DETERMINING THE RELIABILITY AND VALIDITY OF THE
CLINTON MECHANICAL ABILITY TESTS

by
FRANK WESLEY OLIVER

A THESIS
submitted to the
OREGON STATE AGRICULTURAL COLLEGE

in partial fulfillment of
the requirements for the
degree of

MASTER OF SCIENCE
June 1937
APPROVED:

Professor of Education
In Charge of Major

Head of Department of Education

Chairman of School Graduate Committee

Chairman of College Graduate Council
ACKNOWLEDGMENT

The writer wishes to express his appreciation to Dr. R. J. Clinton for the many helpful criticisms and suggestions given by him throughout the preparation of this thesis.

He also wishes to thank all those friends who assisted in any way in the investigation connected with this study.
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Chapter I  Introduction

Present Day Need of Mechanical Aptitude Tests

Today we commonly hear people speak of the mechanical and industrial era in which we live. It seems to be a well-accepted fact that we are living in a machine age—an age that has become so mechanized that many critics say that civilization is rapidly becoming unstable due to a state of unbalance between our mechanical and industrial advancement, and progress in social adjustments. In another sense we are accelerated in physical sciences and retarded in social sciences, when judged on the same scale. Again, with a somewhat finer analysis of the situation, we recognize that the present age has developed a new problem in the form of vocational maladjustments. While industry is specialized, it has not adequately picked its personnel. People trained as specialists find themselves unfit for the position for which they have trained themselves or else they are unable to find an opening by which they may enter their selected fields. Vocational adjustments necessitate intellectual, technical, and physical fitness for the work in which the individual is employed. Industry today has learned this principle as a result of many misfits that have left its machines and factories. As a result, the business and economic world is seeking some scientific
means of picking men and women for the positions to be filled.

Vocational Guidance in the School

In a similar manner, education is attempting to direct its students into the vocational fields for which they are best suited. Scientific measuring devices seem at the present time to be the best solution for the problem and a large number of standardized tests are rapidly being developed by which one's aptitudes and abilities can be measured. However, while much progress is being made along this line, much improvement in the measuring instruments is possible, and continued experimentation and investigation is rapidly making aptitude testing and analysis a science in itself. In the school, the function of determining wherein a person may best find vocational success as based on a study of his aptitudes is known as vocational guidance. The principles underlying diagnostic and prognostic testing are coming to be more or less accepted. (1) Stenquist states:

Techniques of diagnosis and prediction in the vocational field involve the same basic principles as those in the academic fields. They demand also analysis and measurement, not only of the mental and manual traits of the individual but of vocational opportunities in the world as well.

Stenquist also suggested in the preceding statement the need of so-called job analysis—or, in another sense, he suggested that it is possible to analyze most types of jobs and to determine methods of measuring the abilities required in the performance of them. Similarly, the diagnosis of aptitudes has drawn attention to the differences in individuals, so that now it is assumed that certain occupations demand a definite type of workmen and that these people can be picked by analysis of their make-ups.

Nature of the Problem

In order that the reader will not misconstrue the writer's conception of aptitude testing and its predictive value, it seems necessary to go into a short discussion of the limitations of aptitude testing. Any attempt to predict an individual's success in a field on the basis of his success or failure to make a high score on a reliable and valid test is not very dependable. In measuring any aptitude, not all of the factors necessary for success in a given vocation are being measured. Hence, if an individual scores high in mechanical ability, it is not desirable to predict that he can be assured of success in the field of mechanics. The high score merely indicates that he possesses some of the essential qualifications for success in the field. Likewise, it is assumed that the higher his score is on the test, the more likely he is to succeed.
With more assurance, however, one can predict that a person scoring very low on such a test is not apt to achieve success in the mechanical field. In other words, it is easier to predict failure than success.

