it not be possible for them to achieve equal success in some more profitable occupation?

TABLE 8

Errors made by a mentally-defective boy.

Trials	Errors
1	6
2	8
3	10
4	2
5	6
6	15
7	7
8	3
9	2
10	5
11	3
12	3
13	5
14	3
15	3
16	6

TABLE 8 shows what the error-free good star he was able to trace.

CHAPTER IX

THREE OTHER GROUPS

Before this study comes to a close, three other groups, more or less involved in this experiment, should be mentioned. First, there is a small group from the Massachusetts State College. At the very beginning I had planned to use some of the graduate students from the psychology department as subjects. After twelve had been approached and several trials made, the idea was abandonned. No one made more than seven trials--one left-handed one, and six right. Of the twelve, ten were already "wise" to mirror-drawing procedure. It was a common occurrence for them to preface their attempts with "I can't do it. I never could. It drives me crazy." One girl announced that success was not the award of effort, so she made no conscientious endeavor. Furthermore, aware of the results of other investigators, they were a bit suspicious about participating in an experiment of doubtful prognostic content. Instead of an investigation to reveal what it might, my experiment was transformed into a demonstration showing that mirror-drawing skill varies inversely with intelligence! On the whole, the results were decidedly unsatisfactory; some one else had their learning curve. It seemed better to confine this study to the less sophisticated

high school students.

The second group was comprised of friends, older than either high school or college students. Without exception they regarded mirror-drawing most intricate and perplexing. Usually, they did not care even to attempt a left-hand tracing. In any line it is usually true, adults do not care to take over too much that is new. Ten, twelve, or fifteen minutes were not uncommonly long for the first tracing. The finished product, as a rule, was a fairly respectable star, but the tracing of it, in many instances, was attended with much nervous energy. Apparent with the college students, and still more evident with the older ones, the time factor showed an inverse correlation, though not a high one, with age.

And lastly, we come to the group of which the author is the sole representative. In the beginning it seemed that of all poor subjects, she was to be the worst. Progress was slow. The initial drop in the time curve did not come until after more than twenty-five tracings, seven more than in the series made by the pupils. Even then it took more than a minute to trace a best star. The stars, themselves, were nervous-looking figures, with no more distinguishing characteristic than the length of time consumed in executing them. More than one hundred twenty-five tracings have been

Figure 38. Copy of a star traced by the author.
(This star was traced fairly early in the series)

