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A critical study of certain tests of mechanical ability

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A CRITICAL STUDY OF CERTAIN TESTS OF MECHANICAL ABILITY

BY

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CONTENTS

LIST OF FIGURES

LIST OF FIGURES (Cont'd)

LIST OF FIGURES (Cont'd)

LIST OF TABLES

LIST OF TABLES (Cont'd)

CHAPTER I

INTRODUCTION

1. The Problem.

That intelligence is no single capacity or factor but is a composite of many different abilities which are by no means perfectly correlated is a commonly accepted idea. That the extent of these abilities varies in different individuals has been fairly well established. The educational significance of this uneveness is apparent. It has emphasized the importance of adequate educational and vocational guidance that each individual may be given the opportunity to develop his special capacity or aptitude. This need of directing an individual into the field of his special ability has stimulated the development of tests to measure aptitudes. Among these special aptitudes for which tests have been developed is mechanical aptitude.

There are available today several tests which measure this aptitude. As such, it is evident that these tests must tap somewhat the same abilities. So far there has been submitted but little evidence to indicate whether they do or not. It is the purpose of this study to shed some light upon this situation, so that a better understanding may be had of the relationships existing between them.

There are conflicting beliefs regarding the extent of relationship existing between mechanical ability and motor ability. There is a question as to what extent success in one is predictive of success in the other. With this problem in mind, a test of manual dexterity will be included in the battery of tests used, and the degree to which mere dexterity is a factor for success in the mechanical tests will be determined.

While previous investigations seem to indicate that the relationship between mechanical ability and abstract ability is relatively low, there is still opportunity to submit further evidence concerning their agreement. Accordingly, the achievement in the mechanical tests will be compared statistically with the achievement in a test of abstract ability.

2. Method of Study.

The plan for carrying on this study involves the following procedure:

(a) The selection of tests of mechanical aptitude to be compared in the study.

(b) The administration of tests to two hundred boys of high school age.

(c) Statistical treatment of data, including computation of correlations.

(d) Drawing of inferences and conclusions.

CHAPTER II

THE TESTING OF APTITUDES

1. The Need of Aptitude Testing.

The reduction of the great economic and social loss resulting from vocational misfits is one of the serious problems which confront us today. These misfits are largely the result of the "hit-or-miss" methods by which life vocations have been selected. For a person to enter a vocation and spend the necessary time in a period of training as a means of discovering whether or not he is fitted for that vocation is certainly a dire waste of human time and effort. Many, after having gone thus far, only to discover that they are not suited by nature for that particular vocation, find themselves in circumstances which make it impossible to bring about a new choice. The economic loss and the loss in human happiness is apparent.

This situation has given rise to an insistent demand for reasonably quick, accurate, and inexpensive methods of detecting latent aptitudes. Many methods have been advocated, some of which are known to be of distinct value, while the rest have little or no value. As aptitude prognosis is a relatively new science, we have reason to believe that new and entirely different procedures from those now in use may develop in the future.

At present, various kinds of psychological tests are the chief means used in making aptitude predictions.

They are of all kinds and include tests of the higher mental processes, motor control, psycho-motor reactions, constructive skills, physical development, etc.

2. The Basis of Aptitude Testing.

In all applied sciences testing is carried out on the basis of random samples. In aptitude testing, the method is essentially the same, except that the sample is different. That which is sampled is a phase of human behavior and the psychological test is the device used to measure it. These tests are so devised and the technique of administration so developed and standardized that the sampling of behavior may be carried on in an approved scientific manner.

3. The Rise of Aptitude Testing.

The conception of specialized aptitudes and the desirability of having specialized tests to measure these aptitudes is certainly not a product of modern thought. It is, in fact, an idea which dates back to Plato and is expressed in his "Republic." He recognized the fact that no two individuals were born exactly alike and that they inherited natural gifts which fitted them for specific vocations. He believed that when each individual was employed at the vocation which best suited his natural endowments, the results of his labor would be superior in quality and would be produced with greater ease and skill, while the individual himself would enjoy greater satisfaction in his everyday work.

He proposed methods of determining natural endowments which qualified persons for specific vocations; as an example, he suggested that those persons being considered for the military service of the State be given "actions to perform," which would test the retentiveness of their memory, their power of resistance to timidity and fear in terrifying situations, and to the seductions of pleasure. Thus he outlined a very definite set of tests for military aptitude (1).

In spite of the fact that Plato pointed out the way, his idea could not be used because the means of carrying it out had not as yet been devised. It was necessary to await the development of experimental psychology before any successful attempt could be made to realize the philosopher's dream of having each man work at a single occupation in accordance with his natural gifts. This development of experimental psychology was slow to come and did not make its appearance until 1879, some twenty-three hundred years later, when Wundt founded his psychological laboratory in Leipsig.

As a science, psychology was among the last to take on a scientific aspect. In its earlier days the emphasis was upon the metaphysical, and when the work in experimental psychology began, interest was centered in determining ways in which men were alike rather than ways in which they differed. However, procedures and techniques were developed which have been of much value to the science of differential psychology which was to follow and upon which all aptitude testing is based (2). We owe much to such men as Wundt, Cattell, Jastrow, Galton, Munsterburg, Binet and Simon, for the splendid beginnings they made in this new science of the study of individual differences.

The earliest tests devised measured differences in sense perceptions and in the simpler mental processes. However, the greatest advancement was made later in the measurements of the more complex mental processes which are involved in learning. These tests, known as tests of "general intelligence," have been developed to a much higher degree than the tests of other special aptitudes.

Intelligence testing gained great impetus during the recent World War. Under ordinary conditions it would have taken many years to accomplish similar results. Tests were given in an effort to place men in the various branches of the Army where they could be of greatest service. For this classification and placement, the scientific methods of discovering talent that had been developed in the psychological laboratory were used. This testing of great numbers of men in a short time made it obviously impossible to use the individual tests; therefore, the Army psychologists developed group tests of "general intelligence," using the few existing tests as the basis. These were given to over a million and a half men, the data obtained being used as the basis for placement.

As a result of the apparent success of the tests in the Army, testing was carried over into business and industry. With little or no modification, these same tests were used to predict aptitudes of the most diverse nature. This attempt to use tests designated for specific aptitudes to measure totally different ones could end in nothing but failure. As a result, aptitude testing received a serious setback for the time being and is today just beginning to recover from the ill-advised use of a testing device that was really valuable in its proper field.

4. <u>The Aptitude Prediction Value of the "General Intelligence" Test</u>.

The results of the Army testing shed some light on the question of occupational intelligence levels. They indicated that few, if any, required a specific level of intelligence; instead, average intelligence was sufficient, in the sense of being the minimum requirement for probably three-quarters of the occupations of industry (4). In most of the vocations represented by the men of the Army, there was a wide range of intelligence, ranging from high to low intelligence. There has been an attempt to classify occupations on the basis of intelligence needed for success in them. The ranges given, however, are too broad to be significant(5). A proper interpretation of these occupational intelligence classifications shows that a person with a given I. Q. will find that there are many occupations which require an average I. Q. level of the same magnitude. Some occupations have very low I. Q. levels; others very high. As for the majority of trades, almost every degree of intellectual brightness is found among the workers. The clerical and professional groups are made up of people who for the most part are superior in intelligence to the rank and file of tradesmen; yet every trade has in its ranks men of superior intelligence while in the clerical occupations there are found men of inferior intelligence. This seems to indicate that attempts to develop occupational intelligence levels are more or less experimental and tentative rather than authoritative.

Much of the difficulty that has arisen from the attempt to use the tests of "general intelligence" to predict vocational success is undoubtedly due to the misapplication of the tests. Psychologists are beginning to concede that the tests of "general intelligence" in use today are not tests of "general intelligence" but tests of scholastic aptitude, or ability to do academic work. It must be admitted at the outset, however, that the group of aptitudes collectively known as scholastic aptitude constitute an extremely important group. Nevertheless, it is apparent that a test of this ability could not be successfully used as the sole criterion for guiding an individual into a vocation. There are other abilities that play an important part in vocational fitness that are not measured in these scholastic aptitude tests. The emphasis is accordingly shifting from the idea of measuring "general intelligence" as the goal of testing to the forecasting of specific aptitudes. To this end, many special aptitude tests are being developed to predict ability to learn specific subjects, while in the field of non-academic aptitudes, tests have been devised to measure artistic, musical, clerical, manipulative, and mechanical ability. This shift of emphasis will put vocational guidance on a more scientific basis. Its reliability will be greatly increased when guidance is given only after every effort has been made to discover by test the aptitudes that have vocational significance.

CHAPTER III

MECHANICAL ABILITY

1. Preliminary Investigations.

In 1915, Stenquist, Thorndike, and Trabue used tests of various mental functions, including a test of ability to put simple mechanisms together. When the results of this test were correlated with the results of the test of "general intelligence," a relatively low correspondence was revealed. Many who could put simple mechanisms together very well were rated comparatively low in "general intelligence," while some of those ranking well in the latter could not make a good score in mechanical performance. This relatively low correlation suggested that mechanical ability might be specialized to some degree.

Later Stenquist carried out extensive tests and standardized a scale for mechanical performance. Measuring individuals for "general intelligence" and mechanical ability, a correlation of rarely more than .40 was obtained (6). This indicated that ability to put mechanisms together was not reliably predictable from the results of the "general intelligence" test.

Later workers, Toops and O'Rourke (7), using Stenquist's test, have reported correlations of from .14 to .24 with the scores of intelligence tests, thereby substantiating the work begun by Stenquist.

The results of this experimental work led to the conclusion that there was a distinct kind of intelligence which has been designated as "mechanical intelligence."

Leta Hollingsworth on this point, however, contended that it was improbable that such a distinct species of intelligence really would be demonstrated to exist. She believed "that the reduction from unity seen in the correlations cited is no doubt due chiefly to the participation of the motor capacities of the individual, to a great extent, in the available tests of mechanical ingenuity. The role of the muscles in these tests is illustrated by the fact that a bright eight-year-old child may know what the dismembered mechanisms composing the test are, though he cannot 'put them together,' because his motor strength and coordination are not sufficiently developed. His fingers are not strong enough to handle the springs and levers, and his movements are not sufficiently accurate to bring them into the proper relations with each other. In fact, the tests upon which the correlations have been based cannot be performed manually by children under 12 years of age, no matter how able they may be to tell another how it should be done. Since the correlations between physique and intellect are far from perfect, we must expect far from perfect correlations between tasks which depend largely upon muscles, on the one hand, and tasks which depend not at all upon muscles, on the other. Such a lack of unity in performance need not imply the division of people into different categories as respects intelligence. It may imply merely that some intelligent people have relatively poor manual dexterity while some people of excellent muscular equipment have relatively inferior intelligence (though on the whole the intelligent are more dextrous than the stupid as the positiveness of the correlation would indicate)" (8).

Hollingsworth's conclusions seem to be based entirely on the assumption that performance in the assembly tests is entirely dependent upon manipulative ability. This being granted, one would expect the correlation between the assembly test and "general intelligence" would be low, for research has shown that intelligence does not correlate with motor control and hand strength. Muscio (9) found that motor control is relatively independent of intelligence, while

Shepard (30) found that correlation between a motor control test and intelligence test scores was .14.

Stenquist, however, believes that "in addition to the 'dexterity' required to put parts together to form the completed machine or device,---it involves a generous amount of the best kind of thinking,-- and calls for the ability to recognize parts of ordinary mechanical devices, for ability to make judgments as to the reasons for the particular size, shape, weight, and nature of parts"(10).

From an analysis of the tasks performed in the assembly test, one is inclined to agree with Stenquist that more than manipulative ability is required for successful performance. It is hoped that the results of this study will give definite evidence of this relationship. To this end a test of pure manipulative ability was given in addition to the assembly test and others, to determine what part this factor played in a successful performance of the assembly test.

Stenquist devised also two series of paper group tests of mechanical ability. These include pictures of mechanical toys cut in half to be matched and series of questions relating to mechanical properties of typical machines. While the value of these tests as measures of mechanical ability is questionable. Stenquist maintains that "ability to answer the questions does not depend much upon a direct experience with such machines, as upon insight into mechanical principles and usages" (11). While these tests correlate well with the assembly test (.65 average correlation), they correlate more highly with the test of "general intelligence," (.60 average correlation) than do the assembly tests. This would indicate that they do not measure exactly the same abilities as the assembly test; however, they have some predictive value.

2. <u>More Recent Studies</u>.

Other investigators developed tests which have attempted to measure mechanical aptitude. Healy developed a puzzle box which he characterized as a test to "bring out abilities or defects in manipulative powers, in the ability to analyze a slightly complicated physical situation, in powers of attention, and continuity of effort" (12). Margaret McFarlane, using this puzzle box, found an average correlation of .22 with intelligence test scores. She found it more discriminative of practical ability than any of the other tests she used. 71.6% of the technical subjects (children taking a highly specialized course in manual training) exceeded the median of her random subjects (13). She is of the opinion that the test "requires good judgment, based upon visual and kinesthetic clues, and ability to keep in mind successive steps."

Mann and Thorndike (14) carried on investigations to determine the capacities required by the professional engineer. The fifteen tests employed included Stenquist's assembly tests and achievement tests in English, mathematics, and physics. They were given to thirty-four engineering students at Columbia. The scores of all the tests with the exception of the three physics tests and the assembly test correlated from .62 to .75 with a rating of "general intellect." The physics tests and the Stenquist test, however, correlated .60 with each other.

Thorndike concludes that everyone of the tests except the Stenquist test indicates "general intelligence" and when combined, more strongly indicates "general intelligence". However, he does not tell what he means by "general intelligence". He further states that the tests fall into four groups; namely, a group which measures, mainly, general intelligence; a group (three physics tests mentioned before) which measures the same abilities as the former group, and in addition, other unnamed abilities which seem likely to be specially predictive of success at engineering; the Stenquist mechanical test, which has much in common with the former group and much peculiar to itself; and an English group, which has much in common with the first "general intelligence" group and much peculiar to itself.

H. C. Link gave Stenquist's assembly test and a test said to measure "perception of form," a form board with pieces of odd sizes and shapes cut out, some being quite different in shape, while some were nearly alike in shape, but differing slightly in size. The intercorrelations were found to be .42 for thirty-one gun assemblers and .58 for another group of twenty-six. Link suggests that these correlations indicate special abilities in the tests. It indicates also that there must be a common unitary factor running throughout them which was measured by the scores made. It is evident that this factor is mechanical ability (15).

Kelley devised an elaborate constructive ability test which attempts to measure creative and imaginative powers in construction in addition to mere mechanical or manual dexterity (16). It consists of a set of drilled boards, blocks, dowel pins, etc., with which the individual is allowed to construct anything he may wish. While this test is of value in that it attempts to measure a valuable quality which is not measured in the other tests mentioned, it obviously presents a difficult problem in scoring.

McFarlane carried on an extended study of what she called "practical ability" with five-hundred English school children. She devised constructive tests for boys and girls, which included a wheelbarrow, a cradle of wood and a frock and coat of cloth to see (1) whether boys excel in all forms of "constructive tests" and whether the nature of the medium or the particular material involved has the greater effect on performance (27). She concludes in answer to the first question that boys have this special ability in a higher degree than girls, while in answer to the second she has found that the nature of the medium has greater significance than the material (18).

3. Summary of Studies to Date.

The weight of the evidence submitted to date seems to prove without a doubt the existence of this specialized capacity or aptitude which is not measured by the test of "general intelligence." This evidence has given rise to a belief in the existence of a specialized intelligence, which has been called "mechanical intelligence" as apart from "general intelligence." While there are some who are not ready to accede to this belief, such men as Thorndike, Burtt, Link, Dawson, Toops and Poffenberger are in agreement that such a specialized intelligence exists.

This specialized intelligence or capacity is known by various names. Stenquist calls it "mechanical ability," McFarlane refers to it as "practical ability," Dawson speaks of it as "concrete ability," and Kelley undoubtedly has in mind the same type of ability when he speaks of "constructive ability." While there is considerable diversity as to name, this lack of uniformity will unquestionably be adjusted in the near future and a name decided upon which will be broad enough to include all the elements which constitute this special aptitude. In this study the term "mechanical ability" will be used for want of a better one.

4. The Nature of Mechanical Aptitude.

Stenquist in his study (20) refers to mechanical aptitude as "general aptitude in the management and manipulation of things mechanical. It implies a general knowledge of mechanical principles and usages, but does not imply any trade skill." McFarlane (19) defines it as the total response to a problem of a certain kind, viz., one which demands for its solution changing some portion of the physical world and includes:

(a) Grasp of problem.

(b) Ability to plan a series of movements necessary to bring about change.

(c) Ability to execute the movements successfully.

Muscio, on the other hand, identifies practical ability with motor ability.

A careful study of the investigations to date indicates that mechanical ability seems to be a composite of many factors. Among them are included the following:

1. Spatial perception.
2. Memory of spatial forms.
3. Perception of relationship of form.
4. Kinesthetic discrimination.
5. Body rhythm.
6. Constructive imagination.
7. Visual imagery.
8. Manual dexterity which involves
    (a) Accuracy or precision of movement.

(b) Accuracy or steadiness of movement.

(c) Quickness of movement.

(d) Physical strength and endurance.

9. Sensitivity of touch.
10. Ability to analyze a physical situation.
11. Reaction time:

(a) Visual.

(b) Auditory.

(c) Kinesthetic.

12. Visual discrimination and acuteness.
13. Ability to see possibilities or impossibilities in a situation.
14. Ability to profit by experience.
15. Continuity of effort.
16. Ability to follow directions.
17. Span of attention.

These factors were determined on the basis of the "job analysis" method of various typical mechanical problems. They are the ones which seem to be necessary for successful pursuit of a mechanical vocation. However, it must not be inferred that all of these factors are peculiar to mechanical ability alone, especially those towards the end of the list which are common to other types of activity as well.

The various tests which have been devised to measure mechanical ability have been developed with the idea of measuring performances which involve these factors. It is obvious that because of the difference in the nature of the tests they may involve various combinations of factors. An analysis of what each test used seems to measure is left for a later chapter.

CHAPTER IV

RESEARCH

1. Tests Used in Study.

The tests which were used in this study are among the most commonly used to discover mechanical ability through the medium of a standardized test. Those which involved actual manipulation of materials were selected in preference to the pencil and paper tests, since they bring into play many factors which constitute a very important phase of mechanical ability. From its very nature mechanical ability involves concrete situations which obviously cannot be adequately presented in a paper test. The only deviation from this policy in the selection of the tests was in the case of the MacQuarrie test, a pencil and paper test, which was used since it was entirely different from the others in its class.

A description of each test, an explanation as to what it measures, and a summary of its use previous to this study, is included in the paragraphs which follow.

2. The Assembly Test.

This test was devised by Dr. John L. Stenquist as the result of several years of experimentation with mechanical tests. It involves the assembling of ten common mechanical objects which have been previously taken apart.

According to Stenquist (10) this test "measures ability to assemble and manipulate things mechanical. It calls for ability to recognize parts of ordinary mechanical devices, for ability to make judgments as to the reasons for their particular size, shape, weight and nature of parts; in short, for the mental ability to think through in some degree the same steps as those employed by the designer of each machine. Manually, they call for the dexterity required to put parts together to form the completed machine, or device, after it has been decided how they shall go. Much of the performance of a typical child is, of course, mere trial and error manipulation, in which he hopes somehow to make the thing work. But the nature of the various models is such that only a very low score is possible for the individual who depends merely upon thoughtless manipulation of the parts. A generous amount of the best kind of thinking is thus required to make a high score. It involves accurate perception, reasoning and judgment applied to each model."

While it would be desirable to include other operations besides assembling, this one activity was chosen as representative of many mechanical tasks and calls less for special trade skill than most mechanical operations.

The idea of presenting a disassembled actual commercial article, such, for example, as a bicycle bell or mousetrap to be assembled, was first suggested by Professor E. L. Thorndike as a promising method of reaching certain capacities more or less untouched by the more common verbal pencil and paper tests.

The models which are used to make up this series are:

(a) Cap pistol

(b) Elbow catch

(c) Rope coupling

(d) Expansion nut

(e) Sash fastener

(f) Rubber stopper

(g) Inside calipers

(h) Four-piece paper clip

(i) Double-acting hinge

(j) Lever lock

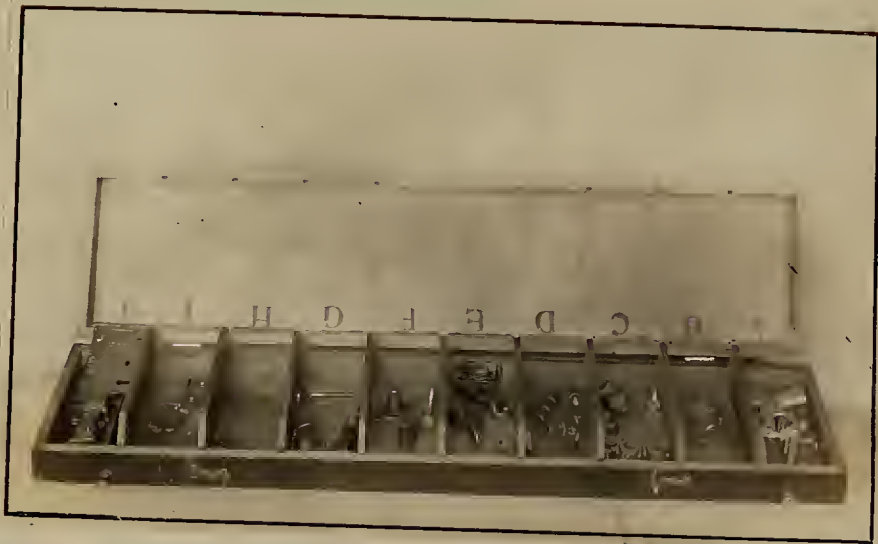


Fig. 1

Stenquist Assembly Test, Series II, As It Is presented to candidate for Assembly.

They are arranged in order of their difficulty and the parts which go to make up each thing are in separate compartments as shown in Fig. 1.

Stenquist sets a time limit of thirty minutes to complete the test or an average of three minutes apiece to assemble each model. In scoring, ten points are given for each correctly completed model and for models partly completed a partial score has been assigned (see Appendix A). The sum of the scores for each model is the total score of the test.

He has worked out norms for his assembly tests, series I and II, and while he admits that they are based upon a relatively small number of cases, a high reliability is indicated. Using shop marks as a criterion and where the true abilities of pupils are well known, correlations as high as .87 have been obtained between the assembly test and shop ranks. Between Series I and Series II for about four hundred cases of boys of seventh and eighth grade, a reliability of .60 was obtained.

The fact that the test selects abilities markedly different from that discovered by verbal tests of "general intelligence" is indicated by the low correlations obtained. A very exhaustive study was carried on in New York City when two hundred and sixty-seven boys in the seventh and eighth grades were given a battery of six intelligence tests and four mechanical tests, the two assembly tests and two picture tests. The results of the six intelligence tests were pooled and a composite intelligence score derived. These composite scores were then correlated with the scores in each mechanical test and then with the combined mechanical tests score. It was found that correlation between the intelligence ratings and the assembly test series I was .23 ± .04, while with assembly test Series II it was .33 ± .06 (21). These results clearly indicate that the assembly tests give us important clues as to abilities which would not be revealed by abstract intelligence alone.

3. O'Connor Wiggly Block.

In the hiring of workers, employers are confronted with the problem of eliminating the fit from the unfit and placing those hired in types of work at which they will be most successful. This problem made evident the need of reliable measures to indicate innate mechanical aptitude which would be of value in selecting and placing factory workers. Among the few who realized this need and who attempted to devise a means of measuring the capacity which fitted men by nature for mechanical vocations was Johnson O'Connor of the Human Engineering Laboratory of the General Electric Company. He developed a mechanical aptitude test, Work Sample # 5, or better known as the Wiggly Block Test, which has proved very reliable in selecting the men best adapted by native endowment for types of work requiring mechanical ability (22).

This test consists of a wooden block which has been cut into nine pieces (see Fig. 2 on page 31) by means of two vertical cuts and two horizontal cuts. It is so cut that each piece will fit on only one place in the assembled block. The block is presented, assembled, to the subject so that he may see how it looks in its completed form. After a careful explanation has been given of the manner in which the block is made, it is disassembled in full view, the pieces mixed thoroughly, and arranged in a row in front of him. The time required to assemble it is recorded. As chance seems to play a considerable part in the selection of the correct block, he is asked to assemble it a second and a third time. The final score is determined by multiplying the time of the second and third trials by factors 1.4 and 1.7 respectively and then averaging the three scores.