As our measuring instruments improve, the reliability of our predictions on the basis of derived scores will also increase. So it is that this study is being made along this line. It is to deal with aptitude testing in the mechanical field in that it will attempt to determine scientifically the reliability and validity of the Clinton Mechanical Ability Tests, and also to make some investigation of the nature of mechanical ability as it is concerned in aptitude testing. It seems desirable that some resume' should be made as to just what the nature of this aptitude is, and how mechanical ability is developed. Then with this background it should be possible to determine better if the Clinton tests are a valid and reliable measure of mechanical ability.

In addition, some time should be devoted to determining what has already been achieved in the field of mechanical aptitude testing. This suggests also a review of those tests already in the field which are similar in nature to parts of the Clinton test, for, since these tests measure the same aptitude, they should have much in common, although they will each possess unique features.
From this point we will advance into the structure and organization of the Clinton Mechanical Ability Tests, taking up in turn the background of the tests, their conception and development, and their rules and regulations as to testing conditions. After presenting a description of these tests, the reliability and validity of the tests will be determined. Explanation of the way in which the data were gathered will be given in the following section.

Limitations of Materials

Due to the nature of mechanical ability, little has been written on this ability. What has been written has been the object, in most cases, of rank disagreement and the result has been one of lack of definiteness in the findings. Many experiments have and are being conducted. Periodicals will serve as the references in most cases in this study, and in a few cases material was found in published volumes, but with the few exceptions listed this material was obsolete and time-worn. The data collected, while not extensive, was over a good sampling of college students. One hundred and thirty-five students enrolled in industrial arts, mechanical engineering, and academic fields made up this group. The academic group was composed of students from schools other than industrial arts and engineering. These students were distributed as fol-
lows: Industrial Arts, 39; mechanical engineering, 45; and academic fields, 51. No selection within the groups was made other than the availability of the student.
CHAPTER II
THE NATURE OF MECHANICAL ABILITY

Definition of Terms

After a considerable amount of study in the field of mechanical ability, it seems to the writer that there is common confusion as to the meaning of several terms to be used frequently in the remainder of this study. In order to clarify this situation and to bring about a unity of understanding, it seems desirable that some definition of terms be made.

**Mechanical Aptitude:** In the field of psychology and measurement, it seems to be commonly agreed that an aptitude is an innate characteristic that in itself enables the individual to develop ability in a certain direction. To say that a person possesses certain aptitudes is to say that he has certain natural gifts or tendencies in some implied form.

(1) Cox in discussing this point makes the following statements:

Since the term "ability" must obviously extend its meaning to cover any kind of performance whatever, it would seem desirable to continue its employment in this wide sense, and to use the term "aptitude" when only the innate character of the ability is intended. Employing the terms in this way we should say that a person actually able to carry out mechanical work has "mechanical ability" while

who has the appropriate innate mental constitution for acquiring this ability (whether he has actually done so or not) may be said to possess "mechanical aptitude".

In like manner, the Minnesota Board, composed of (1) Paterson and others, in discussing mechanical ability tests makes the following statement:

It must be recognized, too, that whatever these tests measure is mechanical "ability", and not mechanical "capacity"; just as whatever is measured by intelligence tests is intellectual ability and not intellectual capacity. Capacity is always an inference of measured ability...... for it is by no means evident that the development of mechanical ability may not be determined to a considerable extent by the presence and availability of tools and mechanical equipment.

(2) Kitson in speaking of abilities and aptitudes makes the following distinction--"Ability is a thing acquired; aptitude is the capacity for acquiring it."

In the above quotations the terms "aptitude" and "capacity" seem to be used synonymously and we may thus define "mechanical aptitude" or "capacity" as those innate characteristics or mental constituents which make it possible for an individual to develop in mechanical functions.


Mechanical Ability: Similarly, it would seem that the above mentioned authorities agree that "ability" is a development of innate capacity or aptitude. They seem also to agree that such influences as environment, training, and motivation may greatly influence the degree to which various abilities are developed. Hence "mechanical ability" may be defined as the product of innate mechanical aptitude and the diffused environmental influences to which the individual is subjected.