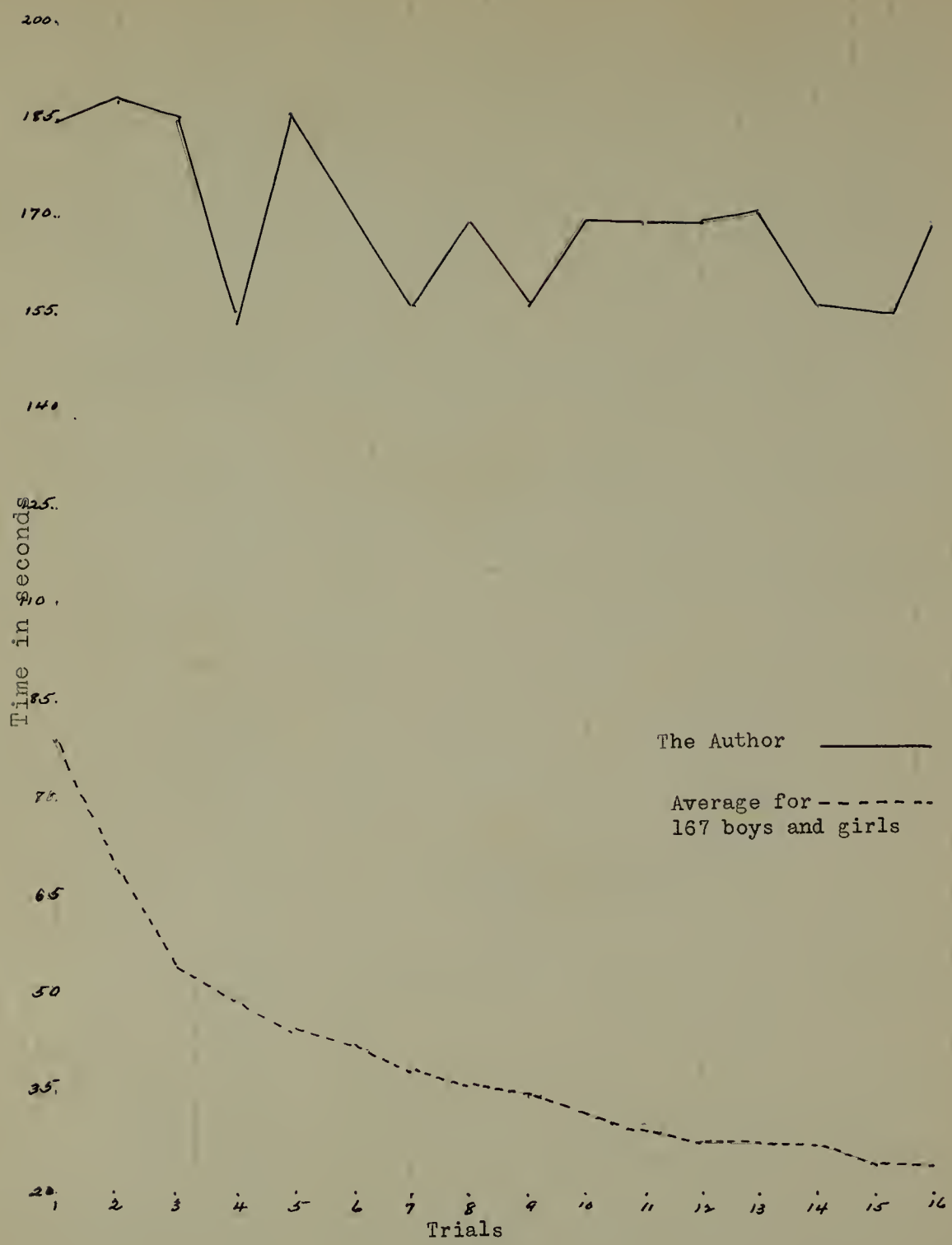


Figure 39. Time Curve of the Author, for 16 Trials; below is the average Time Curve for 167 Boys and Girls.