Four thousand persons have been tested with this block and the norms established serve to emphasize the great difference in innate mechanical ability. The fastest one thousand completed the block in two and three-quarter minutes, or less, while the slowest one thousand took six

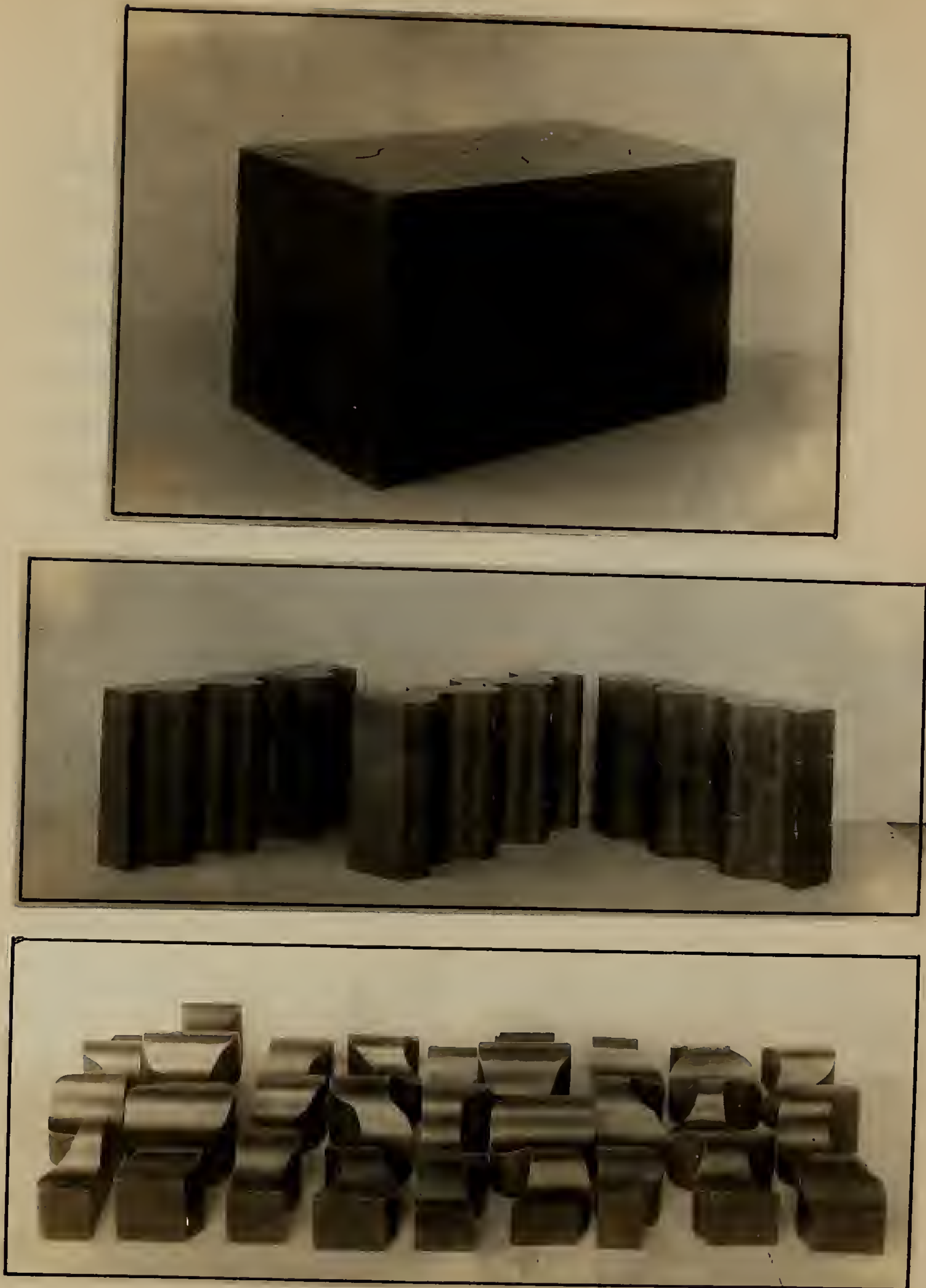


Fig. 2

O'Connor Block Test in Assembled and Disassembled Form.

minutes or more to assemble it. O'Connor has discovered that among those who assemble the block in three minutes, or less, "many are successful in designing and drafting, scientific research, tool and die-making, all-round machining, machine setting-up and repairing, and structural iron and sheet metal work. Only an occasional representative of these professions exceeds six minutes" (23).

Data collected by O'Connor indicates that "it measures an innate aptitude which, after the fourteenth year in a child's life, persists unchanged by education. Engineers solve the puzzle rapidly, not through acquired learning, but because all who originally exceeded six minutes in the block solution have gradually dropped out of the profession (24). As for accountants, inability to solve the mechanical puzzle seems no handicap for "more successful accountants fail on the block than succeed." Likewise, executive success, clerical or inspection work does not require this ability (25).

According to O'Connor, the ability required to solve a mechanical puzzle is obviously not pure analysis, for executives grasp complicated situations and yet fail to size up the relationship of the blocks. Accountants analyze with extraordinary clearness the financial standing of intricate mercantile combinations and yet fail to reason out the block problem. The solution requires a peculiar type of analysis, characteristic of engineers and mechanics. The ability measured by the blocks is strictly mechanical analysis, distinct from analysis in general, and is required for success in every class of work calling for the solution of mechanical problems, in tool and die-making, all-round machining, machine setting-up and repairing, structural iron and sheet metal work, designing, drafting, scientific research work, laboratory experimenting, and technical, designing and construction engineering"(26).

4. Healy Puzzle Box.

This test was used by Dr. William T. Healy of the Judge Baker Foundation, Boston, Mass. It is a box with a hinged cover which is held down by a clasp through which a hook has been passed. A cord leads from the hook into the box and connects to a series of cords and rings which fit over posts. These serve to hold the cover in place. A pane of glass set in the cover so that the system of rings and cords which control the opening of the box may be seen. (See Fig. 3 on page 34.) The object of the test is to open

Fig. 3

Healy Puzzle Box Assembled.

the box in as short a time as possible.

Healy originally characterized the puzzle as one that "may bring out abilities or defects in manipulative powers, in the ability to analyze a slightly complicated physical situation, in powers of attention, and continuity of effort" (12).

He originally set a time limit of five minutes to open the box, but found the time too short, since some failed to open it in that time. However, as a means of determining those who have special ability in this line, the five-minute limit is sufficient (26).

McFarlane found this puzzle box more discriminative of "practical ability" than any of the other tests she used. Of her technical subjects, seventy-one per cent exceeded the median of her random subjects. She considers that the test "requires good judgment, based upon visual and kinesthetic clues, and ability to keep successive steps in mind long enough to indicate the next one" (13).

Norms based upon 277 cases which range from 14 1/2 years to and including adults indicate that this is not an age level test. Norms on the basis of percentiles are found in Appendix A.

5. MacQuarrie Test of Mechanical Ability.

This test was devised by Dr. T. W. MacQuarrie of the University of Southern California in the attempt to provide a standard performance for the measurement of mechanical ability. It differs from the other tests used in this study in that it is a pencil and paper group test and so can be given to large numbers very easily.

During its development some thirty tests ranging from simple tapping tests to elaborate puzzles were selected for consideration. In each case the attempt was made to devise a paper form that would present the same stimuli as a laboratory test (27).

The first battery developed included twenty-four tests. After these were given and the reliabilities determined, all those which did not show a co-efficient of reliability of at least .70 were eliminated. This reduced the number to twelve and upon more careful study this number was reduced to seven parts now used, which include tracing, tapping, dotting, and copying tests; a location test, a block test and a pursuit test. From the sample of the test shown on page 37 it will be seen that there is a practice test which precedes each test giving an opportunity for those being tested to

MACQUARRIE TEST for MECHANICAL ABILITY

A Simple Group Performance Test for the Use of School Counselors and Personnel Managers

By T. W. MacQuarrie, Ph. D.

Professor of Education and Director
of Metropolitan College
University of Southern California

FILL IN THE BLANKS BELOW, BUT DO NOT OPEN THE BOOKLET

City.. Date....................................

School.. Grade..

.... , ...
(Print your last name) (Print first name and initial)

Age, last birthday.................Date of birthday..

RECORD

Tracing..................

Tapping..................

Dotting..................

Copying..................

Location..................

Blocks..................

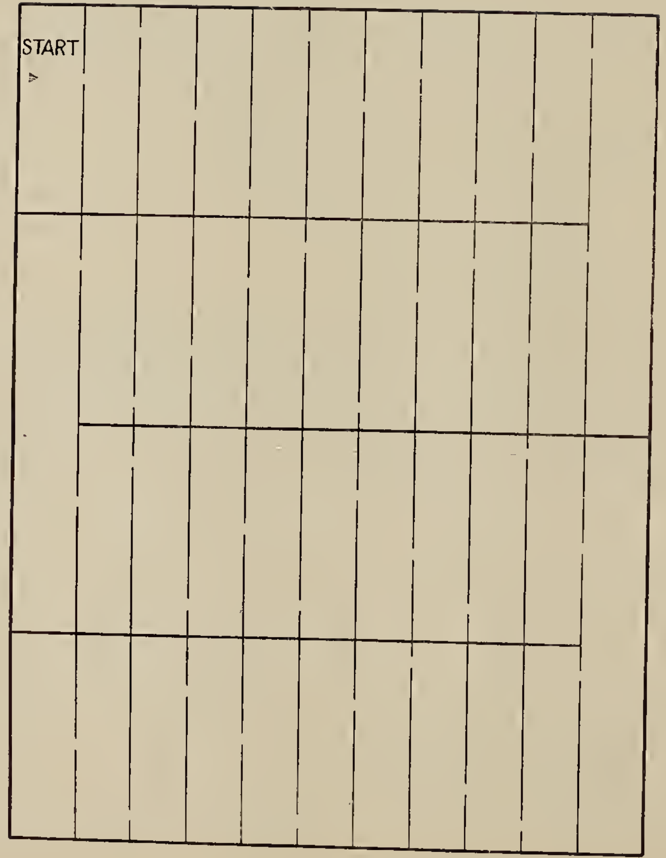
Pursuit..................

Total 3)..................

Score:

Sample of MacQuarrie Test of Mechanical Ability

TRACING



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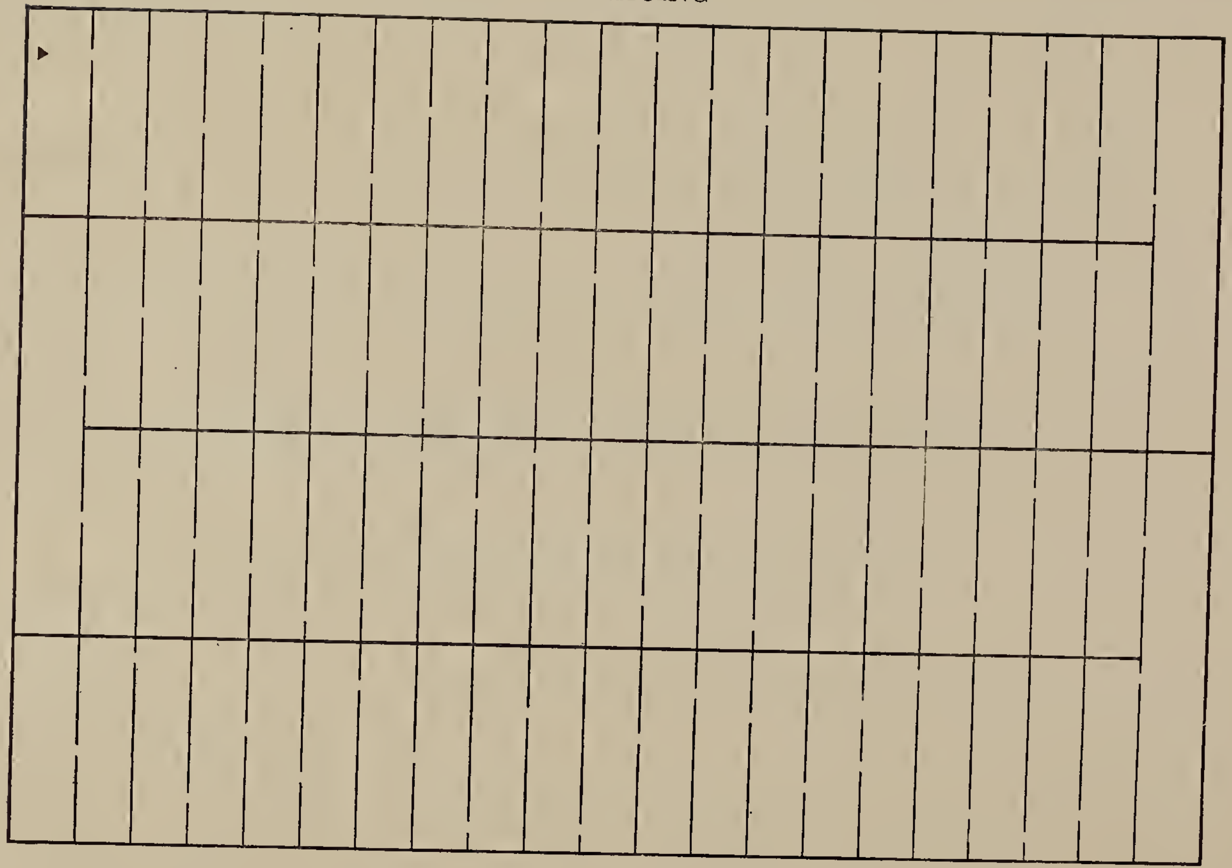

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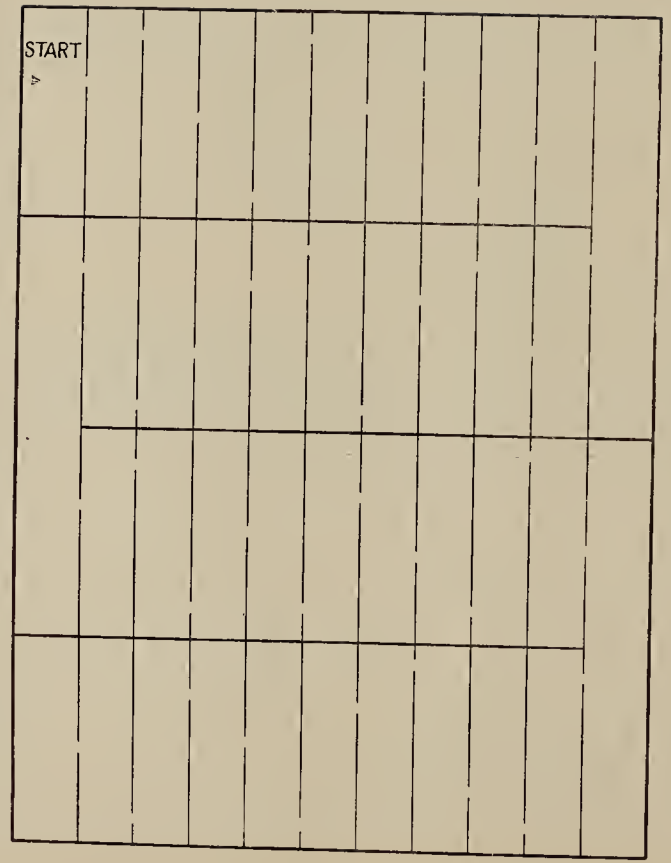

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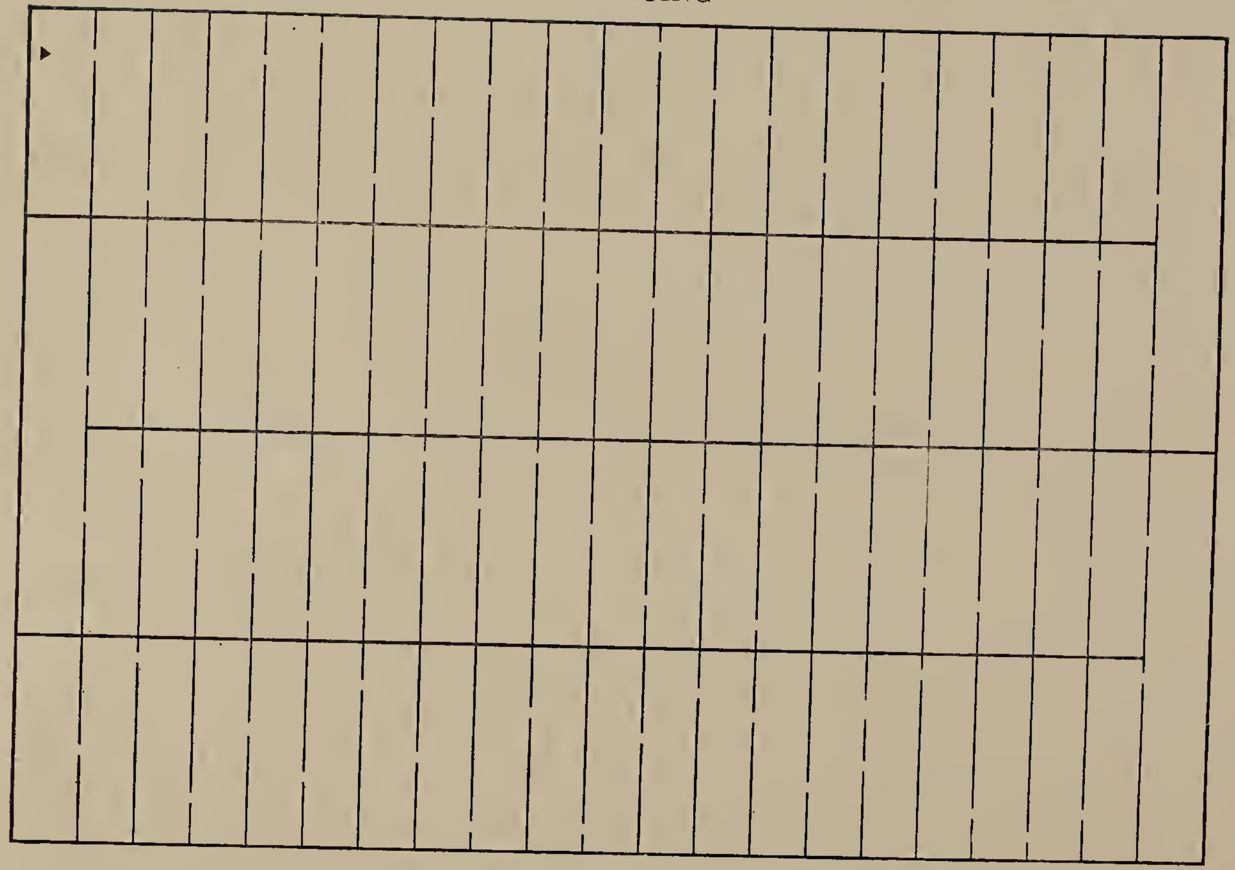

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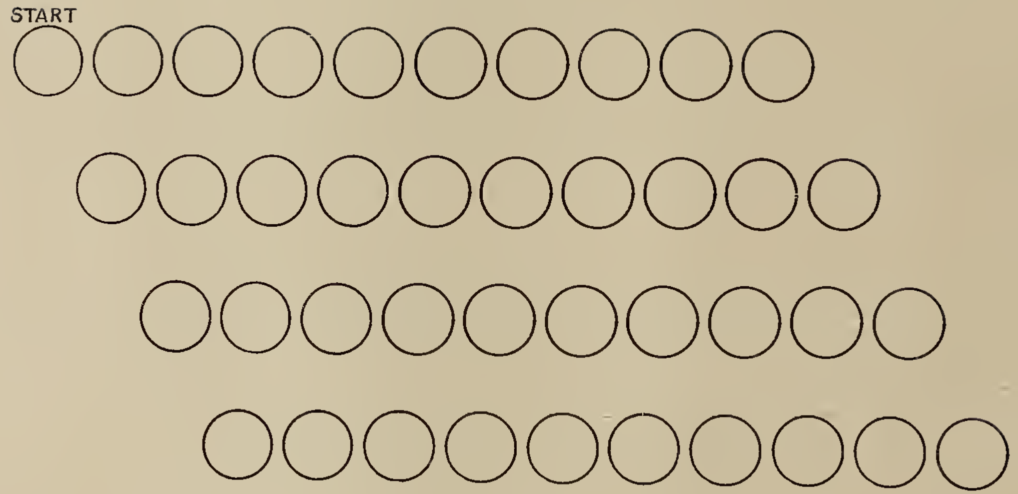

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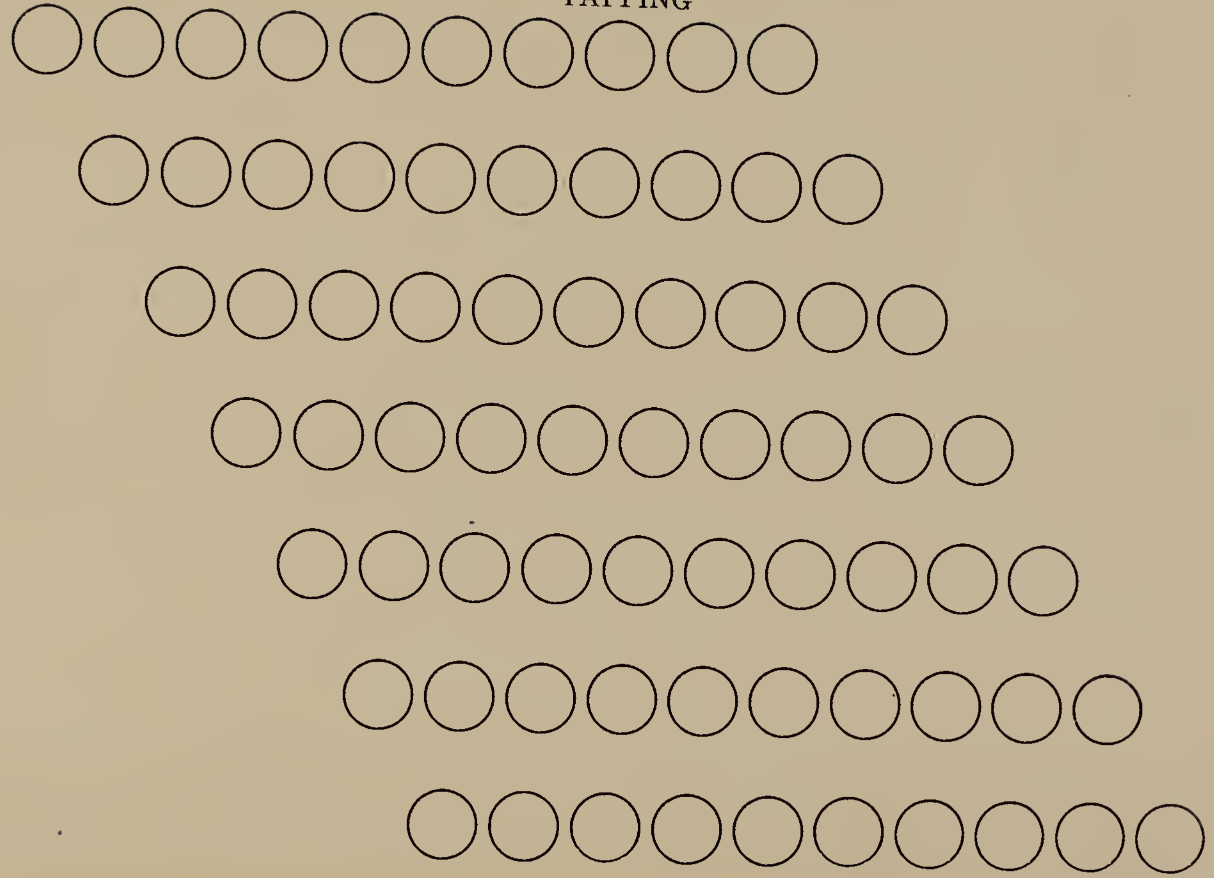

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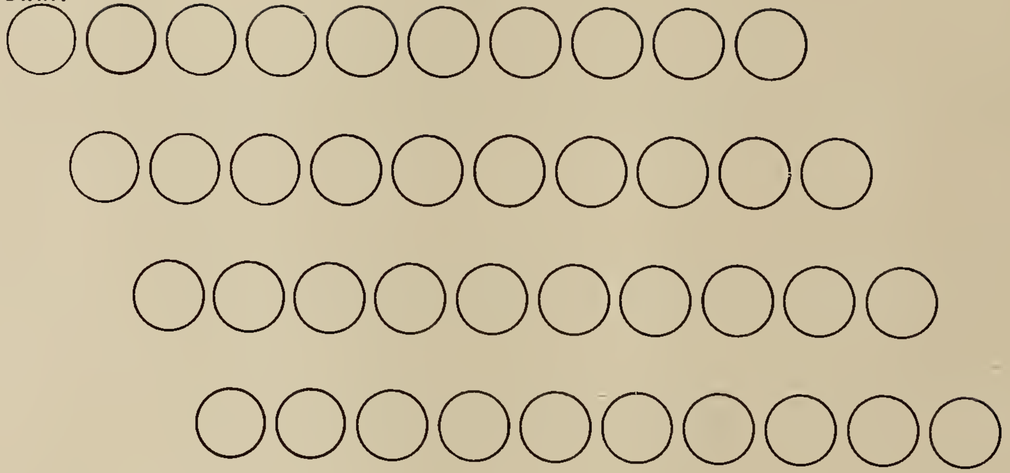