(1)
The Minnesota Board gives this definition of mechanical ability:

......the ability to succeed in the actual manipulation of tools and materials and the ability to secure information about the tools, materials, and their uses.

Unique Traits: Closely allied and essential in the study of mechanical ability is the "theory of unique traits" as suggested by such men as Thorndike, Kelley, Toops and Hull. In the isolation and discrimination of traits and abilities, this theory aids materially. It is based on the following assumptions:

1. That the various degrees of success in all important classes of human behaviour correspond to compounds of relatively unitary traits, combined in various proportions;

2. That these unitary traits can be discovered and measured objectively and are probably not so numerous as to make impossible the task of measuring all of them.

In determining a unique trait, it must correlate positively with at least one criterion of human endeavor and it must give correlations as low as possible with all other unique traits, otherwise it would necessarily show some relationship to the trait with which the correlation was made. Having met these requirements, it is assumed that since a positive correlation with the criterion has been established the trait is recognizable. Secondly, since it has been successfully isolated from its non-essential similar traits—this proves that it is unique in relation to these other concomitants. To do this the test must give a high correlation with the criteria of its ability, but will give a low correlation with measures of other abilities and traits.

Conflicting Theories on Mechanical Aptitudes

Similar to the development of concepts as to what the nature of intelligence is, there has not been any universally accepted theory as to just what the form or character of mechanical aptitude is. It seems, as in the analogous case of intelligence, that the principal point of confusion lies in the determination of whether mechanical aptitude is a single trait or a group of traits. In another sense, is there a general trait that enables its possessor to do all kinds of mechanical work well, or is there a group of traits
that makes possible his development of mechanical ability?

The origin of this confusion dates back to 1904 when Spearman in his studies on the nature of intelligence suggested the existence of what he called a general factor, or as commonly designated "g". His suggestion was based upon the fact that he found a series of positive correlations between measures of different human abilities. His theory then, since human intellectual abilities were assumed to be dissimilar, is that positive correlations between them point to the existence of a general factor which, due to its nature, enters into the measurement of abilities.

In contrast to Spearman's assumption, Thorndike, after certain investigations decided that there was great uniqueness in mental capacities, and in 1909, after conducting experiments in cooperation with Lay and Dean, made the following statements:

In general there is evidence of a complex set of bonds between the psychological equivalents of both what we call the formal side of thought and what we call its content, so that one is almost tempted to replace Spearman's statement by the equally extravagant one that there is nothing whatever common to all mental functions, or to any part of them.

A few years later in 1914, Spearman advanced a new theory based on his previous assumption. This new theory

made the assumption that in any intellectual performance there are two factors at work; namely, general ability, "g" as previously assumed, and specific ability "s" for various types of performances. In Spearman's words, "While the range of the specific factor is exceedingly narrow, that of the general factor is universal; and between these two there appears to be no intermediate."

As a proof of the plausibility of this new theory, Spearman pointed to the fact that hierarchies of tests of intellectual abilities could be formed. In other words, if the tests were arranged on a basis of the magnitude of test intercorrelations, the coefficients would tend to decrease in size by reading the columns from top to bottom, or from left to right.

In 1921, Thorndike withdrew somewhat from his former position and suggested that there might be factors of every degree of generality. This theory of Thorndike's supported the suggestion of Godfrey H. Thomson, that there might be factors of different degrees of generality; that there might be group or intermediate factors in generality between the two.

The Minnesota Board makes the following remarks as to the finding of the above mentioned men.

The evidence on which these theories are based consists, for the greater part, of intercor-

(1) C. Spearman "Theory of Two Factors" Psych. Rev. V. 21, 1914
relations between tests of various abilities. The general principle of interpretation is simple enough. If the correlations between the tests are zero, or very low, the capacities tested are independent and specific; if the correlations are very high--theoretically, they should be perfect--a general factor has been at work in all cases.

While the above discussion has dealt entirely with conflicting views as to the nature of intelligence, it has also implied the existing theories of the character of mechanical aptitude. No well-confirmed theory has been found, and as a result much experimentation is being carried on in this field.