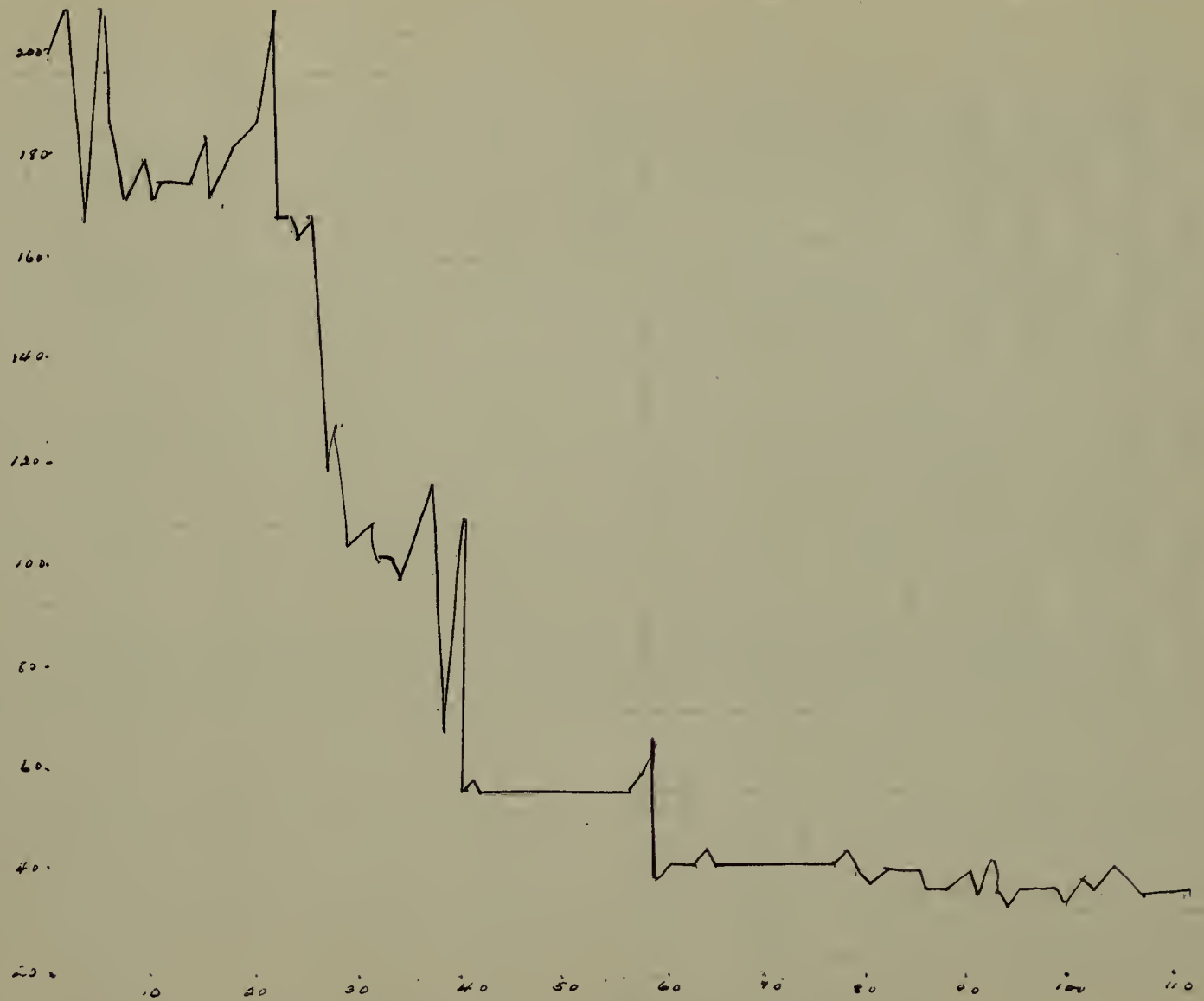


Figure 40. The Time Curve of the Author for 110 Tracings

made, but there seems to be no observable improvement after the seventy-fifth trial. The best time, with a view to keeping errors at a minimum was about twenty-five seconds. Neither the rate of improvement nor the time required is quite in accordance with the records of other investigators. Starch found that improvement continued for nearly one hundred trials, considerably longer than here, and a truly expert mirror-drawer can trace a better star in less than the time used by the author. The ability to draw a good star, or such as it was, and without being in record-breaking time, has been a great convenience, on occasion. Asking others to do what one cannot do oneself, may lead to awkward situations.

CHAPTER X

SUMMARY AND CONCLUSION

In the investigation now reported, an attempt was made to analyze the learning process. The conclusions advanced were based upon a series of tests in mirror-drawing, an intelligence test, and the school grades in drawing and typewriting, of the subjects. The various measures recorded were compared and correlated. Pupils in the Greenfield High School volunteered their services, but there was some selection among them, to the end that there might be as large a variety as possible in both academic and manual accomplishment.

The primary purpose of this investigation was an analysis of the process of learning. Mirror-drawing, one finds, is a highly specialized capacity. The mirror-drawing curve is a typical learning curve, with a rapid initial drop, and a tendency to flatten out before practice is discontinued. The elimination of errors of direction and of correction was due, in part at least, to the development of methods. At the beginning a few subjects tried to use methods but these were usually found ineffective. In the course of practice, methods were used to eliminate the two sources of inaccuracy mentioned.

The mirror-drawing ranks failed to reveal any real difference which could be attributed to sex. Nor does

intelligence, that type of ability which is considered to be measured by school grades and psychological tests, function to any appreciable extent. The intelligence quotient, when correlated with mirror-drawing scores, gave a coefficient that was slightly negative; but these results by no means eliminate intelligence. It is a common occurrence to find surprising expertness or inexpertness in unexpected quarters. The correlational findings indicate that drawing and mirror-drawing are related abilities, but there is no inference that one is the cause of the other.

One further factor that seemed of importance both in learning and in transfer was the initial nervousness and self-consciousness of some subjects. In many cases this was quite marked and easily apparent. After a few trials, the nervous attitude usually, but not always, disappeared and was replaced by an air of confidence.

That mirror-drawing is a motor ability has been assumed and partially substantiated. The coefficient of correlation between typewriting and mirror-drawing was positive but not very high--.279. The scatter-diagram showing drawing and errors in mirror-drawing indicates that drawing and mirror-drawing are related abilities. It is a special instance of skill in handling spatial relationships.

It is obvious that any conclusions based upon the

results must be regarded as speculative and uncertain. A reason for this statement, even more pertinent than the small number of subjects, is to be found in the fact that an explanation of the process of learning involves a satisfactory accounting for the entire field of human reactions. In so restricted a study as this, any interpretation may be condemned on the ground that the attack was on too small a spot in such a vast field.

As an outcome of this work I am convinced that the study of mirror-drawing deserves further serious consideration. Furthermore, skill in mirror-drawing appears to be indicative of a specialized capacity which is of value in some forms of orientation. In particular, it might be worth determining whether mental defectives show striking variations on the manual side that might possibly serve to place them in groups.

The real point of interest in all this is not, of course, the citing of factors concerned in mirror-drawing for its own sake. This is incidental to whether or not mirror-drawing is not indicative of a certain type. The claim has been made here, and partly substantiated, at least, <u>that the mirror-drawing experiment might be used as a test for talent in drawing</u>.

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