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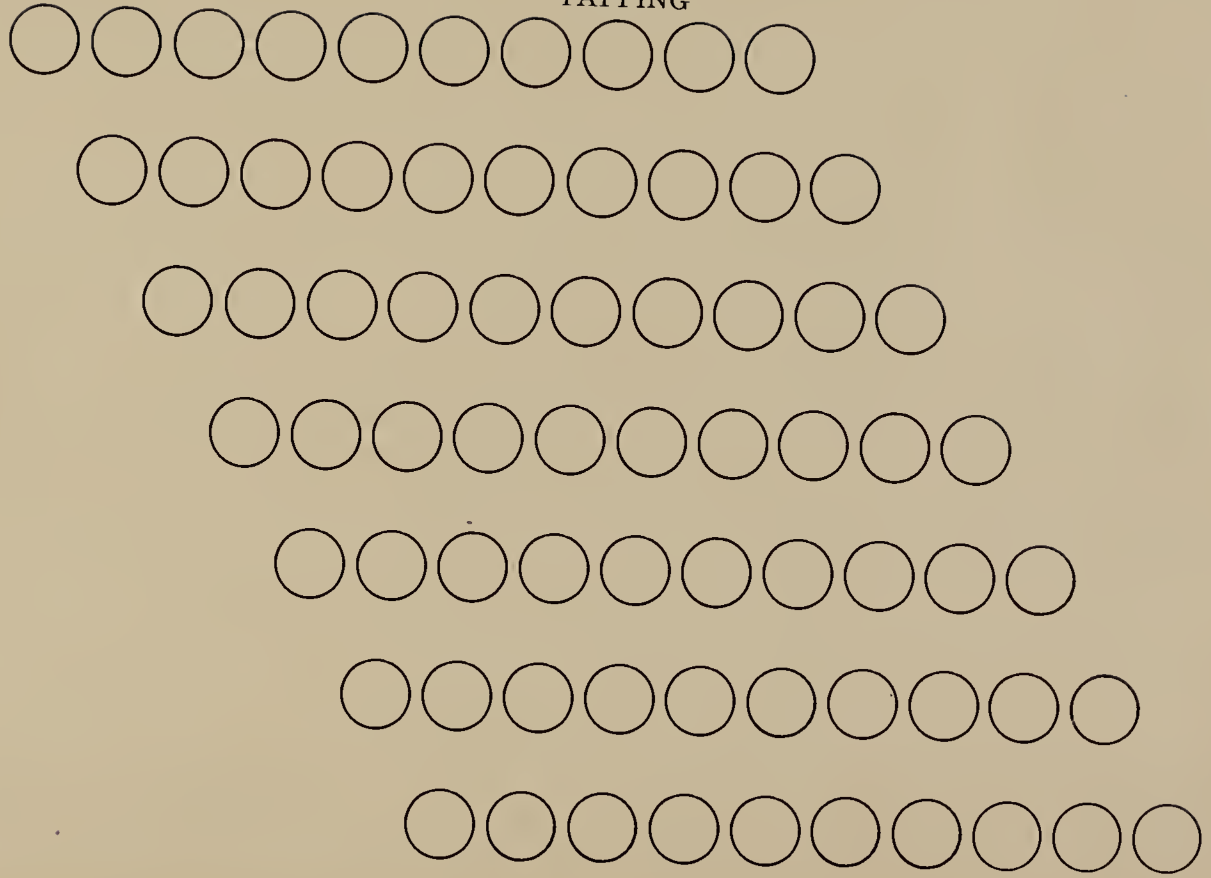

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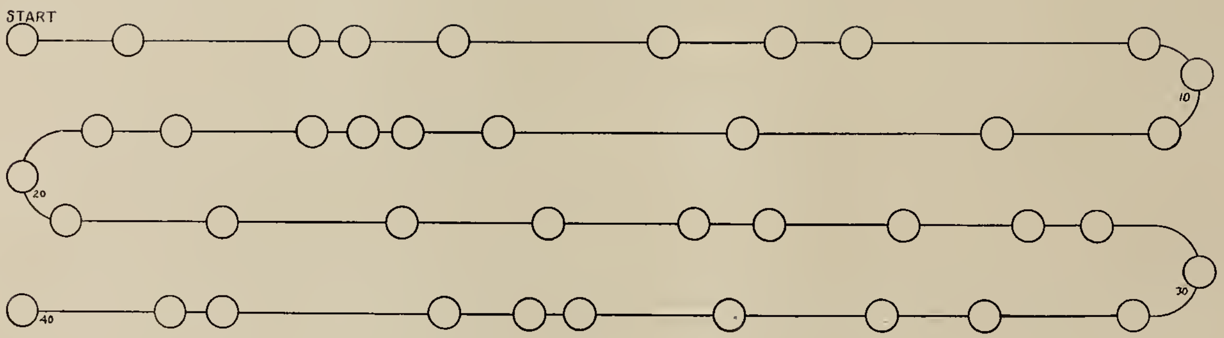

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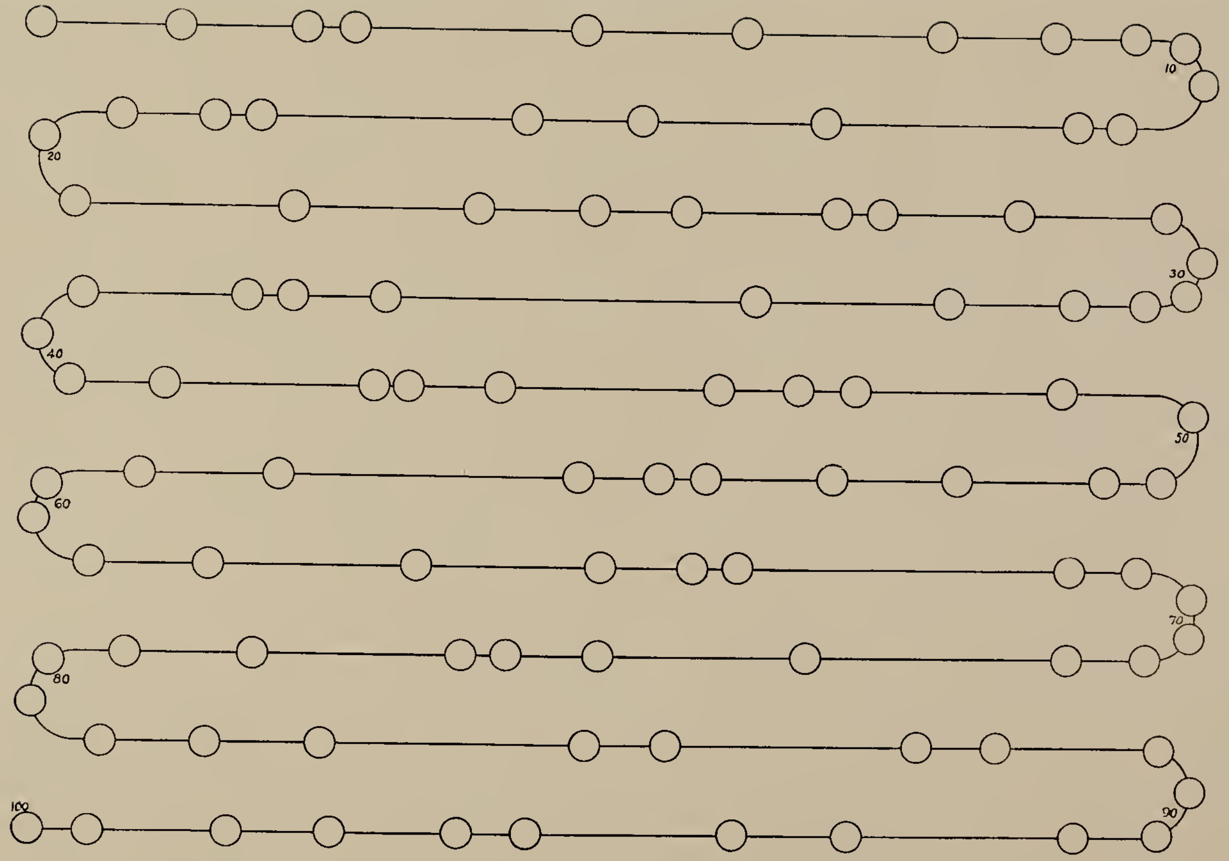

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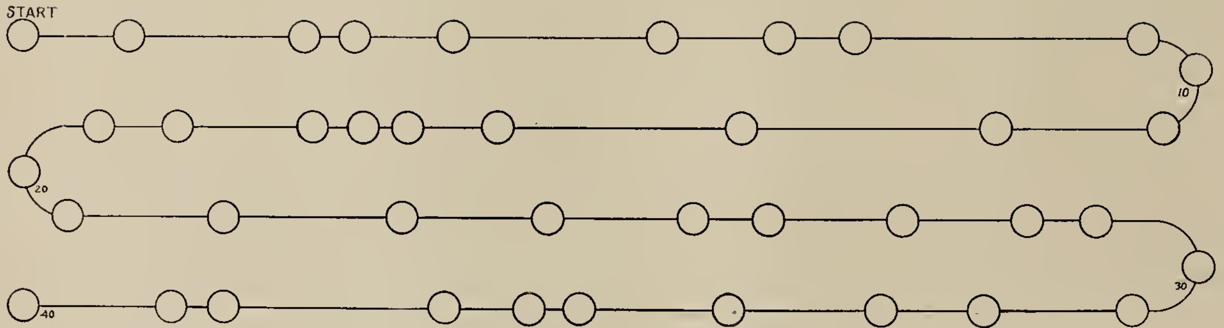

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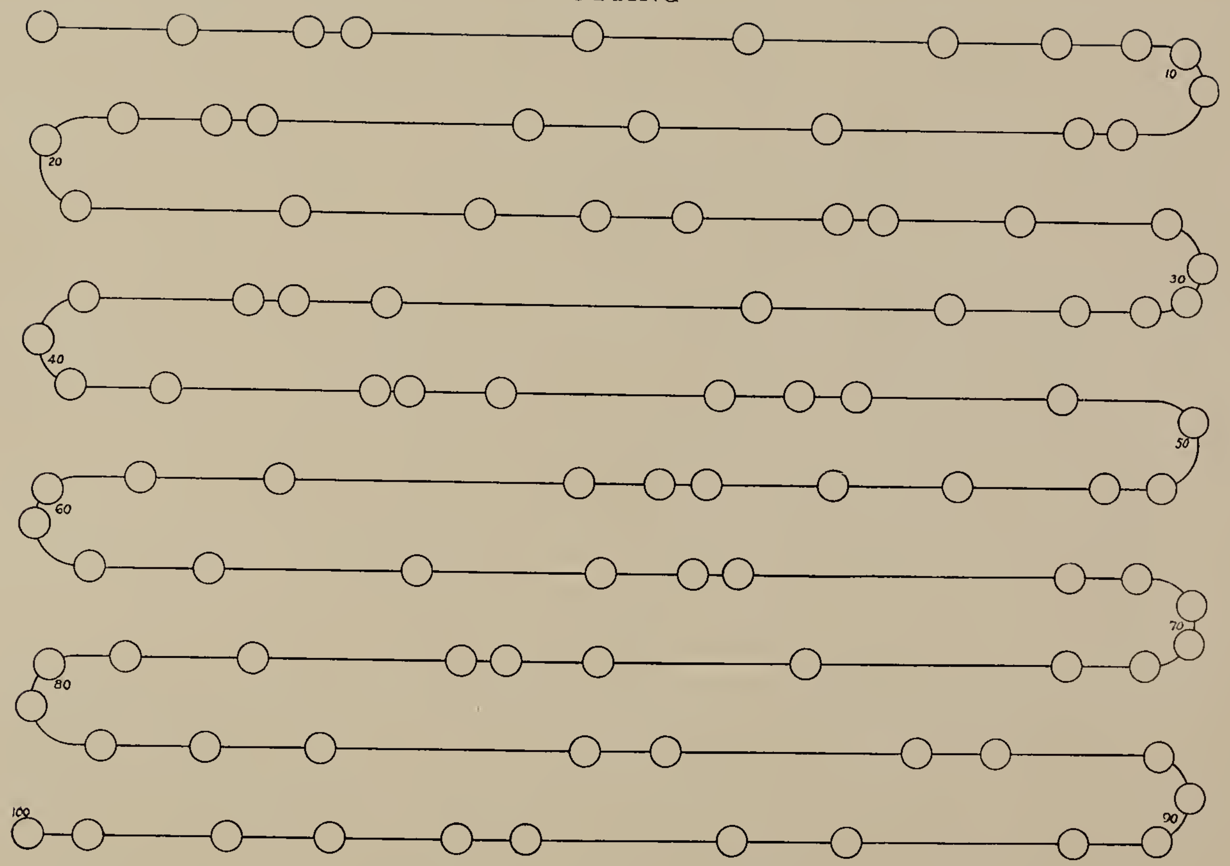

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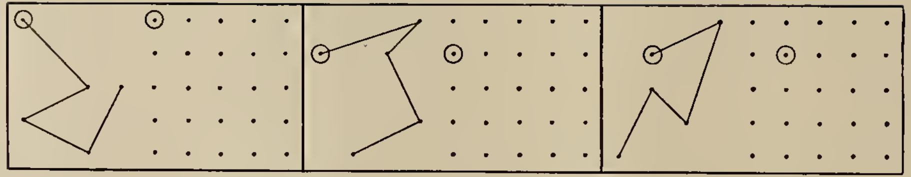

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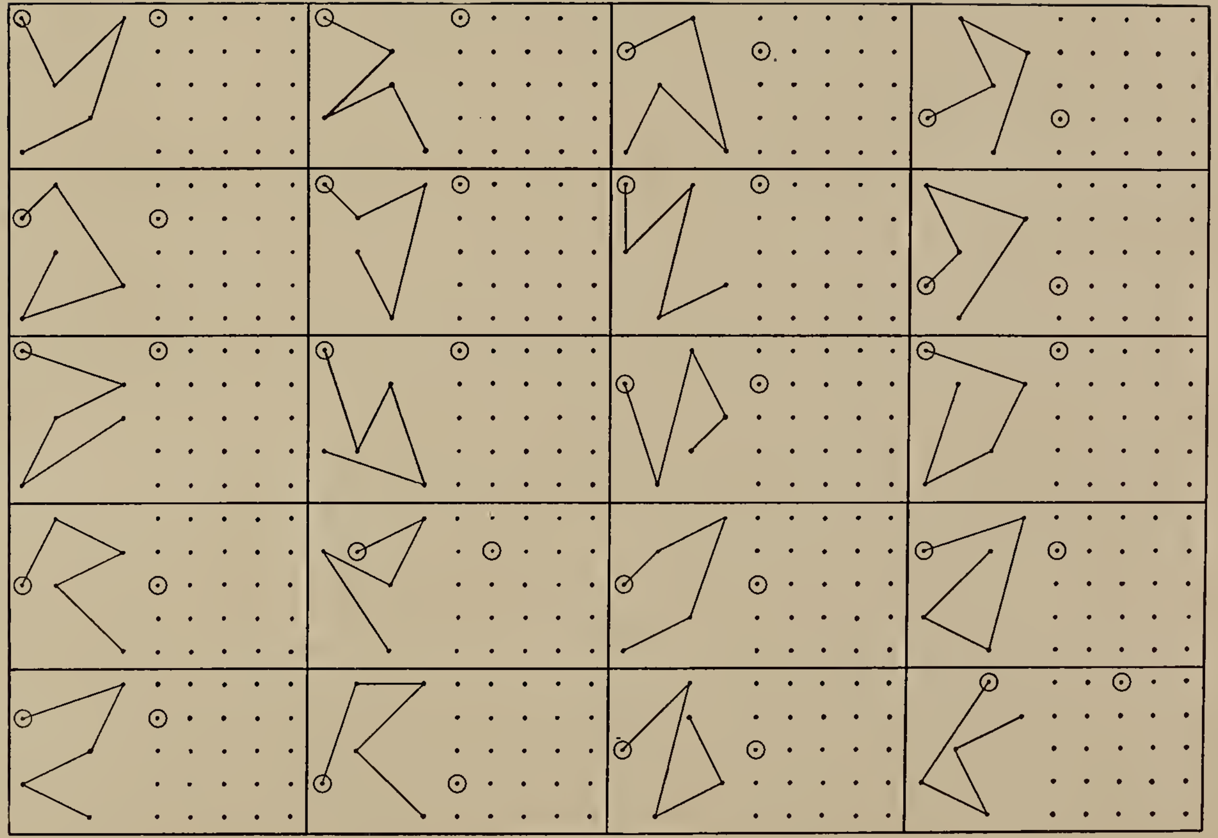

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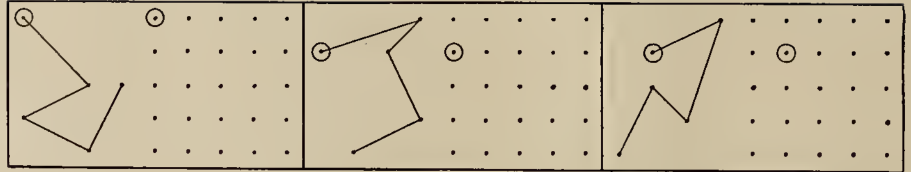

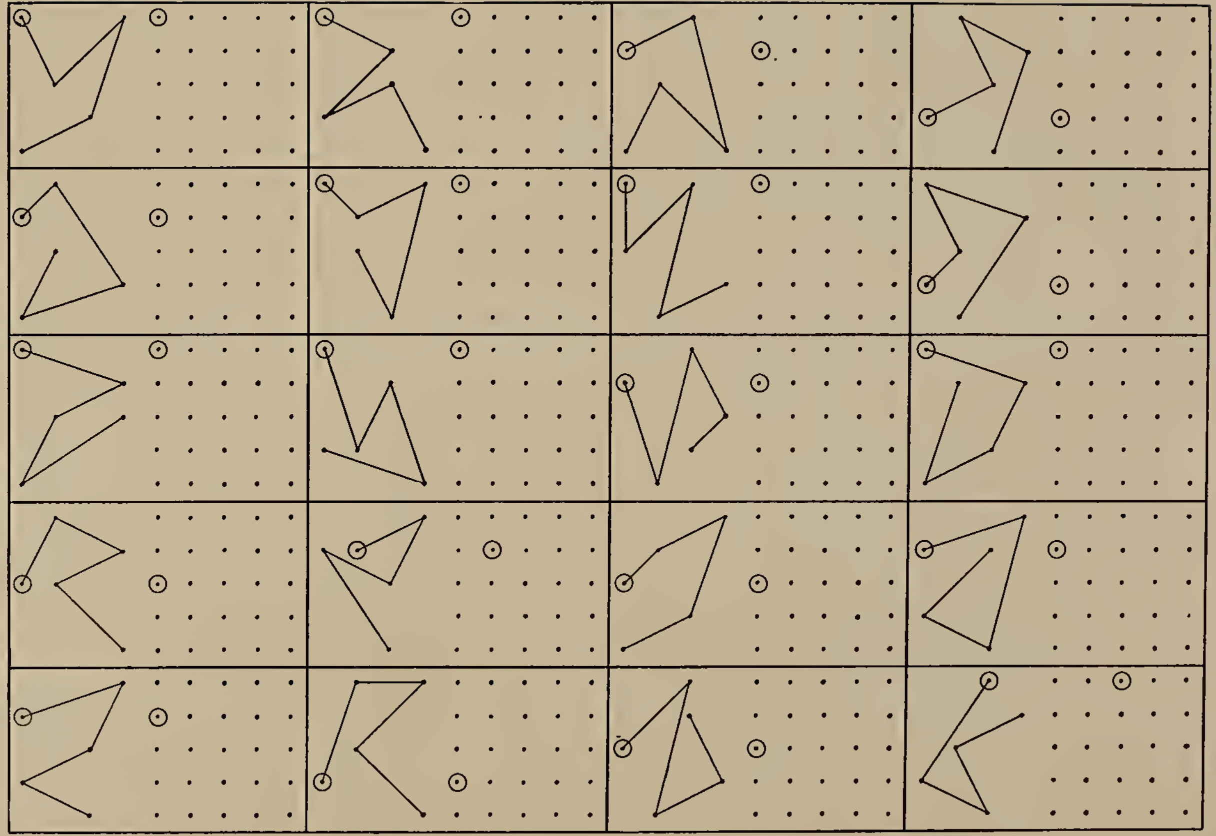

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G	H	J	K	L	M
T	S	R	P	O	N
U	V	W	X	Y	Z
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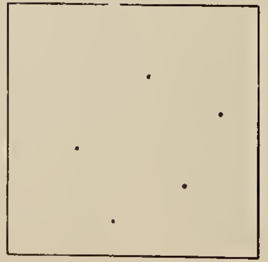

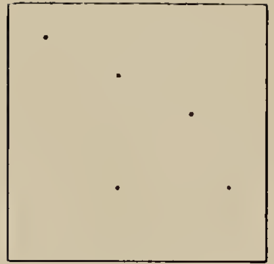

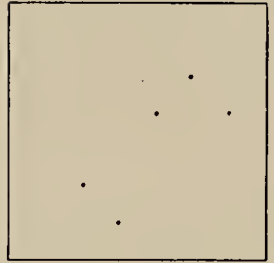

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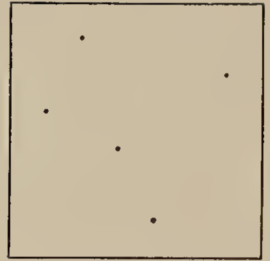

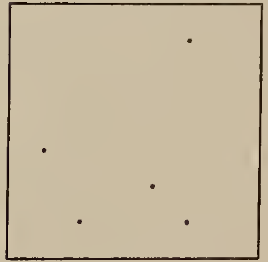

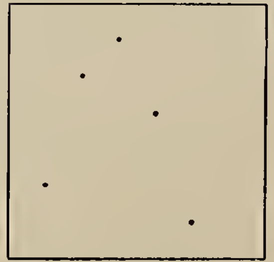

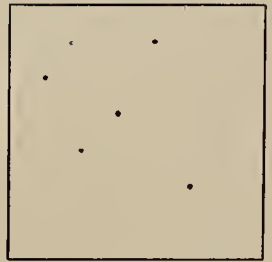

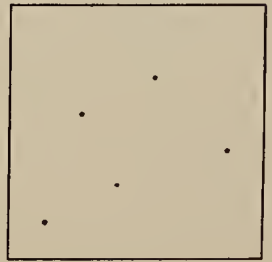

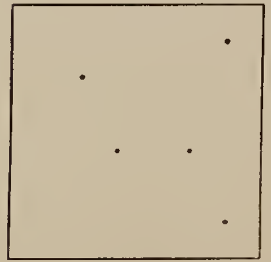

Score..........................

LOCATION

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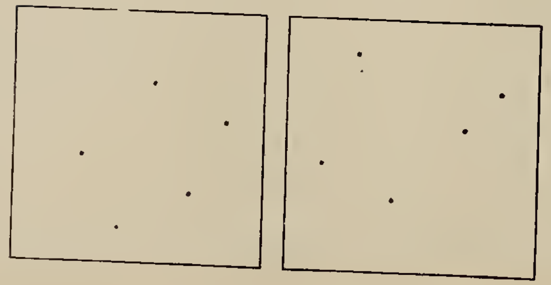
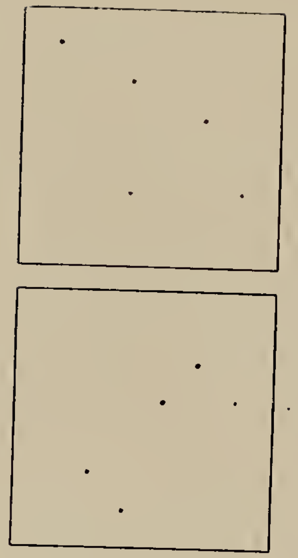
A	B	C	D	E	F
M	L	K	J	H	G





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G	H	J	K	L	M
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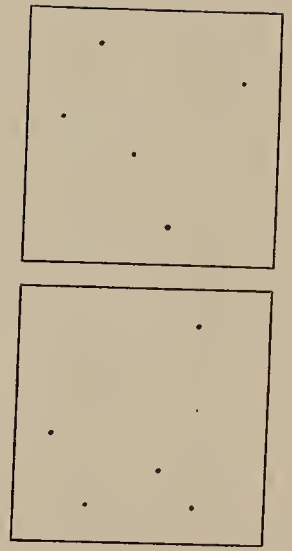
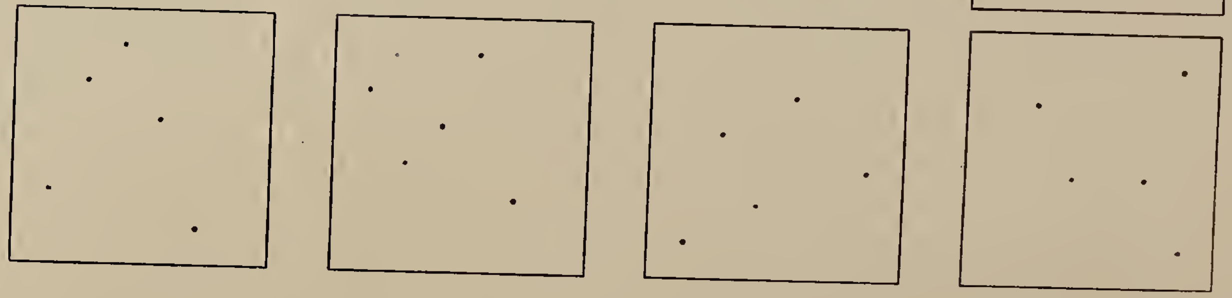
M	L	K	J	H	G





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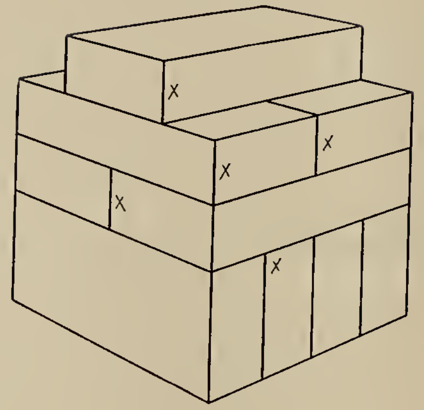

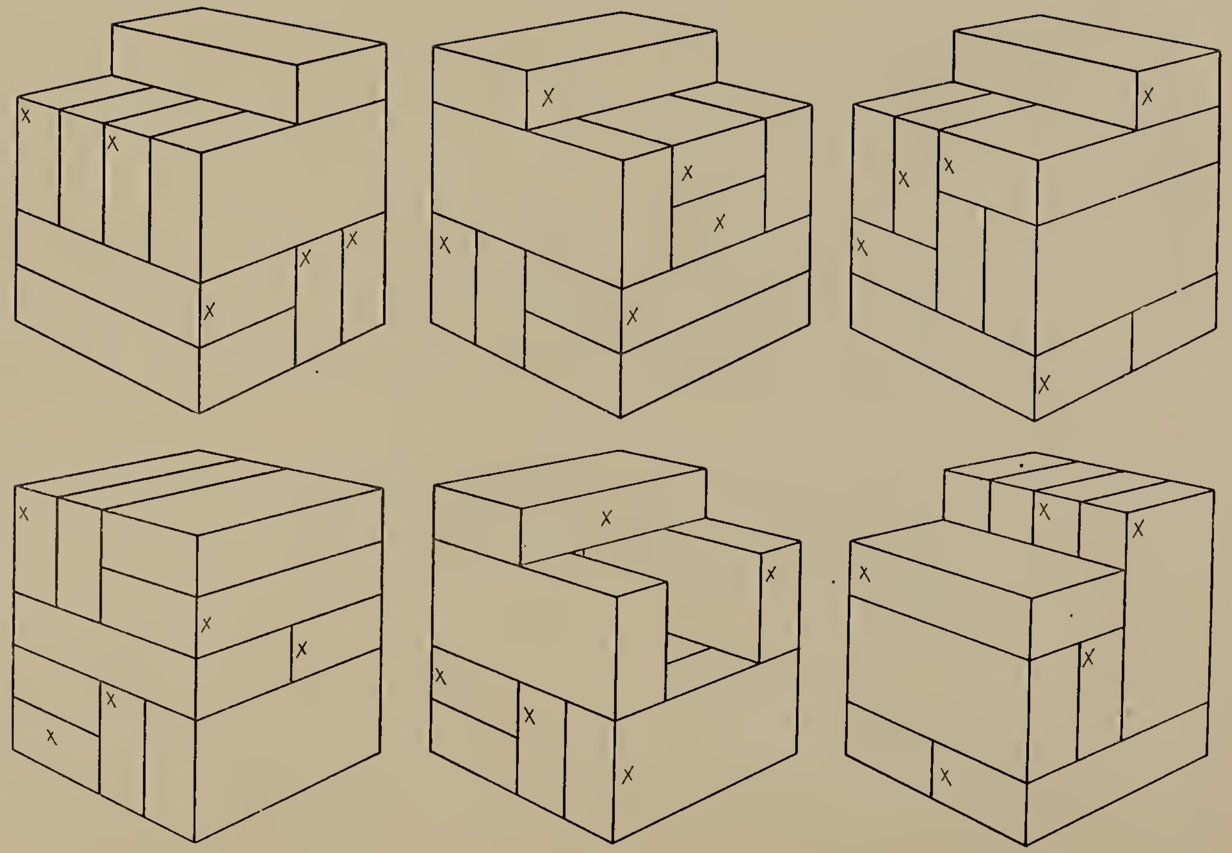

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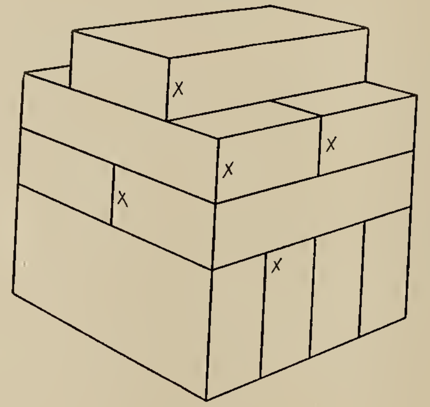

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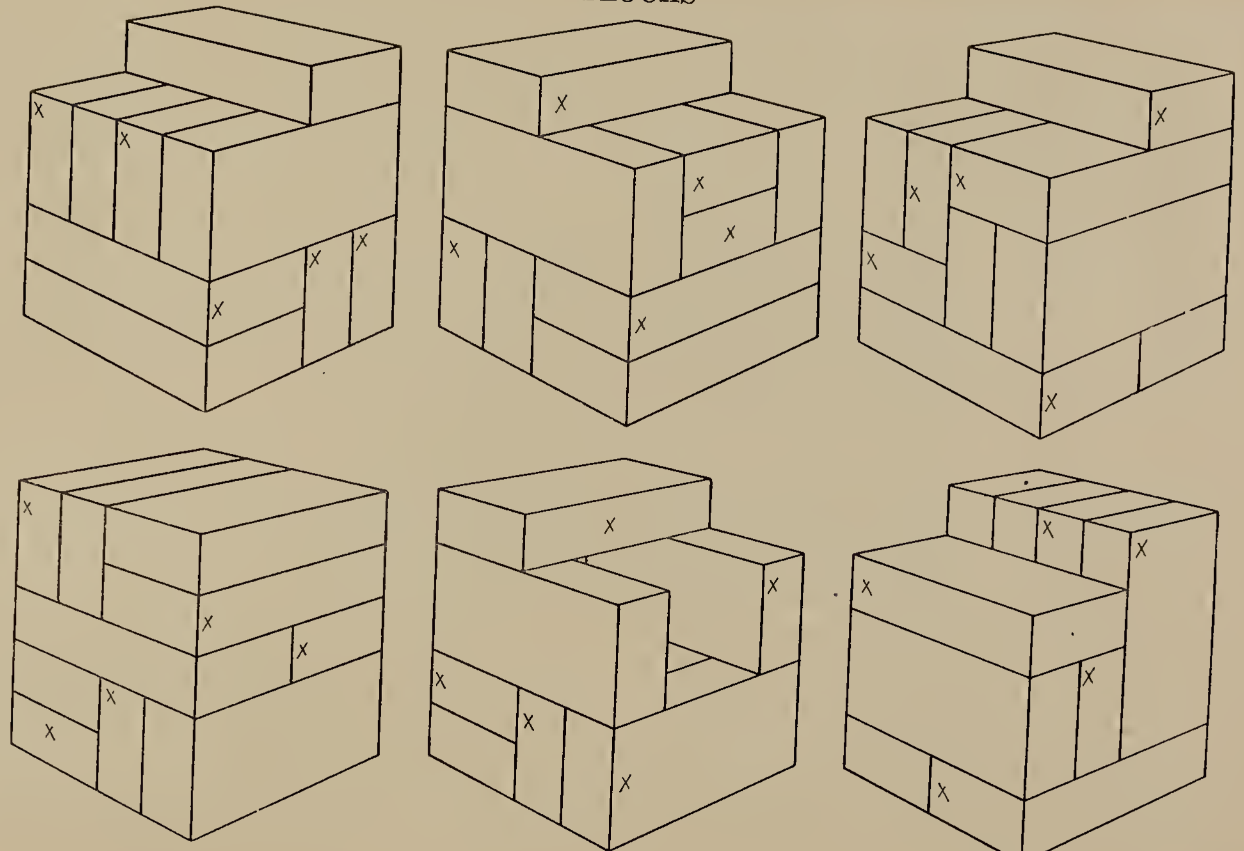

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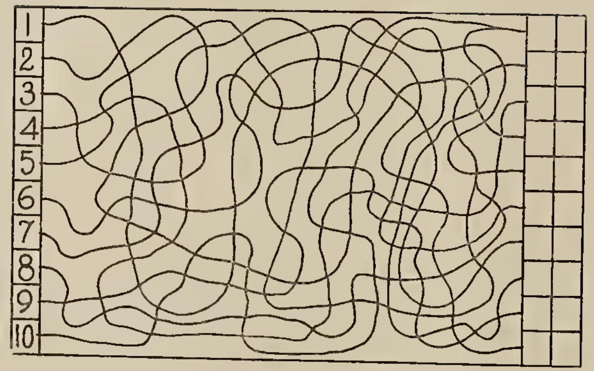

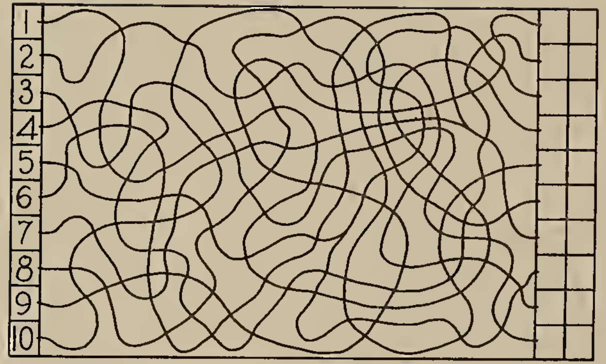

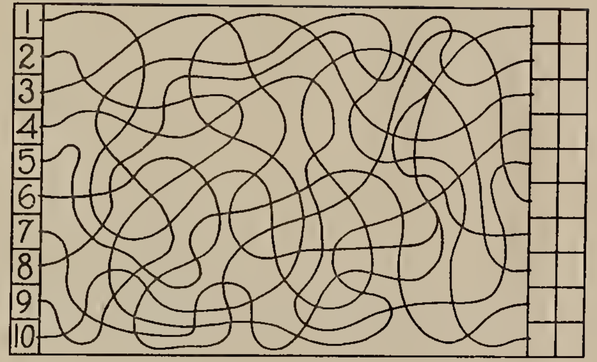

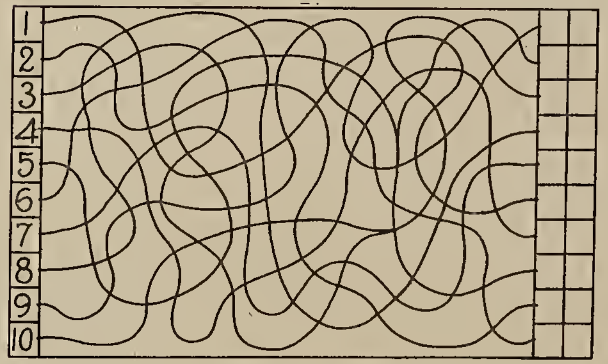

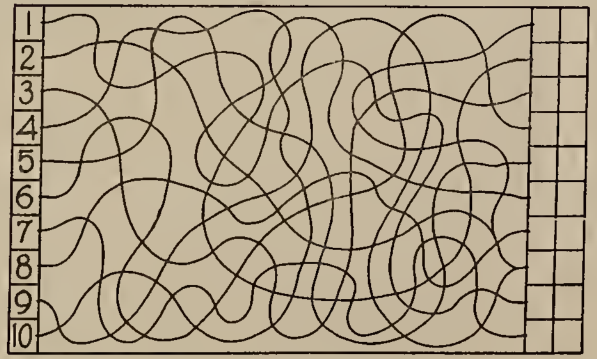

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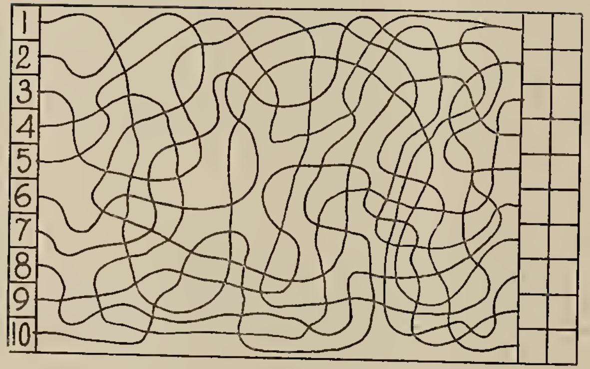

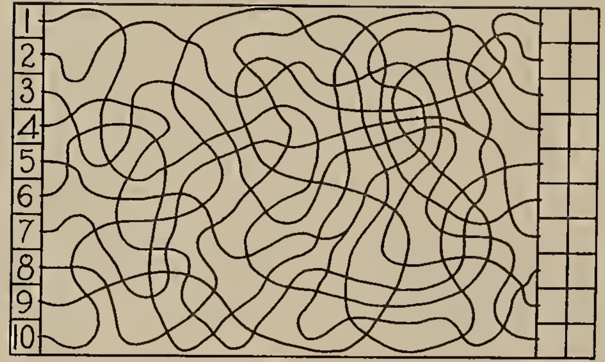

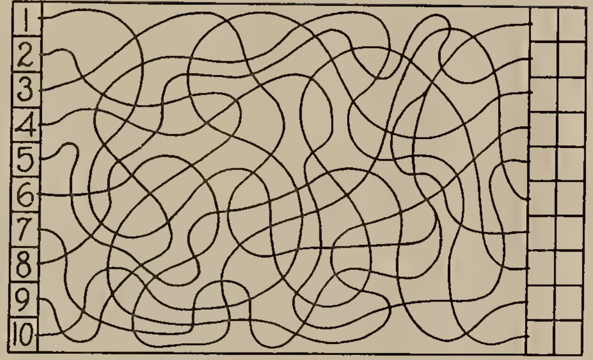

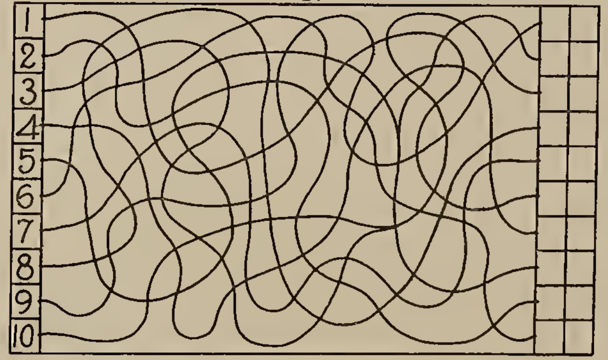

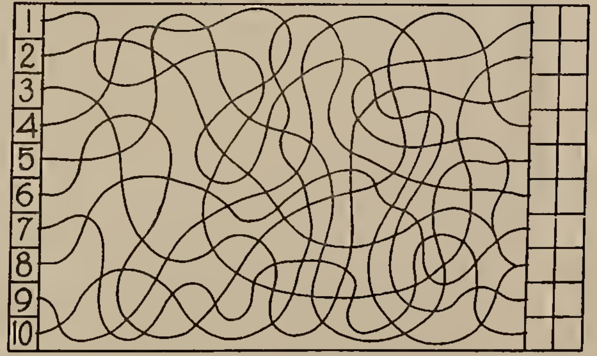

Score..........................

This booklet is put up in packages of twenty-five, with complete directions, scoring keys, available norms, etc. The price is $1.50 per package postpaid to any part of the United States. Checks should accompany all orders from individuals.

A tryout package of five copies of the test with complete directions will be mailed to any address upon receipt of fifty cents.

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become familiar with the procedures required before the record test is attempted.

In his description of the test (27) he states that the location and block tests measure spatial relationships but does not specifically mention the factors of mechanical aptitude predicted by the other five. In answer to the criticism that his test places too much emphasis upon speed, he states that anyone to be successful as a mechanic must be able to work rapidly as well as efficiently. On this point it might be added that O'Connor (28) has found that the old statement "slow but accurate" is a myth. From the results obtained in a number-checking test, he finds that those who take longer to complete the test make more errors than those who complete the test in a shorter time. This has also been shown by O'Rourke, Director of Personnel Research of the United States Civil Service Commission (29).

The test was given to 365 subjects and the data treated statistically. It was found that the composite scores of the test never correlate with scores of intelligence more than .26, and in one group of sixty cases the correlation was .002. On the other hand the correlation of the test scores with teacher's rating of mechanical aptitude of forty-eight students was found to be .81, while in another study it was found to be .32.

The reliability of the whole test determined on the basis of three groups of subjects numbering thirty-five, eighty, and two hundred fifty was found to be .90. The reliability of the individual tests have been found to range from .72 to .86.

The age norms of the test may be found in Appendix A.

6. Manual Dexterity Series.

This test was devised by E. C. Whitman in 1925. It is the result of an attempt to standardize a test series governed by manual dexterity as apart from higher mental processes according to Whitman (30). "Various manual tests in common use have other primary factors such as learning ability, mechanical ingenuity, and reasoning, and so do not give a true picture of manual ability."

Among the component factors constituting manual dexterity which are measured by this series are rapidity and accuracy of movement and to some extent innate body rhythm. It includes the inserting of pins and pegs into boards, assembling and disassembling bolts and nuts and the sorting

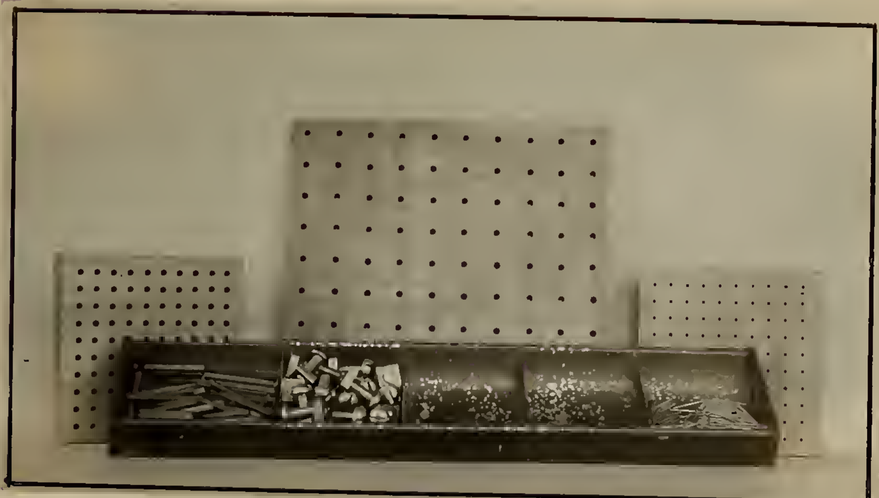


Fig. 4

Whitman Manual Dexterity Series.

of pegs. (See Fig. 4.) It is an individually administered test requiring twelve to fifteen minutes to give.

Age norms were determined on the basis of the testing of 504 school children from the age of 7 years to and including 15 years and are noted in Appendix A.

"Myers Mental Measure" was given to 434 of these children and the scores were correlated with the scores obtained in the dexterity tests. The average of the correlation by years was .36.

This test was included in the battery to determine to what degree mechanical aptitude is dependent upon manipulative ability.

7. Subjects Used in Study.

The data for this study was obtained from the testing of 206 boys of the ages of 13 to 18 years. Of these boys, 189 were students of the West Springfield, Mass., High School, 9 were high school seniors from nearby communities who were candidates for the Edison scholarships, and 8 were members of an ungraded group in the West Springfield, Mass., Junior High School. The two smaller groups represent the two extremes of scholastic ability, but the largest group, which makes up the majority of the subjects, is an average group of high school students; as unselected as one would expect to find in a general high school offering general, business, classical and technical preparatory courses. They are representative of the type of boy one would expect to find in a typical semi-industrial New England town.

8. <u>The Testing Procedure</u>.

The testing was carried on in conjunction with the vocational guidance program of the school and the findings used as an aid in giving vocational advice. The battery of tests was arranged to permit the testing of two boys simultaneously. This arrangement served the dual purpose of making the program more efficient from the viewpoint of time, and preventing the existence of a strained atmosphere which would exist if the subject were alone with the examiner. The presence of a second boy, even though he was engaged at something entirely different, greatly reduced nervous tension and naturally resulted in a far better performance. After a few preliminary remarks to stimulate the interest and cooperation of both boys, "A" was given the assembly test while "B" was given the block test, followed by the manual dexterity series and the puzzle box. By this time "A" had finished the assembly test and was then given the block test followed by the dexterity series and puzzle box, while "B" was working on the assembly test. This schedule enabled the examiner to administer the block test, puzzle box and the manual dexterity series to one subject while the other was independently engaged in the assembly test. It took from 75 to 90 minutes to complete the program depending upon the subjects tested. The testing of the 200 boys has taken approximately 350 hours.

CHAPTER V

PRESENTATION OF DATA

In this section the results of the tests will be presented. A graphical representation of the distribution of test scores for each age group will be shown and the medians of each group indicated. These medians will then be compared with the medians obtained in other studies.

1. Results for Each Age on the Assembly Test.

Figs. 5 and 6 give the graphical distribution of the scores of thirteen, fourteen, fifteen, sixteen, seventeen, and eighteen-year-old boys on the assembly tests. Table 1 gives the medians obtained in this study as well as those obtained in the studies of Stenquist (31).

It will be noticed that these medians are slightly higher than those obtained by Stenquist, except for the thirteen-year-old group, the boys of this group making a much lower score than boys of the same age studied by Stenquist. This difference is no doubt due to the small number of cases tested for this age.

Inspection of the graph shown in Fig. 7 will show

Distribution on Stenquist Assembly Test, Series II for 13, 14, and 15 Year-old Age Groups.

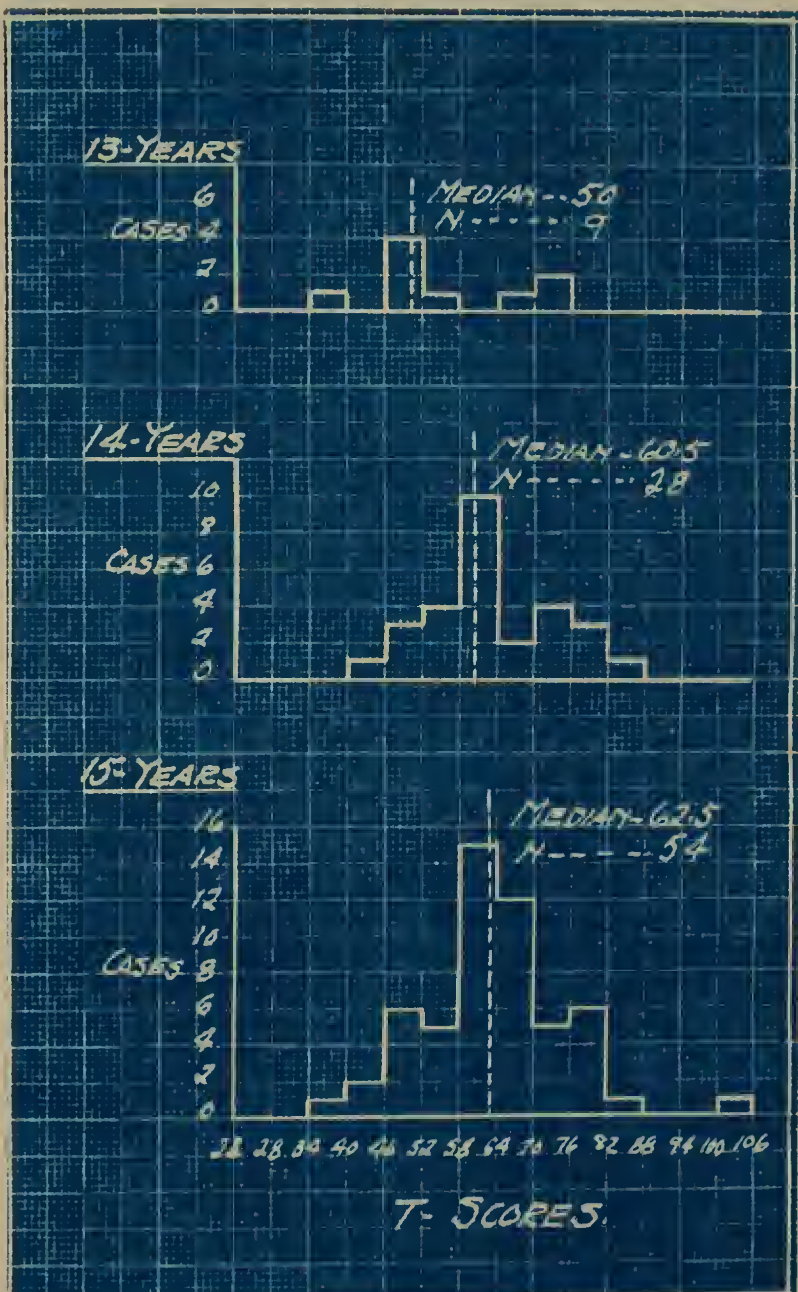


Fig. 5.

Distribution on Stenquist Assembly Test, Series II,
for 16, 17, and 18 Year-old Age Groups.

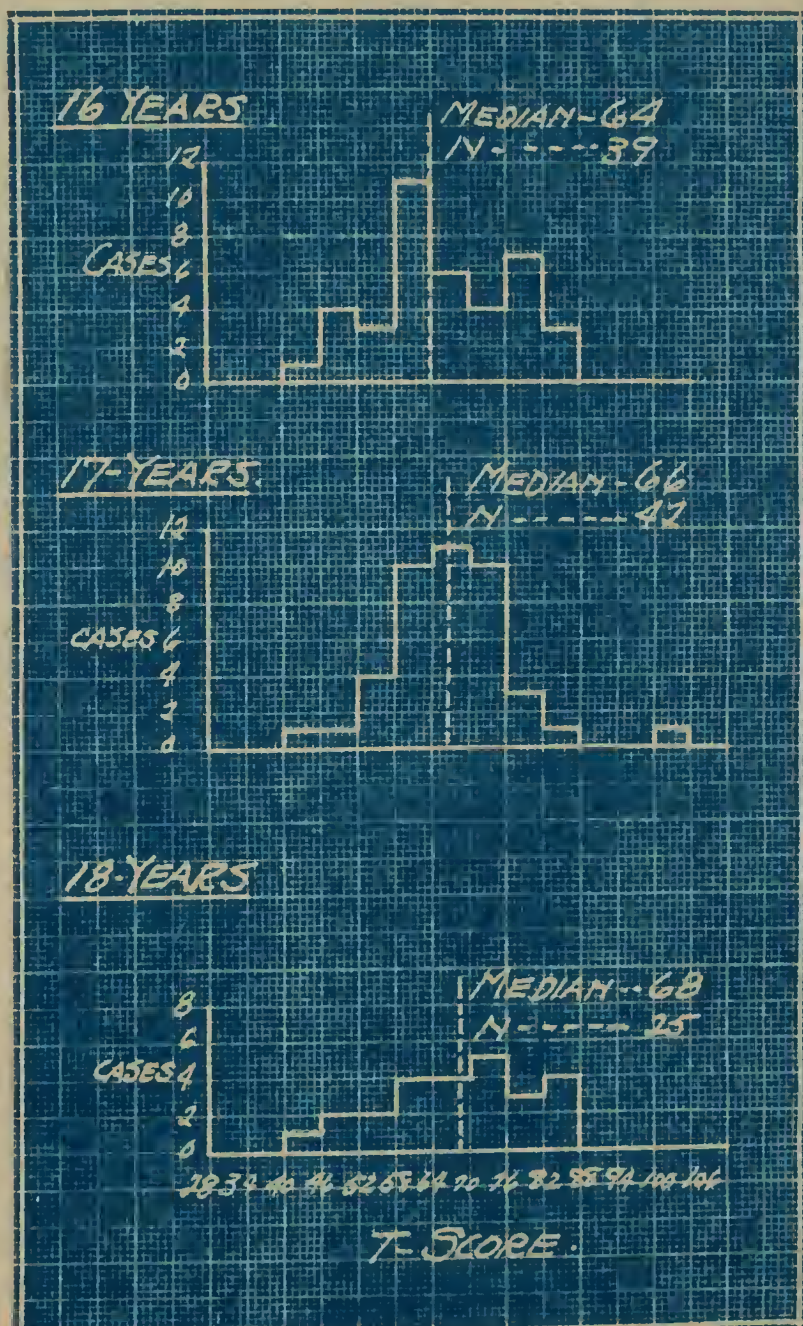


Fig. 6.

Table 1

Summary of Results In This Study on Stenquist Assembly Test for Each Age, and Comparison with Stenquist's Results.

Age	Median T-Score	
	This Study	Stenquist
12		50.
13	50.	56.
14	60.5	58.
15	62.5	60.
16	64.	
17	66.	
18	68.	

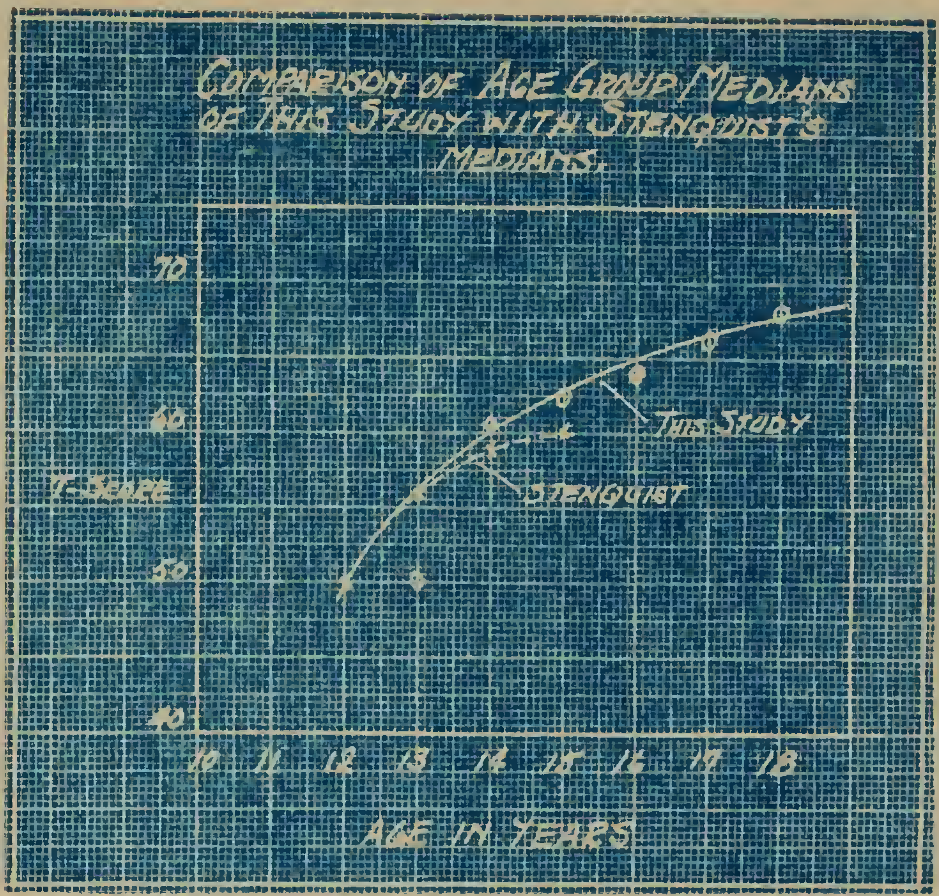


Fig. 7.

that the age medians fall along in a smooth ascending curve which differs somewhat in character from Stenquist's. The lower end of the approximation curve coincides with Stenquist's, but in the higher age groups it ascends much more steeply. A study of his curve would lead one to believe that the increase in median scores for age groups over fifteen would be very slight, if any at all. Results of this study, however, tends to indicate that improvement is constant up to the eighteenth year and apparently does not cease at that point. As to just what part experience plays in bringing about this increase is a question. Light may be shed upon this problem from an analysis of the findings of the other tests.

2. Results for Each Age on Block Test.

The graphical distribution of the scores of the five age groups on the block test are shown in Figs. 8 and 9. The medians of the age groups are shown in Table 2, which also shows the medians obtained by O'Connor (22) and Clark (32).

The norms obtained will help increase the scope of the block test by furnishing medians for age groups not studied by O'Connor. It also adds additional data to check those medians already established.

It will be noticed from Table 2, that O'Connor's sixteen-year-old boys took 1.18 minutes longer to assemble the block than boys of the same age did in this study. In explanation of this, O'Connor says that he does not consider his norms for this age group as final, since he has studied relatively few cases of this age. The median for seventeen-year-old boys is practically the same as O'Connor's median.

Distribution on O'Connor Block Test for 14, 15, and 16 Year-old Age Groups.

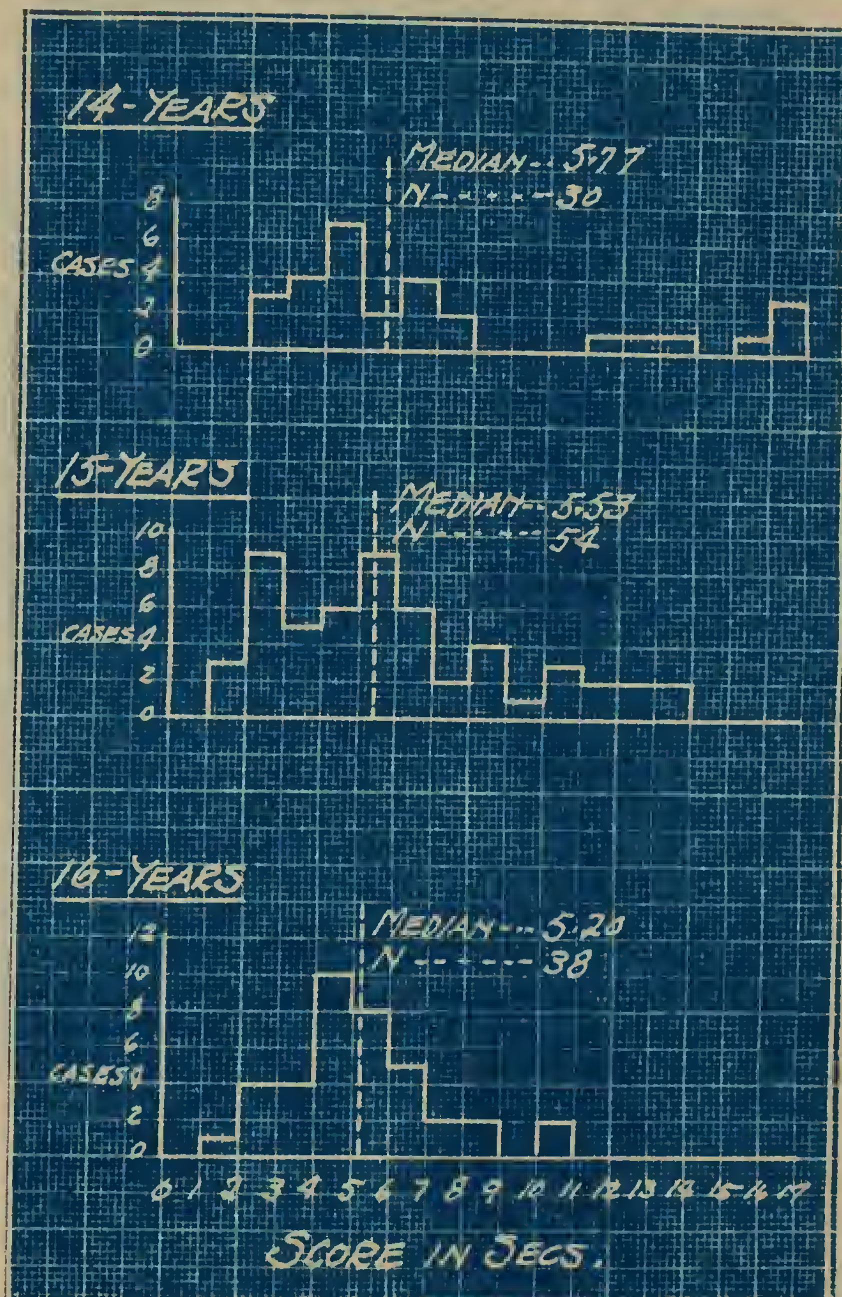


Fig. 8

Distribution on O'Connor Block Test for 17 and 18 Year-old Age Groups.

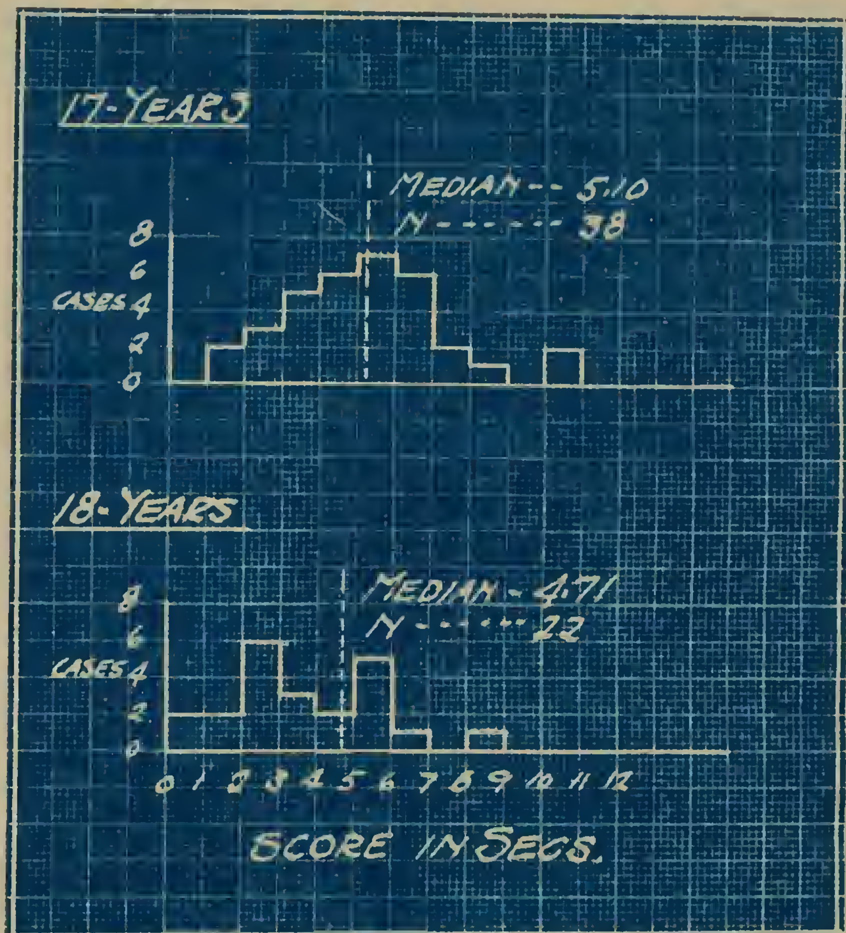


Fig. 9

Table 2

Summary of Results on Block Test for Each Age and Comparison with Results of O'Connor and Clark.

Age	Scores in Minutes		
	This Study	O'Connor	Clark
14	5.77		6.13
15	5.53		5.60
16	5.20	6.38	5.50
17	5.10	5.17	4.85
18	4.47	4.78	4.50
19		4.57	4.00
20		3.98	

while there is a slight difference in the medians for the eighteen-year-old groups.

Clark's study with Springfield Vocational School boys was carried on at the same time as this one and furnished a check. It will be noted that except for the difference of 0.36 for the fourteenth year, they closely parallel the results of this study.

The age medians for the three studies are shown graphically in Fig. 10. It will be noticed that the smoothed curves representing median scores of this study and Clark's study nearly coincide except at the lower end; i.e., the fourteenth year. The curve representing O'Connor's age medians is somewhat lower all along except at the twenty-year-old level. The coinciding of the curves representing the age medians of this study and of Clark's is of much interest, since the boys constituting Clark's group were vocational school students, and those making up the group tested in this study were students in a general high school. One would have ordinarily assumed that the scores of vocational school boys in assembling the block would have been higher, since they have elected by choice to train for vocations

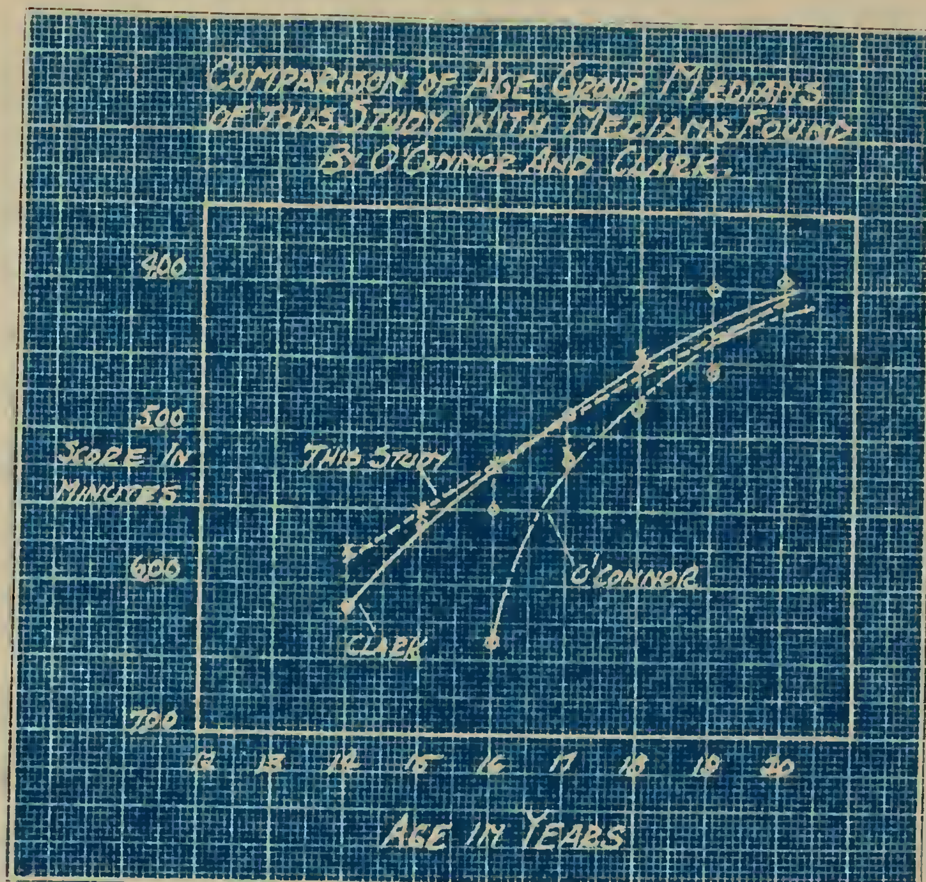


Fig. 10

which for the most part are mechanical in nature. Aptitudes are thought to be predictable from interests, yet the results of these two studies seem to indicate that this assumption is not borne out by the facts of this case. Apparently the vocational school group is as unselected at least for mechanical analysis as the general high school group.

3. Results for Each Age on The Puzzle Box.

The distribution of the scores of the five age groups on the puzzle box are represented graphically in Figs. 11 and 12. It will be noticed that the distributions are not symmetrical but are skewed to the right. For comparison with the work of other investigators the median scores of each age group were determined. These are listed in Table 3, together with the results of Healy, Woolley (33) and McFarlane (34).

It will be noticed that the fourteen year-old medians of this study are the lowest of the group. That these boys took much less time to open the box is no doubt due to selection, since this group did better than the average group of the same age in the block and MacQuarrie tests. The sixteen year-old median is lower than that obtained by Woolley and by McFarlane with her random cases, but is higher than McFarlane's technical cases. These technical boys correspond to the boys who attend our vocational schools.

While the median of all cases studied was 132, which is much lower than the medians of all ages in the other investigations, comparison is out of the question

Distribution on Healy Puzzle Box for 13, 14 and 15 Year-old Age Groups.

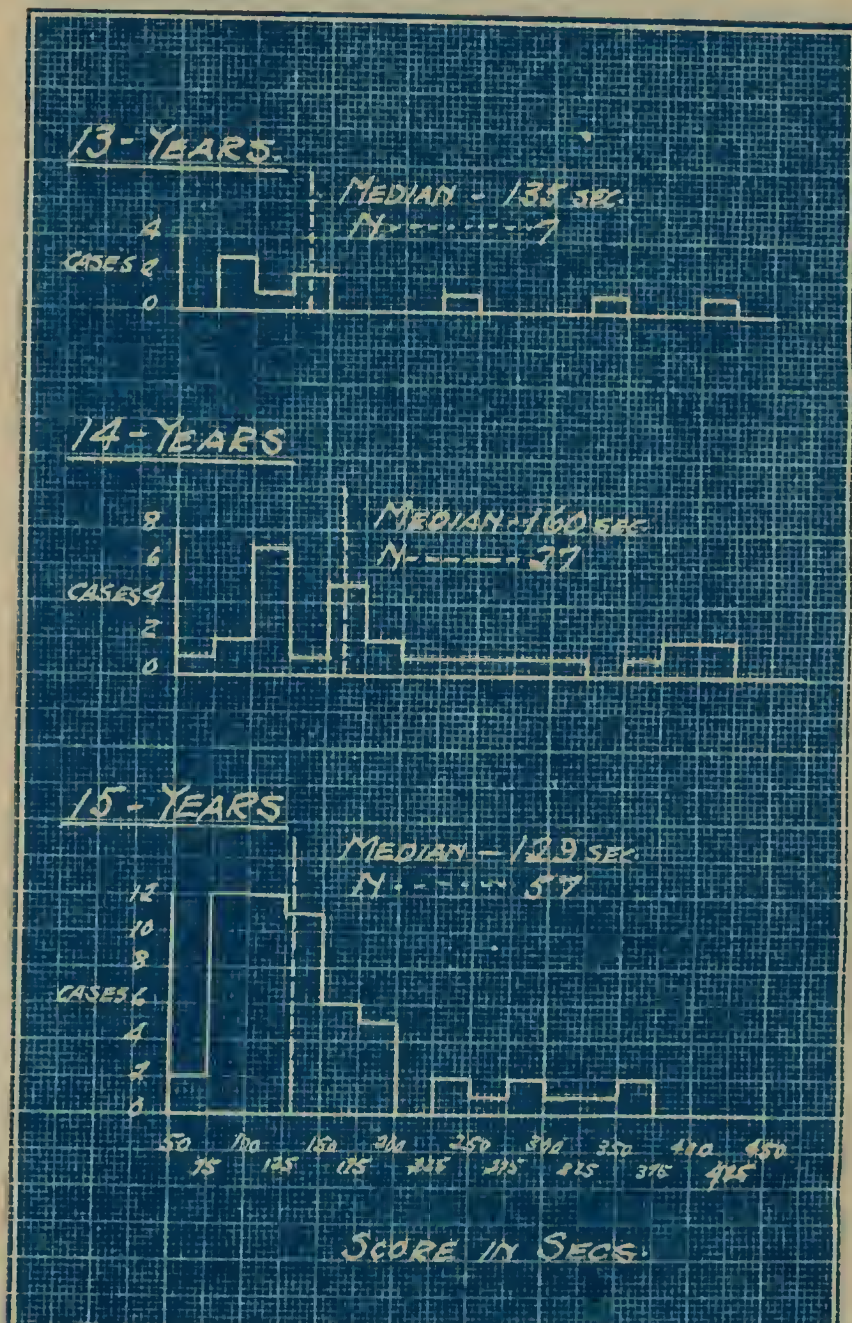


Fig. 11

Distribution on Healy Puzzle Box for 16, 17, and 18 Year-old Age Groups.

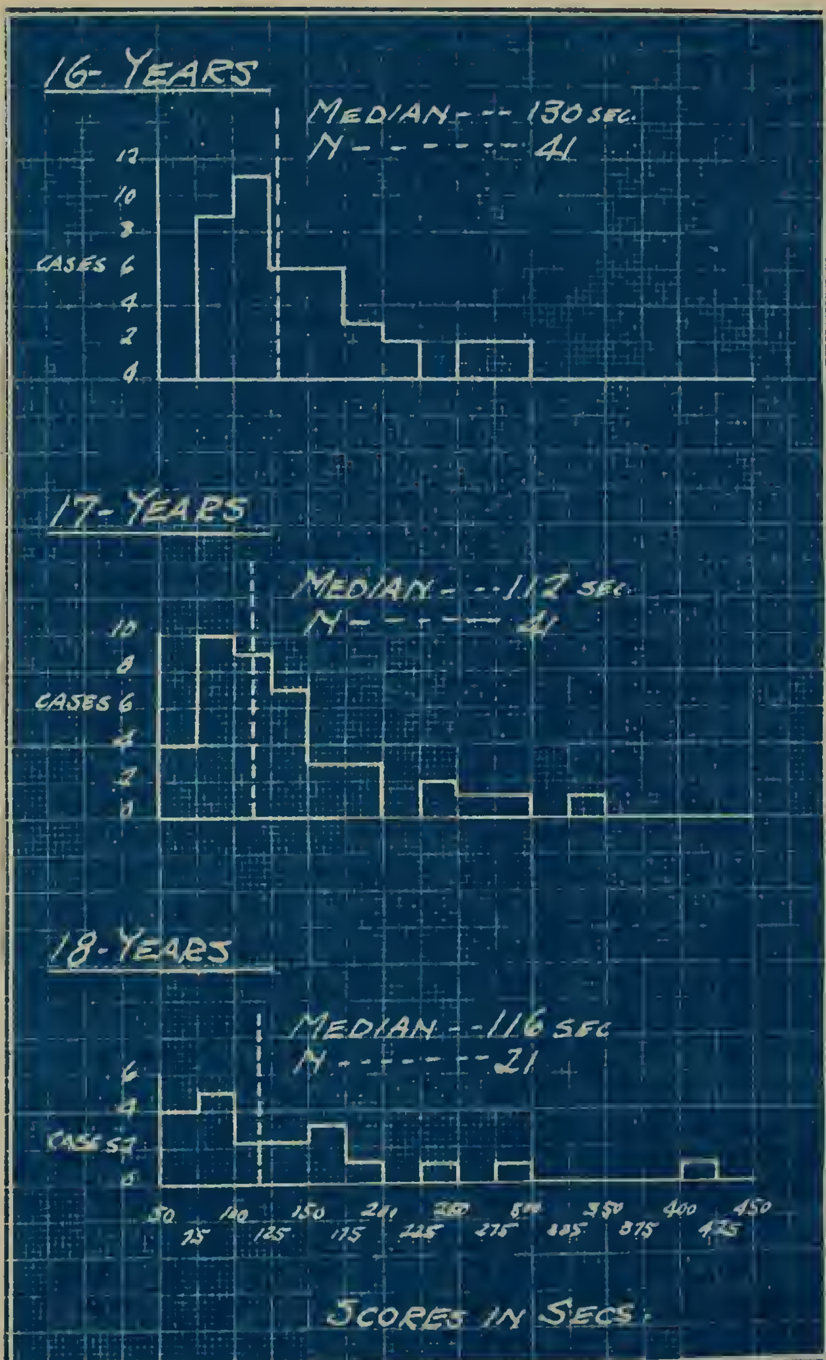


Fig. 12

Table 3

Comparison of Medians on Puzzle Box with Those

Obtained by Healy, McFarlane, and Woolley.

Study	Medians					
	Ages					All
	14	15	16	17	18	Ages
This Study	160	129	130	112	116	132
McFarlane, Technical	186		126			155
McFarlane, Random	253		150			219
Woolley, Random	251		153			202
Healy, 14 to & incl'd. Adults						199

because of the differences in the age groups studied. This is especially true in the case of the study of Healy, whose 277 cases ranged from fourteen years to and including adults. The median of 199 for these cases is not particularly significant, since the scores of younger subjects are poorer than those of older subjects. Thus if a large proportion of the individuals studied were of the lower age groups, the median would be quite different from that obtained if most of the subjects were of higher age groups.

This use of an "all age" median was due to the fact that preliminary statistical work indicated that this test was not an age-level test (36). However, the results of this study, the work of Woolley, and that of McFarlane seem to indicate the contrary. Analysis of the medians shows that there is improvement with age, the higher age groups making better scores. Graphical representation of this improvement is shown in Fig. 13. The smoothed curve drawn between the age medians clearly indicates that there is improvement with age. It is interesting to note that the medians of McFarlane's technical subjects are found to lie along this curve, giving further evidence to prove this point. Further research is needed to establish more definitely these age norms.

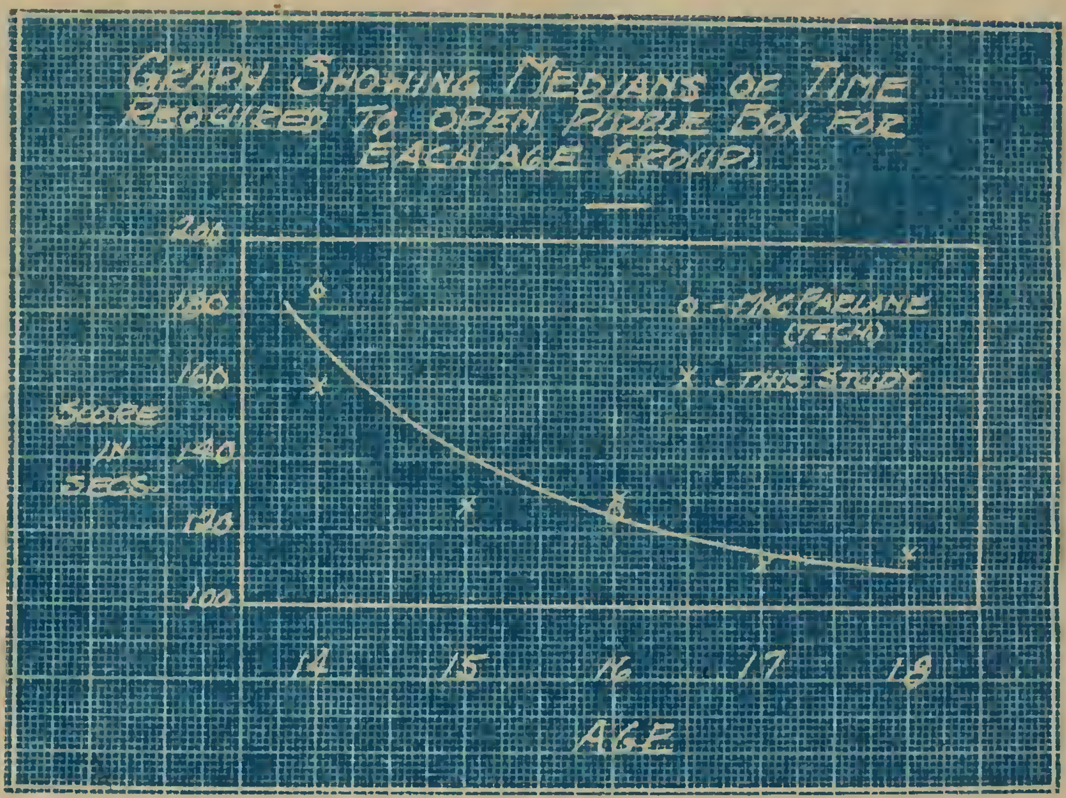


Fig. 13

Graph Showing Medians of Time required to Open Puzzle Box for Each Age Group of This Study and the Technical Subjects Studied by McFarlane.

4. Results for Each Age on MacQuarrie Test.

Figs. 14 and 15 give the graphical distribution of the scores of the groups tested on the MacQuarrie test. The age-group medians are noted in Table 4, together with those obtained by MacQuarrie.

The medians for the ages studied are slightly higher than those obtained by MacQuarrie with the exception of the median for the fourteen-year-old group. The scores of this group were very high, the median being 62, which is higher than that of the sixteen-year-old group. It is difficult to explain this median other than that it is due to some selective factor which operated for this group. This explanation seems to be borne out by the fact that the variations of the other age medians from MacQuarrie's medians were very small, being in all cases but slightly higher.

Inspection of the graphical representation of these medians shows that the MacQuarrie medians were evidently taken for each age from the smoothed curve, as all points fall within it. While the smoothed curve derived from the medians of this study follows the general

Distribution on MacQuarrie Test of Mechanical Ability for 13, 14, and 15 Year-old Age Groups.

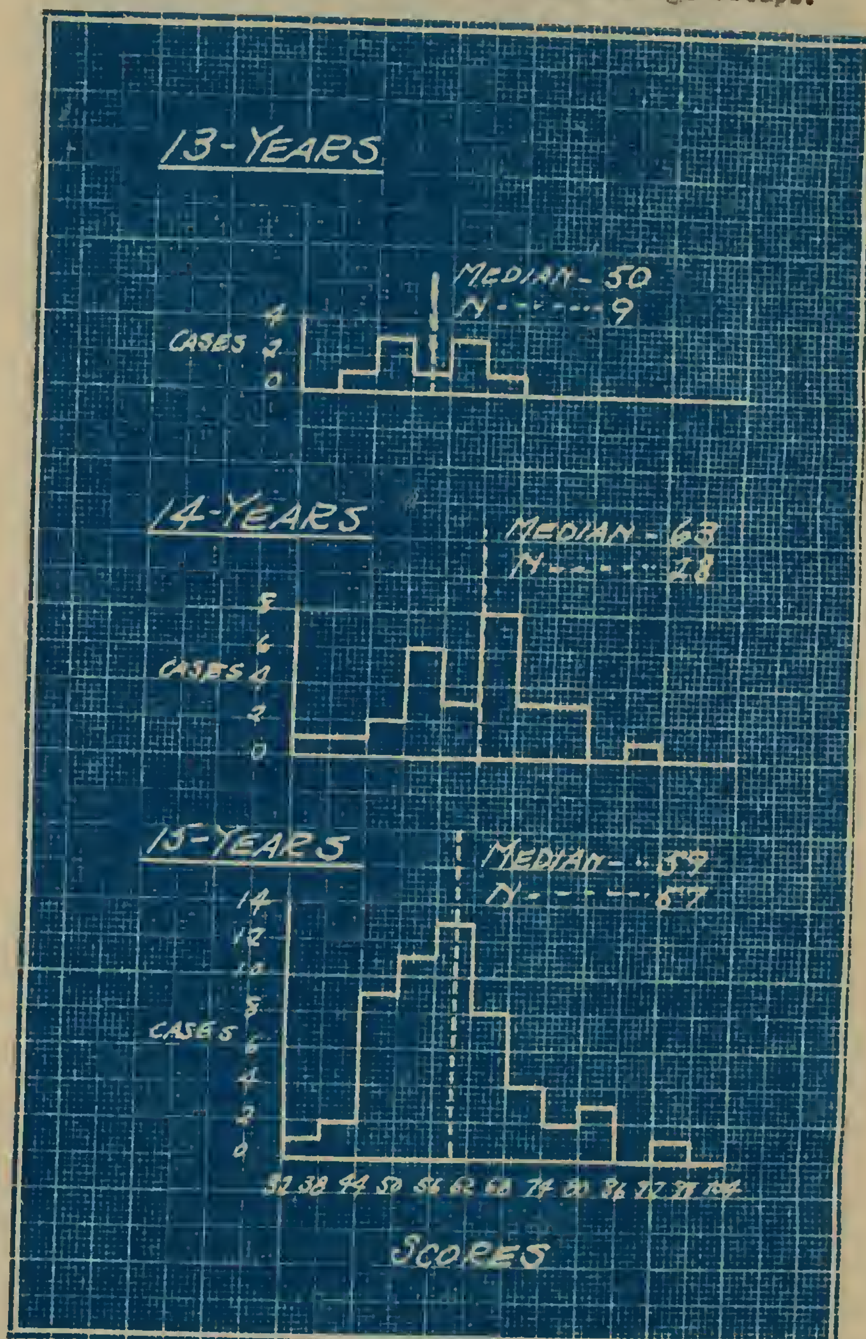


Fig. 14

Distribution on MacQuarrie Test of Mechanical Ability for 16, 17, and 18 Year-old Age Groups.

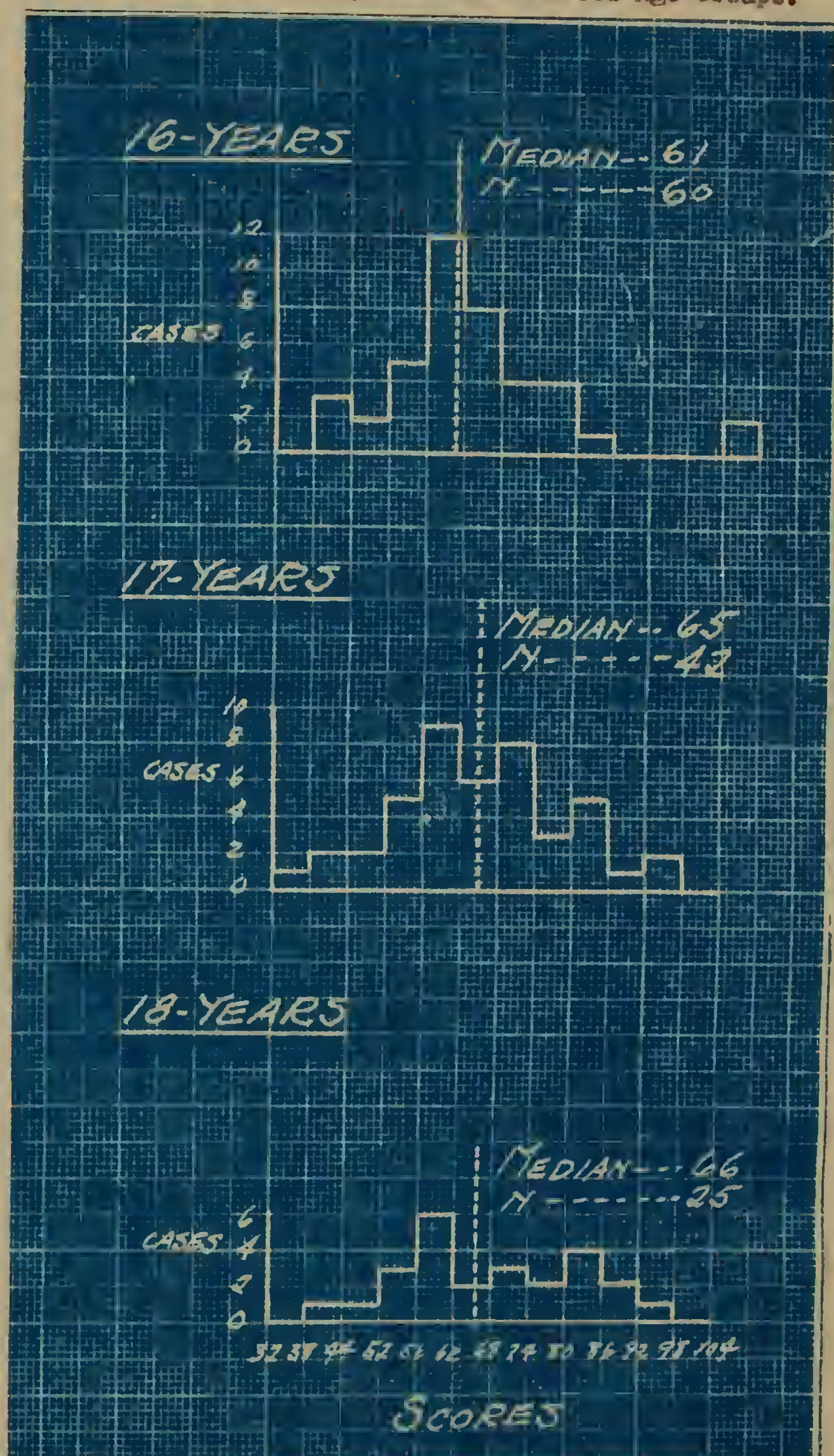


Fig. 15

Table 4

Summary of Results in This Study on MacQuarrie Test
for Each Age and Comparison with Results of MacQuarrie.

Age	Median Scores	
	This Study	MacQuarrie
12		44.
13	50.	49.
14	62.5	52.
15	59.	57.
16	61.	60.
17	65.	63.
18	66.	65.
19		67.
20		68.

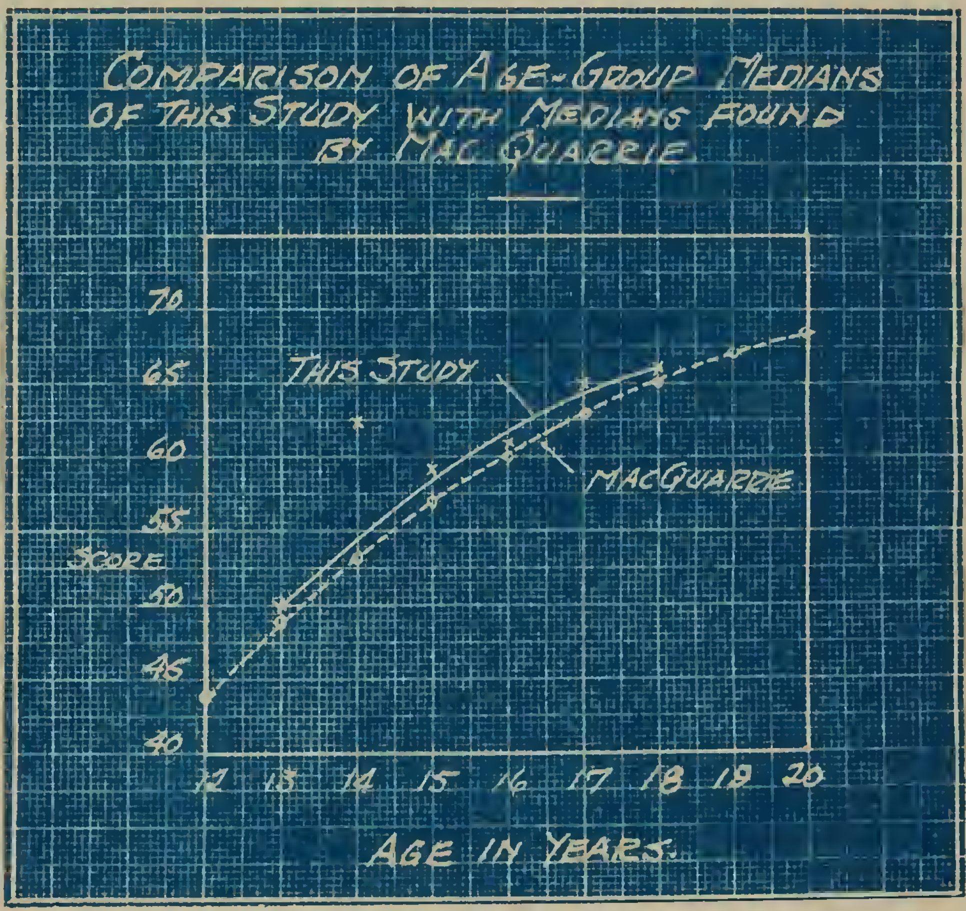

COMPARISON OF AGE-GROUP MEDIANS
OF THIS STUDY WITH MEDIANS FOUND
BY MAC QUARRIE
THIS STUDY
MACQUARRIE
SCORE
70
65
60
55
50
45
40
12
13
14
15
16
17
18
19
20
AGE IN YEARS

Fig. 16

contour of MacQuarrie's curve, it averages two points higher all along. Whether the groups tested were somewhat selected or whether the medians furnished by MacQuarrie are a trifle low cannot be easily determined.

5. Result for Each Age on Manual Dexterity Test.

The distributions of scores on the dexterity test for each age groups are shown graphically in Figs. 17 and 18. The medians of the age groups are shown on Table 5. This table also shows the medians obtained by Whitman (30) for the age groups included in her investigation which were covered by this study. Her medians are based upon about fifty cases in each age group.

The median for the thirteen-year-old group is the same as that found by Whitman. The fourteen-year-old median is six higher and the fifteen-year-old is nine higher. Whitman (30) in the report concerning her study states that the scores of the fourteen-year-old boys were for the greater part on the low side of the mode, that high scores were relatively few, due to some unaccountable selection. Accordingly the median for that age group shows a lack of improvement over the thirteen year-old group. Analysis of

Distribution on Whitman Manual Dexterity Series
for 13, 14, and 15 Year-old Age Groups.

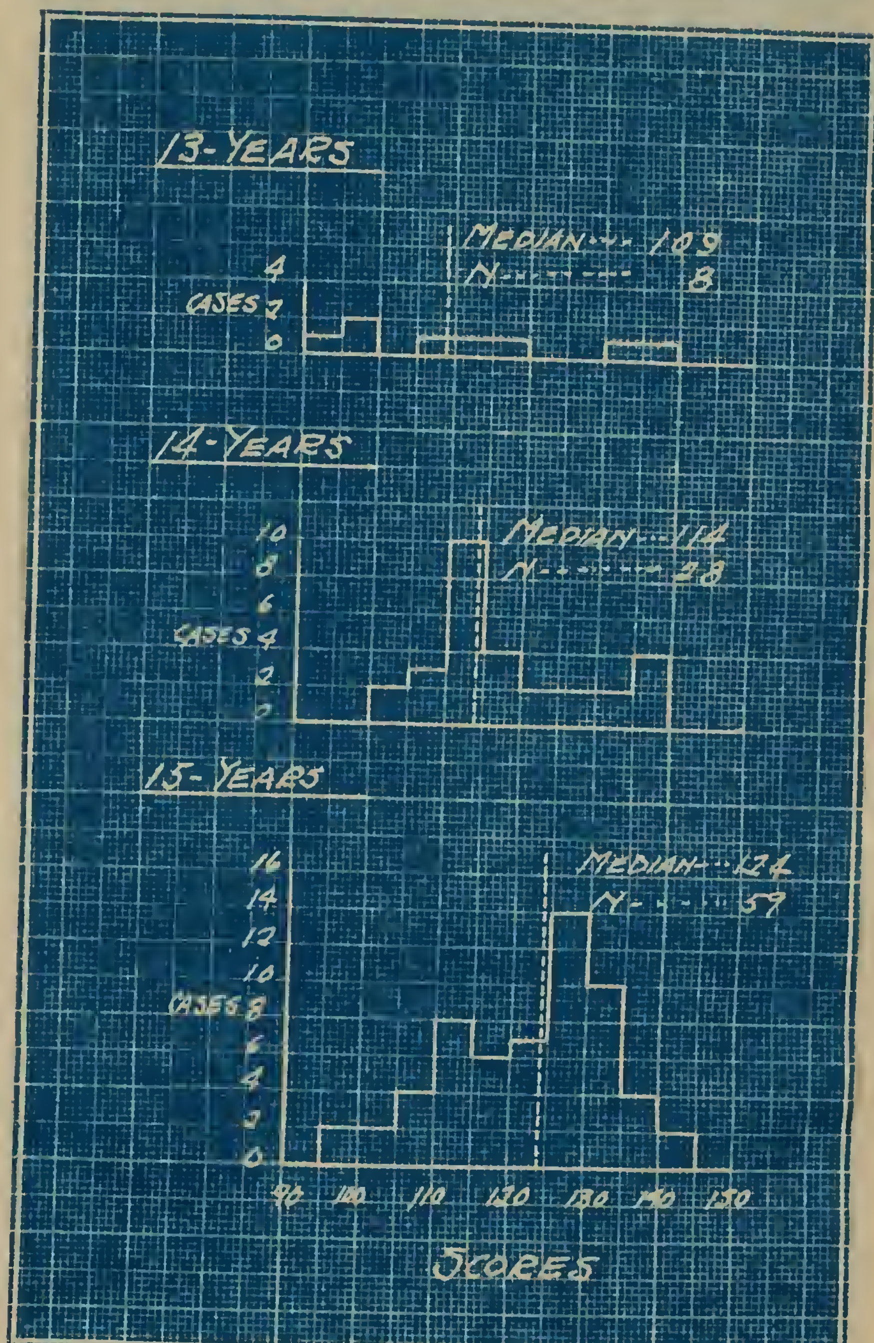


Fig. 17

Distribution on Whitman Manual Dexterity Series
for 16, 17, and 18 Year-old Age Groups.

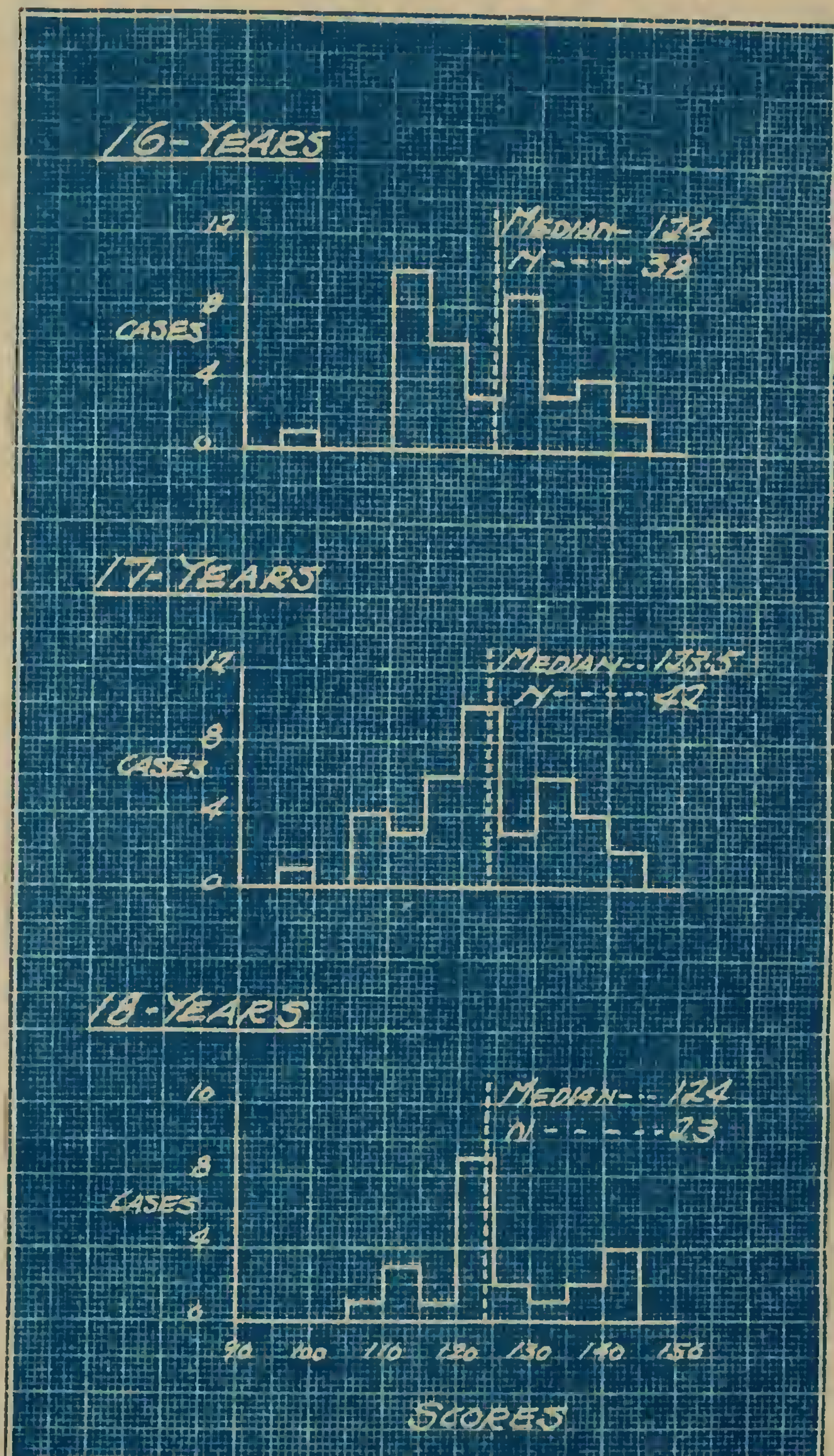


Fig. 18

Table 5

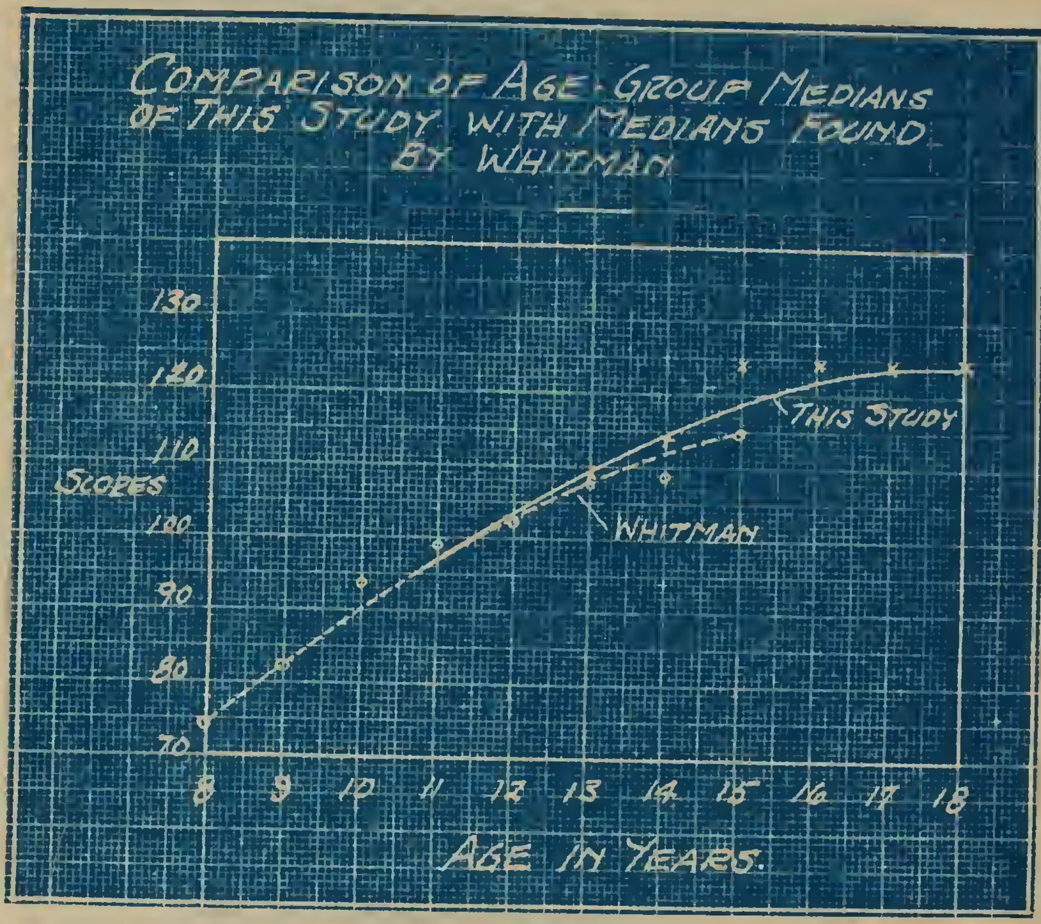
Summary of Results in This Study for Each Age on Manual Dexterity Test and Comparison with Whitman's Results.

Age	Median Scores	
	This Study	Whitman
13	109	109
14	114	109
15	124	115
16	124	
17	123.5	
18	124	

the results of this study indicate that there is no improvement after the fifteenth year. This would indicate that either there is no further increase in power to manipulate after fifteen or else the groups in some unaccountable way were selected. An analysis of the graph shown in Fig. 19 will help to offer an explanation. It will be noted that smoothed curve based upon the two sets of medians passes through the thirteen, fourteen, seventeen, and eighteen-year-old medians of this study, and midway between the two medians at fifteen years. It is evident that the fifteen-year-old median of this study is high, while that of Whitman's study is low, the true median lying between them as is indicated by the curve. As is shown by the curve, improvement decreases rapidly with the upper age groups and ceases after seventeen. It appears evident that improvement in innate manual dexterity ends after an individual reaches the age of seventeen.

6. Summary of Results from Study of Data.

(a) For each age on each test the scores are slightly higher than the scores found by the other workers.



COMPARISON OF AGE-GROUP MEDIANS OF THIS STUDY WITH MEDIANS FOUND BY WHITMAN
130
120
110
SCORES
100
90
80
70
THIS STUDY
WHITMAN
8
9
10
11
12
13
14
15
16
17
18
AGE IN YEARS.

Fig. 19

(b) The data obtained has helped to extend the age norms of the assembly, block, and manual dexterity tests.

(c) The data shows that the Healy Puzzle Box is an age-level test. The time needed to complete the test is affected by age.

(d) It was found that the improvement in innate ability to manipulate as measured by Whitman's tests, ceases at approximately the seventeenth year.

(e) Ability to assemble mechanisms as measured by the assembly test increases constantly through the eighteenth year and there is no indication that the increase ends there.

Chapter VI

CORRELATIONS BETWEEN TESTS

1. Correlation of Mechanical Tests with "General Intelligence."

The test scores were correlated with the intelligence quotients which had been previously determined on the basis of scores in the Terman Group Test of Mental Ability. The correlations obtained between the mechanical test scores and I. Q.'s ranged from .07 to .24. They are listed in Table 6.

It will be noted that all of the correlations between the test scores and the I. Q.'s are low. This lack of agreement corroborates the findings of other workers who have studied the relationship between mechanical ability and abstract intelligence. The findings of this study add emphasis to the fact that relationship between "ability with ideas" and "ability with things" is very slight. In Table 7 which lists the correlations found by other workers between various mechanical tests and "general intelligence" it will be noted that in most cases the coefficient of correlation is between .10 and .30. This seems to be

Table 6

Correlations between I.Q.'s and Mechanical Tests.

Tests	r
Assembly Tests	.14
Block Test	.24
Puzzle Box	.13
MacQuarrie Test	.24
Manual Dexterity	.07

(All correlations in this study were calculated by means of Pearson's coefficient of correlation formula.)

Table 7

Correlation between "General Intelligence" and Mechanical Test Scores Noted in other Studies.

Test	Study	Intelligence Test Used	Cases Studied	r
Assembly	Brown (38)	Heggerty Delta	436 boys, 10 to 13 years	.24
Assembly	Gaw (39)	Stanford rev. Binet		.29
Assembly	Stein (40)	Army Alpha	15 college students	.10
Assembly	Toops (7)	Read. and Arith. scores	433 boys, 12 to 15 years	.10 to .26
Assembly	Toops and O'Rourke(41)	Army Alpha	145 high school boys	.14
Assembly	Stenquist(20)	Scores of 5 tests pooled	367 boys, grades 7 & 8	.23 to .34
Puzzle Box	McFarlane(37)		238 English cases	.28
MacQuarrie	Board, and others (36)	Terman Group	500 boys, 6th and 7th grade	.23
Manual Dexterity	Whitman (30)	Myer's Ment. Measure.	434 boys and girls, 7 to 15 years	.37

the extent of the relationship between the two intelligences, mechanical and abstract. The lowest correlation of the study was found between manual dexterity and abstract ability. That this relationship should be the lowest is to be expected since the correlation between intelligence and motor coordination has always been found to be approximately zero.

2. <u>Intercorrelations of Various Mechanical Tests.</u>

The correlation between the block test and the puzzle box was found to be .34. While this correlation indicates that there is a certain degree of relationship existing between the two tests, it also indicates that this relationship is not very great. There are apparently factors involved in the puzzle box which are not found in the block and vice versa. McFarlane, using the puzzle box and a painted cube test, found a correlation of .35 between them. Since it is known that the response called for in the assembly of this block is of the same nature as that called for in the wiggly block, further evidence is added to this conclusion.

A correlation of .45 was found between the puzzle box and the assembly test. This correlation may be considered as indicating a considerable degree of relationship, giving evidence that both tests measure, along with other factors, similar types of ability. The opening of the box requires the ability to analyze the complicated system of cords, hooks, rings, etc. and to arrive at a definite plan of procedure for its opening. It is evident that this requires to a considerable degree the same type of mental processes as are required to assemble correctly the mechanisms constituting the assembly test.

The correlation .26 found between the puzzle box and the MacQuarrie test indicates that there is not as much in common between these two tests as there is between the puzzle box and either the assembly or block test. A study of the individual tests which make up the MacQuarrie test shows that only one of the seven tests gives any evidence of measuring to any extent some of the types of activity that are measured by the puzzle. Yet this test, the maze test (see sample of MacQuarrie test on Page 37), shows a correlation of only .29 with the puzzle box. This correlation seems to indicate that the only elements which they have in common and which are indicated by the extent of this correlation are visual perception, the power of concentration and the power of sustained attention and effort.

The low correlation of .18 between the puzzle box and the manual dexterity test shows quite conclusively that dexterity alone contributes but very little to the total response involved in the solution of the puzzle. It indicates that ability to open the box is dependent only to a very slight degree upon motor coordinations.

The correlation between the blocks and the assembly test of .55 was the highest correlation obtained between the various mechanical tests. It gives indication that both tests have much in common although they differ greatly in physical appearance. While O'Connor (22) calls the block test a test of mechanical analysis, it seems to involve as its most important element the ability to visualize spatial relations; that is, the ability to think and work in terms of three dimensions. It is apparent that this type of mental process is one of the most important elements involved in the assembly test. It is called for in the recognition of the parts of the mechanisms, and for making of judgments as to the reasons for their particular size and shape in order that they may be properly assembled.

The correlation of .37 between the block scores and the scores in the MacQuarrie test indicates limited agreement. A study of the tests which makes up the MacQuarrie test shows that only two of the tests attempt to measure specifically the same factor which is measured by the blocks; namely, spatial relationships. These two tests are the location test and the block test (see sample on page 37). The location test involves relationships in two dimensions while the block test involves three dimensions. Since the latter seemed to present a situation more nearly alike that of the wiggly block test, the scores of this test and those of the wiggly block were correlated. Their relationship was found to be indicated by the coefficient of correlation .39. Apparently there are common elements in the assembling of blocks and the visualizing of a pile of blocks represented on paper in perspective. However, there is a difference as to whether the pieces actually exist and are assembled by hand to form a completed block or whether they are simply counted from a paper representation in perspective. Since the wiggly block test calls for actual manipulation of the pieces which make it up while the block counting test does not, it might be assumed that the factor of manipulation might be responsible for this lack of higher correlation.

Yet upon the correlation of both block tests with the test of manual dexterity the correlations were found to be practically the same, .36 and .37. This would indicate that dexterity, a common factor in each test, exists to the same degree and so would not account for the lack of higher correlation between the block tests. The real difference seems to lie in the medium involved.

The correlation of .29 between the assembly and the MacQuarrie tests does not show that there is much agreement in what each one tests. The agreement that does exist is no doubt limited to motor coordination, although there are, no doubt, other more elusive factors involved to a slight degree.

The assembly and manual dexterity tests show a correlation of .35. This correlation indicates the extent to which success in assembling the mechanisms of the assembly test depends upon manual dexterity. It is evident that the rapidity and accuracy of movement is but one of the factors measured by the assembly.

The correlation between the MacQuarrie and the manual dexterity test of .53 indicates quite clearly the importance of motor coordination in this test. It is involved

Table 8

Intercorrelations of Test Scores and I. Q.'s

Tests	I. Q.	Block	Puzzle	Assembly	MacQuarrie	Dexterity	MacQuarrie Blocks	MacQuarrie Maze
I. Q.		.24	.13	.14	.24	.07		
Block	.24		.34	.55	.37	.32	.39	
Puzzle	.13	.34		.45	.26	.18		.29
Assembly	.14	.55	.45		.29	.35		
MacQuarrie	.24	.37	.26	.29		.53		
Whitman	.07	.32	.18	.35	.53		.36	
MacQuarrie Blocks		.39						
MacQuarrie Maze		.29						

P. E.$_r$ when r is			
.00	.20	.40	.60
.047	.045	.038	.032

to such an extent that it might easily be the deciding factor in the success or failure of a performance on this test. While the test measures other factors such as spatial relations in two and in three dimensions, there is much more emphasis placed upon rapidity and accuracy of movement than upon any other factor. MacQuarrie (27) answers this criticism by asserting that speed is a very important contributory factor to success in mechanical vocations and so must be included as one of the factors in a test of mechanical ability. The results of this study shows that there is, however, too much emphasis placed upon this specific element.

CHAPTER VII

SUMMARY AND CONCLUSIONS

While it has been found that all of the mechanical tests correlate positively, these correlations in most instances are not very high. It indicates, as has been mentioned before, that while the tests have something in common, they do not tap exactly the same abilities. The agreement among the tests may be explained by the presence of a "general" factor common to all of them, or by the existence of a number of "specific" factors occurring in different combinations and to various degrees.

The existence of a "general" factor running through all tests of a mechanical nature would easily account for the positiveness of the correlations obtained. Since these tests are mental tests, it might be suggested that the "general" factor is one which is common to all mental tests, irrespective of what type of mental process they measure. Results, however, furnish evidence that a "general" factor that might exist in the mechanical tests is not exactly the same "general" factor that runs through the type of mental test known as the test of "general intelligence." This is indicated by the correlations found between them, which are considerably lower than the correlation among the mechanical tests themselves. There is sufficient proof from the positiveness of the correlations, however, to indicate that mental tests are all related. On the other hand, the higher correlations between the mechanical tests can be used to prove the existence of a number of "specific" factors, not only occurring in different combinations, but also being involved to different degrees in them. An analytical study of the tests used strengthens this idea of the existence of "special" factors. It seems to indicate that mechanical ability is a complex of many factors, each being important for success in a mechanical procedure. This analysis does indicate, however, that many of the processes involved in abstract ability, such as reasoning, analysis, etc., are involved in mechanical ability. The chief reason for the lack of correlation of the tests of these two abilities is apparently due to the difference in the mediums which are used.

The differences between these two abilities indicates that a true picture of an individual's mental state cannot be obtained solely through the use of tests of "general intelligence" now in use. As has been stated before these tests are in reality tests of scholastic ability, and as such fail to call upon types of mental processes which should be investigated. They give at the best but an incomplete picture of a person's mental make-up. However, it must not be construed from this statement that the factors involved in scholastic ability are not of great importance but that there are other factors such as mechanical ability which are of equally great importance. These should be tested along with those constituting scholastic ability.

Since it has been found that the tests used in this study in measuring mechanical ability do not measure exactly the same thing, a battery of tests should be given rather than a single test. From the results obtained from the battery, a composite score could be developed which, with the score of the scholastic ability test, would furnish valuable data for use in vocational counseling.

This is well shown by the analysis which has been made of the distribution of cases for each test. Dividing the scatter diagram into four quadrants by means of the averages of the two sets of scores, the percentage of cases falling in each quadrant was determined. This divided the total number of cases into four groups, those who rank above the average both in "general intelligence" and the mechanical test scores, those above the average in "general intelligence" and above the average in the test scores, and those below the average in both "general intelligence" and test scores. The average percentage of cases for the five tests was then determined in each quadrant. These averages together with the separate percentages for each test are shown in Table 9. An inspection of these results in this table shows that of the total number of cases those in Group C, or 30%, are above the average in both "general intelligence" and mechanical ability. Those in Group D or 18% are above the average in "general intelligence" but are below the average in mechanical ability. It is evident, then, that a boy who is above the average in "general intelligence" is more apt to be above the average in mechanical ability than a boy who is below the average in "general intelligence".

Those in Group A, or 26%, are above the average in mechanical ability but are below the average in "general

Table 9

<u>Analysis of Total Distribution</u>

Low I. Q. High Test Score	High I. Q. High Test Score
Blocks 29%	Blocks 34%
Assembly 27%	Assembly 26%
Puzzle 26%	Puzzle 35%
MacQuarrie 22%	MacQuarrie 24%
Dexterity 28%	Dexterity 30%
Average 26%	Average 30%
Blocks 21%	Blocks 16%
Assembly 28%	Assembly 19%
Puzzle 24%	Puzzle 13%
MacQuarrie 30%	MacQuarrie 24%
Dexterity 24%	Dexterity 18%
Average 26%	Average 18%
Low I. Q. Low Test Score	High I. Q. Low Test Score

intelligence." These boys would probably not succeed as well in clerical vocations, for example, as they would in vocations of a mechanical nature. However, in these vocations their progress would be somewhat limited, since abstract ability is necessary to a certain degree in the higher types of mechanical vocations.

Those individuals that make up Group B, or 26%, are below the average in both abstract and mechanical intelligence. This is the group which will probably fill the ranks of unskilled and possibly semi-skilled workers, the routine machine tenders or rough machine operators, delivery men, truckmen, etc., individuals who, by the laws of chance operating through heredity, are not equipped mentally as the other 75% and who will undoubtedly constitute a great sociological problem in their proper adjustment in society.

It is interesting to note that the current practice of many school systems is to send to the vocational or trade schools, manual training departments, etc., only those boys who are unable to do academic school work. This is done on the basis that they will be more fitted for this type of work. The results of this study shows, however, that only one-half of them would achieve any degree of success in this type of school.

The boys in Group D who possess both "general intelligence" and mechanical ability above that of the average are many times directed into vocations on the basis of their mechanical and abstract abilities alone. It is evident that because of their mechanical and abstract abilities they should do well in such vocations as engineering, surgery, dentistry, etc., callings into which they might not be directed on the basis of abstract ability alone.

This distribution of the scores in the various mechanical tests cannot help but give further evidence as to the unsoundness of giving vocational advice on the basis of the test of "general intelligence" alone. It serves to emphasize further the fact that mechanical ability is largely independent of abstract ability.

APPENDIX A

1. Administration of Assembly Test.

The box is placed in front of the boy so that the cover serves as a tray in which to work. The screwdriver is in the tray. The following instructions are then given:

"In this box are ten common mechanical things that have been taken apart. You are to take the parts and put them together as they ought to be. That is,you are to put them together so that each will work perfectly. Do not break the parts, for everything goes together easily if you do it in the right way. Even though you may not be able to complete some of these things, put as many of the parts together as you can. The parts that go to make up each thing are together." Then indicating to the parts in compartment A, "all these parts go to make up one thing." Then pointing to compartment B, "all these make up another, and so on. Begin with Model A, then take model B, then C, and so on. The numbers under the letters indicate the number of parts each thing has, be sure to get them all out. If you come to one you cannot do in about three minutes, go on to the next. The person who gets the most things right gets the highest score. Have you any questions?" When everything is perfectly clear say, "Start now."

After thirty minutes have elapsed, stop the work and score the test.

In the scoring of the test the special score sheet prepared for these tests was used. A value of ten is assigned to each model assembled correctly. For varying degrees of perfection, partial scores from one to nine are assigned, according to the score sheet. By adding the various partial score values to the scores of the perfect models, the total raw score will range from 0 to 100. A time bonus of one-half point per minute is given for each minute less than the standard thirty minutes. This may cause a score to occasionally go above 100.

2. <u>Administration of Block Test</u>.

Place the nine blocks, assembled, before the examinee with one end toward him and say, "THIS IS MADE UP OF NINE BLOCKS, LIKE THIS." Take one of the top corner blocks in the hand, showing it to the examinee and say, "I WILL MIX THEM UP, AND GET YOU TO PUT THEM TOGETHER AGAIN." Replace

Name ________________________ Age ________________
(Nearest Birthday)

Grade ____________ School________________________

STENQUIST ASSEMBLING TEST
STANDARD SCORE SHEET

FINAL
"T" SCORE: [ ]

Series II

NOTE: Do not fail to place this record inside box when you have finished the test. Fold LENGTHWISE.

Individual Raw Score	
	Model A. Pistol. Two sides properly joined with screw = —1; Hammer in place = +2; Spring in proper position = +7.
	Model B. Elbow Catch. Catch in place = +3. Spring in place = +3. Pin in place = +3.
	Model C. Rope Coupling. Castings properly joined with screws = +1; Center stud properly in place = +5.
	Model D. Expansion Nut. Rings in place and sides O. K. = +4; Nut reversed or bolt reversed = —6.
	Model E. Sash Fastener. Top and Bottom in place, with screw in place, nut down = +3; Same, with nut up = +2. 1 spring in place = +4; Both springs in place = +5.
	Model F. Expansion Rubber Stopper. Rubber properly on cone = +6. Bolt upside down = —4; nut wrong = —5.
	Model G. Calipers. Spring in place on both arms with adjusting screw in place of eye = +5; Pivot in place = +2. Sleeve in place = +1.
	Model H. Paper Clip. Spring in place on jaws = +2; Pin inserted properly = +6; Pin inserted improperly = +1.
	Model I. Double Acting Hinge. For each pin in proper place = +1.
	Model J. Lock No. 2. Bolt in place = +1. Lug in place = +1. Both in place = +4; Spring in place = +6; Cover in place = +1.

TIME BONUS________________
TOTAL
RAW SCORE________________

NOTE TO SCORER: Score all perfectly assembled models 10. "—" means deduct from 10. "+" means "add to zero."

Raw Score	"T" Score
0 to 1	27
2 to 3	29
4 to 5	32
6 to 7	35
8 to 9	37
10 to 11	39
12 to 13	41
14 to 15	42
16 to 17	44
18 to 19	45
20 to 21	46
22 to 23	47
24 to 25	48
26 to 27	49
28 to 29	50
30 to 31	51
32 to 33	52
34 to 35	54
36 to 37	55
38 to 39	55
40 to 41	56
42 to 43	57
44 to 45	58
46 to 47	58
48 to 49	59
50 to 51	60
52 to 53	61
54 to 55	61
56 to 57	62
58 to 59	63
60 to 61	64
62 to 63	65
64 to 65	66
66 to 67	67
68 to 69	68
70 to 71	70
72 to 73	70
74 to 75	71
76 to 77	72
78 to 79	74
80 to 81	74
82 to 83	77
84 to 85	77
86 to 87	78
88 to 89	78
90 to 91	80
92 to 93	82

No. 44073—Stenquist C. H. Stoelting Co., Chicago, Ill., U. S. A.

Score Sheet for Assembly Test

top corner block in original position, and proceed as follows: "NOTICE CAREFULLY HOW IT IS MADE. IT IS CUT THROUGH INTO THREE PILES, WITH THREE BLOCKS IN EACH PILE." While saying this separate the blocks into three vertical piles, three blocks in each. In giving description gesture freely so that a person may understand from the motions, if he has difficulty in following the language. Move the hand down as if cutting the formation twice through into three piles. Touch each pile when it is mentioned and also the separate blocks. Next push the three piles together again, making the block once more as originally assembled. "IT IS ALSO CUT THROUGH INTO THREE LAYERS WITH THREE BLOCKS IN EACH LAYER." While saying this, remove the top two layers of three each, and place them on the table beside the bottom layer, a few inches from it. Then lift the top layer of three from the middle layer, and place it so that the three layers are arranged before the examinee in this order, bottom, middle, and top. These blocks should be moved so that the movement in disassembling will be from the examinee's left to his right.

Separate the three blocks in the lower layer keeping them parallel, leave them a moment and then push them together again. In the same way separate the three blocks, for a moment, in the middle layer, and then in the top layer. "REMEMBER THAT IT IS THREE (touch bottom block) BLOCKS (touch middle block) HIGH (touch top block) AND THREE (touch left top block) BLOCKS (touch middle top block) WIDE (touch right top block). "NOW I WILL MIX THEM UP." Do not hurry the explanation; allow plenty of time for each step of the description to be followed and understood. Take the assembled block apart with the examinee looking on. This is better than asking him to look away. Take up each block by one end; do not hold by the middle, as this makes the turning end for end too obvious. All blocks not turned end for end should be given at least a quarter turn on its own axis. Make the motions rather slowly; rapid ones disturb the examinee with the idea that you are trying to confuse him. Turn the two upper corner blocks end for end, and put them on the table. Place the middle block from the top, and the two side blocks from the middle layer with the first two without turning end for end. In the same way, the center block in the middle layer turn end for end and place in the pile. The middle block in the bottom layer put in the pile without turning end for end. The blocks to be turned are marked with crosses (X) on the accompanying cross-section diagram.

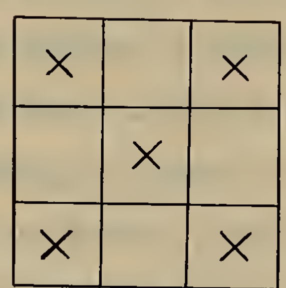


Fig. 20

Cross-section of Block Showing Those
to be Turned End for End.

Now mix the blocks thoroughly but slowly, so that the examinee cannot follow individual ones, but take care not to turn any end for end. Then spread out once more. Each block except of course the center one, should have a flat edge resting on the table top. No blocks should have flat faces toward each other. When the examinee starts reassembling, the blocks should be arranged in a neat row, parallel to one another, an inch or so apart, and with one end of each block toward the examinee. They should not be piled on top of one another or left in an irregular order. Leave a free space of approximately a foot between the examinee and the blocks for the assembling operation. Arrange the test to indicate as nearly as possible mechanical ingenuity and to be affected as little as possible by the dexterity of the examinee, or any other complicating characteristic. Piling the blocks in a heterogeneous pile immediately before the examinee, without leaving working room, requires more dexterity in reassembling than arranging the blocks neatly, providing free space for assembling. Give no help of any kind (other than encouragement if necessary) during reassembling. Time in minutes and hundredths of a minute the reassembling. Tell the examinee whether he has been fast or slow, using judgment in doing so, not to discourage him unduly if he has done poorly. Having answered any questions which the examinee has to ask, proceed as follows: "WE TAKE THE AVERAGE OF THREE TRIALS SIMPLY BECAUSE IT IS A LITTLE FAIRER THAN GIVING ONLY ONE. TRY IT AGAIN IN JUST THE SAME WAY." Mix the blocks as before with no more explanation than the above. Repeat a third time with the words, "TRY IT ONCE MORE. THIS IS THE LAST TIME."

In scoring, the time of each trial is recorded in minutes and hundredths of minutes in a tabulation as indicated below and the final score computed.

Time of 1st trial	x 1.	=	....
Time of 2nd trial	x 1.4	=	....
Time of 3rd trial	x 1.7	=	....
Final Score			
		3	:
Average time of 3 trials			

As was stated before, the examinee is allowed to assemble the blocks three times so as to eliminate the chance element. However, as a result of learning, the time of the second trial should be better than that of the first, while the time of the third trial better than the second. To compensate for this, O'Connor has developed the factors 1.4 and 1.7 from the results of the improvements made in the second and third trials by several hundred persons.

3. <u>Administration of Puzzle Box</u>.

The puzzle box and a buttonhook are given to the examinee. He is then given the following directions. "You see that this box opens by lifting up the lid. The glass is put in so that you can see the way to open it. You can work through the holes and use this buttonhook (handing buttonhook). Study the box; if you do the right things in the right order, it can be readily opened. Do not break the strings or the glass. Open it as quickly as you can." The time that it takes to open the box is the score and it is expressed in seconds. Healy has set a time limit for five minutes for its opening.

4. Administration of Manual Dexterity Test

Test 1. The material for test 1 is placed in front of the person being tested as shown in Fig. 21 below. He is then given the following directions:

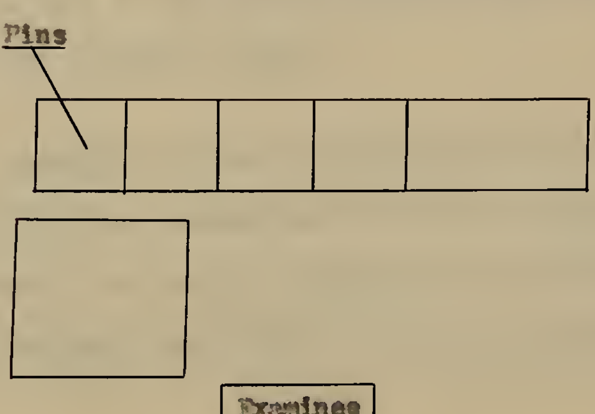


Fig. 21

Arrangement of Block and Tray for Test 1, 2, and 3.

"I have a number of things for you to do with your hands. Do them as quickly as you can. The first thing I am going to ask you to do is to see how many holes you can fill with these pins before you are told to stop. Use your right hand (or left--the preferred is essential). Remember you are to use only your right (left) hand and pick up only one pin at a time, filling one row of holes after another." At this point demonstrate with three or four pins. "Now have a pin in your hand and be ready to start. Ready--go." After one minute, "Stop."

The score of the test is one-third the number of holes filled to the nearest integer.

Test 2. In this test the same pegboard is used and the directions given are alike except that the other hand is used. The time is one minute while the score is again one-third of the holes filled.

Test 3. For this test pegboard "B" is used in place of "A". The instructions are given as follows: "This tim you are to use both of your hands and put three of these pins in each hole, like this." The examiner then fills the first five holes. "You can do it any way you wish as long as you use both of your hands. Have three pins in your hands for the first hole and do it any way you wish. Ready--go!" Then after two minutes have elapsed, "Ready--Stop!"

The score of this test is the number of holes correctly filled.

Test 4. For this test the large pegboard "C" is placed in front of the person being tested as indicated in Fig. 22.

The following directions are then given: "With your right (or left) hand again you are to pick up one peg at a time. You will put a red peg in the first hole, skip a

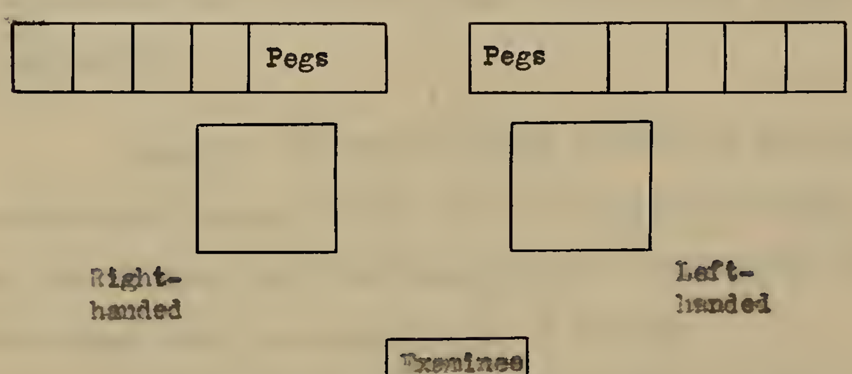


Fig. 22
Arrangement of Pegboard and Tray for Test 4.

hole and put in an orange peg, skip a hole and put in a yellow peg, then a green peg and then a purple peg, remembering to skip a hole between each color." The examiner then demonstrates by filling two horizontal rows. Then saying, "Do each row in the same order, red, orange, yellow, green and purple. See how many rows you can fill in the way these two are filled before I tell you to stop." The two rows of pegs filled by examiner are replaced in tray. "Now, have a red peg in your hand. Ready--go!" After one minute, "Stop!"

The score is the number of holes correctly filled. Occasionally a person with color blindness has difficulty in discriminating between certain colors. In such instances the color series is changed, these colors causing trouble being outlined.

Test 5. The tray is placed in front of the person being tested as shown in Fig. 23. The examiner sees that all the bolts and nuts are threaded so that the top of the bolt shows about even with the top of the nut.

The directions given are as follows: "You are to

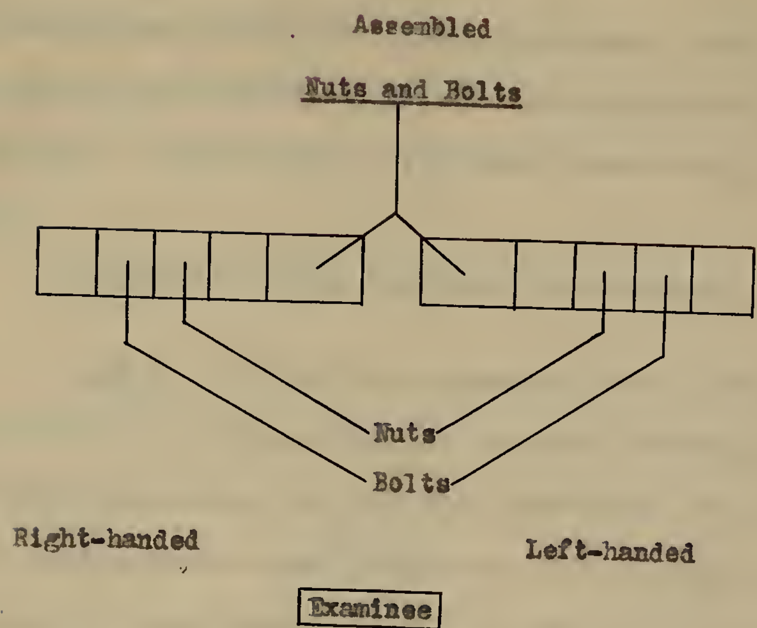


Fig. 23

Arrangement of Tray and Bolts for Tests 5 and 6.

take as many of these nuts and bolts apart as you can in the time I give you. Hold the bolt in your right hand (or left) and the nut in your left (or right). Keeping the nut stationary, thread the bolt out of the nut. Like this." Demonstrate. "Then drop the bolt in this compartment and the nut in that one." This procedure is demonstrated and the person being examined is asked to try it. When the instructions seem clear, the examiner continues, saying, "Have one in your hands ready to start and remember to turn only the bolt. Ready--go!" After thirty seconds say, "Stop!"

The score is twice the number disassembled.

Test 6. The tray is arranged as in the previous test but with the bolts and nuts in separate compartments. The examiner then gives the following directions: "Now you are to put together as many as you can. Take a bolt up in your right (or left) hand and a nut in your left (or right). Holding the nut stationary, thread the bolt into the nut until the end of the bolt comes about even with the top of the nut; then drop the assembled bolt in this compartment." Then say, "Now try one." When it is clear that the examined understands the procedure, say, "Now put as many as you can together until I tell you to stop." "Ready--go!" After 30 seconds, "Stop!"

The score is twice the number of bolts correctly assembled in the time given.

<u>Test 7</u>. The tray is arranged in front of the person being tested as shown in Fig. 24.

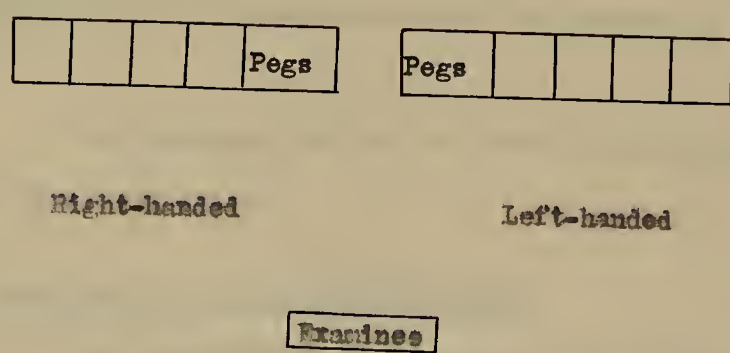


Fig. 24

Arrangement of Tray and Pegs for Test 7.

The following directions are then given. "This time you are to sort as many pegs as you can in these compartments. In the first compartment put a red peg, in the second compartment a yellow peg, in the third a green peg, and in the last one a purple peg (illustrated by sorting the colors out twice). Always do it in the same order, first, red, then yellow, green and purple, and remember to use only your right (or left) hand and take only one at a time. Have a red one in your hand ready to start. Ready--go!" After thirty seconds, "Stop!"

The score is the number of pegs sorted according to directions. In this test as in test 4 if the person being tested shows evidence of color blindness, the color series is changed and the troublesome color eliminated from the tray.

The scores of each of the seven tests are added to obtain the final score.

5. Administration of MacQuarrie's Test.

The standardized directions for the administration and scoring of this test are outlined in the attached booklet.

MacQuarrie Test for Mechanical Ability

By T. W. MacQuarrie, Ph.D.

This test is an attempt to provide a standard performance for the measurement of mechanical ability.

The term **mechanical ability** has never been carefully defined, in fact, a complete analysis would be very difficult. We assume that it takes mechanical ability to do the work of the mechanic, but we have a feeling that such ability is also used in greater or less degree by the barber, typist, motorman, waiter, telephone operator, tailor, plasterer, dentist, draftsman, baseball pitcher and pianist. These, and many others in addition to the mechanics, require manipulative skill, recognition of space relations, speed, muscular control, visual acuity, and all those accomplishments which we usually associate with the mechanical trades.

No estimate of mechanical ability can be anything but rough. Nor is an accurate measurement necessary. There is no valid evidence at present to show that the carpenter requires more mechanical ability than the machinist, nor that the house painter must develop greater skill than the plumber. As a matter of fact, men with various degrees of mechanical ability do function in the same trade. If we had a definite minimum norm for entrance to each mechanical trade, then it would be important to have accurate measurements. Since there are no such norms, the best we can do is to say that a candidate for a mechanical vocation should show a high degree of mechanical ability before money is spent upon his training. There are not so many mechanics in the country that we need to take candidates haphazard. If we are to increase efficiency, we must train only those best fitted for the work.

If a shop foreman were asked to judge a strange mechanic, he would probably have the man do a piece of work in the trade. The skill he showed in handling his tools, the speed with which he worked, and the quality of his product would determine the man's rating in the mind of the foreman. Other competent foremen, however, would no doubt give the man different ratings, for it is a fact, here as elsewhere, that judges disagree.

In view of the fact that there is no standard piece of work requiring mechanical ability, this test has been developed with the hope that it might meet such a need. It is very simple. It requires for its material—paper, and for the single tool used—a lead pencil. It takes very little time to give and score. It has a high reliability and a satisfactory validity. Women and girls can take it as well as boys and men. It is well adapted to ages of ten years and up. Some eight and nine year olds even have made good scores. It has a very low correlation with inteligence test results, indicating that it measures something different. Those who take the test find it interesting, and teachers of shop work have approved of it as a mechanical job. They feel that it requires many of the abilities they use in making a table, or an elbow, or a piston ring. Considerable statistical evidence has been produced already to show that it is a satisfactory measure of general mechanical ability, and it is offered to those interested with the hope that it will be of service in selecting candidates for the mechanical trades.

At the present time, many counselors in junior and senior high schools, and a number in universities are placing scores on this test on the personnel cards of their students. In that way they have always on hand a standard measure of mechanical ability, and they may offer advice when the proper time comes which is something more than the usual off-hand guess. One dental college is already using the test to get an estimate of the aptitude of their candidates for training in manipulating dentistry. Dental training costs the student about ten thousand dollars, and the man who has little mechanical ability cannot possibly be a success.

A boy or girl should make a high score in mechanical ability before being approved by the counselor for a mechanical trade. Our estimates are bound to be rough, and we shall be more nearly right if we accept high scores only. A subject with an average score might be approved for a mechanical trade under specially favorable conditions, but it is very doubtful if a school is warranted in attempting to train anyone who makes a low score. In general it will be found that those who make low scores are not very much interested in mechanical trades, and respond readily to suggestions for other vocations.

Norms have been worked out for ages from ten to twenty. There is a wide range of scores for every age, and a great deal of overlapping. There is little increase from age to age, but it is rather steady. About a thousand cases, mostly school and college students were used to compute the norms. Later additions will change them somewhat, but not to any great extent.

For each age the mean is given, and also norms a standard deviation below and above the mean. A score which is near the highest norm for the age might well be considered high, one near the mean is average, and one near the lowest norm is certainly low. In the table given below, a few cases above the range were included with the twenties, and a few cases below were included with the tens.

AGE NORMS

Age	Low	Average	High
10	18	26	34
11	28	37	46
12	33	44	55
13	37	49	61
14	40	53	66
15	43	57	71
16	45	60	75
17	47	63	79
18	49	65	81
19	51	67	83
20	52	68	84

In interpreting the above norms it might be said that the subject who gets a score that is **high** would be about number sixteen from the top in a hundred unselected cases of that age arranged in the order of their mechanical ability. A **low** score would indicate that he would be about number sixteen from the bottom, and an **average** score would be in the middle.

A full description of this test will be found in the January, 1927, number of **The Journal of Personnel Research.**

DIRECTIONS

The usual rules for group test procedure, standard directions and standard conditions, apply in this case.

Ordinary school lead pencils, of medium hardness (No. 2) should be supplied. They should be sharpened on a pencil sharpener at both ends each time before using. (After the first sharpening they can be kept in proper condition very easily.) Other pencils should not be permitted.

A stop watch is desirable. The time can be taken from an ordinary watch which has a second hand, but a stop watch is easier to use, and more satisfactory.

Commands for starting and stopping should be given sharply and so all can hear. Where necessary, comments may be made at the end of practice tests for the benefit of those who start before the signal, or who do not stop promptly.

The examiner should pass quickly from each record test to the following practice test in order to interfere with attempts to add records after time is called. It is desirable, however, to take sufficient time on a practice test to be sure instructions are fully understood before going on to the record test.

Where large groups are being tested it is advisable to have one or more trained assistants in the room in order to assure standard procedure.

GIVING THE TEST

(As soon as booklets and pencils are distributed.)

Fill in the blanks on the cover, but do not open the booklets.

(Allow about two minutes.)

This is a test to see what you can do with your hands and eyes. Use the pencils provided, as they are all the same. If a lead breaks, use the other end of your pencil, and go right on. You will have opportunity for practice before each test. Do your work as well as you can and as fast as you can. The signal will be READY, GO! and READY, STOP! Be sure to start and stop instantly.

Turn to Page 2. Fold your booklets back flat each time, like this. (Examiner illustrates.)

PAGE TWO

This is the practice test for TRACING.

Notice the little black triangle under the word START. You are to begin at the little triangle and draw a curved line through the small openings in the vertical lines without touching them. Draw first to the right and then back to the left in one continuous line. (Examiner should illustrate by holding up a test form, and showing how to do it.)

READY. Put pencils on the little triangles, GO!

(THIRTY SECONDS.)

READY, STOP. (Allow about two seconds between READY and STOP on all tests.)

Now look at your work to see if you have made any mistakes. You should be able to see clear space at every opening between your pencil line and the printed line.

Turn the booklet over to Page 3.

PAGE THREE

This is the real TRACING test. The instructions are the same.

READY, GO!

(FIFTY SECONDS.)

READY, STOP!

Turn to Page 4.

(The examiner should see that the booklets are folded back each time a page is turned.)

PAGE FOUR

This is the practice test for TAPPING. Here you are to put three pencil dots in each circle just as fast as you can. Start at the left of each line and work to the right, as you do in writing. Count to yourself as you tap, and very fast, 1, 2, 3 — 1, 2, 3, etc. Try to make just three dots each time, but do not stop to correct. Speed is of more importance than accuracy. You do not need to strike hard nor raise your pencils high. Be sure to start and stop instantly.

READY, GO!

(TEN SECONDS.)

READY, STOP!

Cross out any dots you made after the STOP signal.

(Do not permit further practice in tapping, as an element of fatigue will enter and spoil the test. In fact it is best to allow a moment for relaxation before going on.)

Turn to Page 5.

PAGE FIVE

This is the real test for TAPPING. The instructions are the same.

READY, GO!

(THIRTY SECONDS.)

READY, STOP!

Turn to Page 6.

PAGE SIX

This is the practice page for the DOTTING test.

Here you are to put one dot in each circle, as fast as you can. Follow the string. Dots must be clearly within the circles, and only one dot will be counted for any circle. Little dashes will not do.

READY, GO!

(FIFTEEN SECONDS.)

READY, STOP!

Now see if you have made any mistakes. There should be just one dot in each circle, and it should not touch the circumference. (Be somewhat deliberate here.)

PAGE SEVEN

This is the real DOTTING test. Put one dot in each circle just as fast as you can.

READY, GO!

(THIRTY SECONDS.)

READY, STOP!

Turn to Page 8.

PAGE EIGHT

In this test you are to copy each of the figures in the dotted space to the right of it. The little circles show you where to begin. There is a dot for every corner. Your lines do not have to be straight, but they should begin and end on dots. Correct, if you wish, but do not waste time erasing.

(The examiner should illustrate, and may have to assist individuals with further explanations.)

READY, GO!

(TWENTY SECONDS.)

READY, STOP!

Check your work to see if you have copied the figures correctly.

(Some additional explanations may be necessary, but the examiner must guard against wasting time with the few who do not really understand.)

Turn to Page 9.

PAGE NINE

This is the real COPYING test. Work across the page in each row. (This is not vital, but helps somewhat in scoring.)

READY, GO!

(TWO AND ONE-HALF MINUTES.)

READY, STOP!

Turn to Page 10.

PAGE TEN

This is the LOCATION test. Notice the letters in the large square, and the five dots in each of the small squares below. For each dot in a small square, there is a letter in the same place in the large square. Put right on each dot the letter that stands in its place in the large square. For instance, the upper dot in the first small square is in the position of the letter K in the large square, so you will put a letter K on that dot.

READY, GO!

(THIRTY SECONDS.)

READY, STOP!

In the small square at the left you should have V. K, N, E, K. In the one at the right you should have E, U, C, O, M.

(Take a little time here for consideration of errors.)

Turn to Page 11.

PAGE ELEVEN

This is the real LOCATION test.

READY, GO!

(TWO MINUTES.)

READY, STOP!

Turn to Page 12.

PAGE TWELVE

Here is a pile of blocks, all the same size and shape. On five of the blocks, you will see X's. You are to find out how many blocks touch each block that has an X on it, and then mark the number right on the X. For example, the top block touches two other blocks, so a two will be put on that X. Put it there now, and you may have twenty seconds in which to number the other X's.

READY, GO!

(TWENTY SECONDS.)

READY, STOP!

You should have 2, 4, 4, 7, 4.

(Allow a moment for consideration.)

Turn to Page 13.

PAGE THIRTEEN

This is the record test for BLOCKS.

READY, GO!

(TWO AND ONE-HALF MINUTES.)

READY, STOP!

Turn to Page 14.

PAGE FOURTEEN

This is the PURSUIT test. Notice the numbers in the little squares at the left, where the curving lines begin. Follow each line by eye from the square where it begins at the left to the square where it ends at the right. Remember the number at the beginning of the line, and put it in one of the small squares at the end. Do not be disturbed if two lines end in the same place, but just use both squares for your answers. Do not use your pencils to follow the lines if you can possibly help it. You will work much faster if you depend entirely upon your eyes.

READY, GO!

(FIFTY SECONDS.)

READY, STOP!

Your answers should read from top to bottom: 10, 3 and 8 together, 4, 2, 7, 5, 1, blank, 9, 6.

(Some further instructions may be necessary in individual cases.)

Turn to Page 15.

PAGE FIFTEEN

This is the real PURSUIT test.

Do not follow the lines with your pencils if you can help it.

READY, GO!

(TWO AND ON-HALF MINUTES.)

READY, STOP!

Close the booklets.

(Booklets and pencils should be collected promptly.)

SCORING THE TEST

Scoring for this test is very easy, and highly objective. It is good practice to score at one time, the same page right through all of the pamphlets. When all of the forms have been checked, the results should be recorded in the blank spaces on the cover, and the final score determined.

TRACING, PAGE THREE

This test has been placed first in the battery because the pencils are then in good condition.

Score is the number of openings through which the pencil line passes without touching. If to the scorer the line seems to touch as it passes through an opening, the attempt is counted an error. There is a total possible score of eighty, twenty openings in each row. One good method of scoring checks all the errors first, and then subtracts from the total attempted. If more than one attempt is made at an opening, credit is given for only one correct. Touching the printed line at a point other than an opening does not count an error. Short breaks in the pencil line are not noted, but if the total response is merely a series of dashes at the openings, no credit is given. Occasionally all of the tracing is done to the right. Full credit should be given in this case for openings properly passed.

TAPPING, PAGE FIVE

In such a test as this slight approximations may be made. The score is one-third of the number of dots, approximately the number of circles attempted. Since this test is an attempt to measure motility, all dots are counted even if they are not wholly within the circles, or even if some of them are entirely without the circles. The directions are merely for the purpose of spreading the dots so they can be counted. Occasionally more or less than three dots will be made in a circle, but usually they will contain just three. The scorer should glance over the page to see if most of the circles have the required three dots, and if that number appears to be in the great majority, the score is simply the number of circles attempted. If there is much variation the dots may be counted and divided by three, using the nearest whole number for the score.

DOTTING, PAGE SEVEN

The score in this test is one-third of the number of correct responses. This is not a test of motility, but rather of aiming, and no dot is counted unless it is clearly within the circle, and does not touch the circumference. If in doubt whether it touches or not, mark it wrong. It is best to check the errors first, and then subtract their number from the number attempted. Only one dot can be counted for any circle. Divide the total by three to get the score, using the nearest whole number.

COPYING, PAGE NINE

Score is the number of correct lines on the page. To be correct, a line must have proper length and direction.

It is not penalized by previous incorrect lines, however. That is, it does not have to be in correct position with reference to the starting circle, but it should have proper length and direction and be intended evidently for a certain line in the figure. Lines should begin and end on dots, but slight discrepencies in this respect should be disregarded.

Scorer should take a general view of each figure, and if it is a correct copy, count 4 for it. Where some errors have been made, all correct lines should be counted and added to the total.

LOCATION, PAGE ELEVEN

Score is the number of dots correctly lettered. Beginning at the upper left, and following the string of small squares around to the upper right the answers are as follows, reading from the top down in each small square. F J O C F, L P N B K, D H P A H, C G R V E, K S Z C M, A H W Y G, B U D L H, E M T W J.

These letter answers may be written beside the proper squares on a used form, and then the squares may be cut out making a stencil that will aid much in scoring. Scores for each square may be marked right on the square and totaled later.

BLOCKS, PAGE THIRTEEN

Score is the number of blocks correctly marked. The strip printed below indicates the answers. Cut out the strip very close to the figures and paste it on a piece of cardboard, cutting the latter to fit. Then the strip may be placed between the upper and lower rows of blocks, and the answers will be in proper order for the X's to which they apply.

PURSUIT, PAGE FIFTEEN

Score is number of squares correctly numbered. The answers are as follows:

Upper left: 9, 4, 5, 1, 10, 8, 6 & 7,—, 2, 3.
Lower left: 9, —, 3 & 10, 8, 7, 1, 4, 5, 2, 6.
Upper right: 3 & 7, 8, 10, 2, 4, 6, —, 1, 5, 9.
Lower right: —, 1, 3, 6, 5, 10, 8, 2 & 9, 4, 7.

Cut out a rectangle of cardboard or heavy paper three inches by four and a quarter. This card will fit in between the answer columns. Record the answers given above at the proper places, and scoring will be made easier. Answers may be recorded for each section and totaled later.

TOTAL SCORE

Record the form scores on the front cover of the booklet. The total score is the sum of the form scores divided by three, using the nearest whole number.

5 6 6 7 5 4 3 5 4 6 5 5 4 4 3
3 2 5 4 7 4 5 2 3 4 6 5 5 8 4

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