It may be well at this point to give the positions of several recent investigators who are interested primarily in the study of mechanical aptitude. Harvey seems to have made a rather clear discrimination of the positions held by current investigators represented mainly by Cox and the Minnesota Board.

Cox's position:

1. That he sought to discover, if possible, that innate "aptitude" which underlies the ability to carry out mechanical work;

2. That, as a result of experimentation, such an aptitude was found to actually exist;

3. That is is unique in its relation to "g" (Spearman's "general factor");

(1) C. L. Harvey "Mechanical Aptitude or Mechanical Ability?--A Study in Method" Jr. of Educ. Psych. V. 22, p. 517-519.
4. That it is a single group factor; and
5. That it is not the same as motor ability.

Minnesota Board's Position:

1. That they sought to discover whether there was a "mechanical ability", that is, the ability to succeed in the actual manipulation of tools and materials, regardless as to whether or not that "ability" be entirely attributable to innate capacity;

2. That, as the outcome of experimentation, they have revealed such an ability;

3. That it is unique in relation to verbal intelligence;

4. That it is, however, probably not a single group factor, but a constellation of factors of high specificity;

5. That it is unique in the relation to motor agility.

(1)

At this point Harvey, in commenting on the "frank contradiction" of the findings of the above studies, attempts to explain possibly the difference in findings, in that one clearly claims "m" to be a single group factor, while the other equally clearly claims that very probably it is not a single group factor, but rather consists of a number of highly specific factors.

Possibly a significant reason for the difference in findings lies in the definition of the field of investigation. Although both studies claim to have revealed "m", actually Cox limits his investigation to the aptitude which makes mechanical ability possible; it excludes manipulative ability; it deals purely with the cognitive processes involved in the eduction of spatial

(1) Ibid, p. 519-520.
relations. The Minnesota study, on the contrary, clearly seeks to measure manipulative ability pure, the ability to use tools and materials. If, then, the ability to educe spatial relations is a function actually distinct from the ability to manipulate objects, it would appear evident that confusion has arisen out of the use of the designation "m". In which case, perhaps all that is necessary is to decide on some other symbolic designation for the factor of "mechanical ability".

Harvey's Conclusions

Continuing from this discussion Harvey goes on to say that to him there would appear to be four phenomena which one should distinguish in dealing with mechanical activities:

1. Specific motor skills.
2. Manipulative or mechanical ability.
3. Mechanical aptitude (an intellective activity involving the ability to educe space relations between objects, without necessitating their prehension and manipulation).
4. The sheer intellective factor, labelled "g" by Spearman, which presumably pervades all cognitive activity, including the mechanical.

Somewhat akin to the Minnesota group, since they seek to measure manipulative ability alone, is a group represented by Seashore, who has been conducting experiments on motor skills. This group would evidently assume mechanical ability to be a group factor--or a constellation of highly specific motor skills. Seashore states:

Individual differences in motor performances are variously considered to be determined by: (1) a

(1) Robert Holmes Seashore "Individual Differences in Motor Skills" Jr. of General Psych. 3: 39
general motor function and other special abilities; (2) a number of simple variables such as speed of reaction times, reflexes, steadiness of hand, etc.; (3) a number of serial motor coordinations, called "basic motor capacities" or; (4) differences in training, both direct and transferred, and including informal types of training.

Since the subject is plainly an object of much discussion and confusion, the writer, having presented a number of views as to the nature of mechanical ability, will adopt somewhat the view of Harvey as given above and proceed with the discussion of the effect of environment and interest on the development of mechanical ability.

Effect of Environment on Mechanical Ability

Studies made as to the effect of environment on the development of mechanical ability have failed to discover any significant relationship between environmental factors and measured mechanical ability. The only factor which seems to have notable effect is the degree to which the individual has actually indulged in work of a mechanical nature, indicating that the ability and its exercise are closely related.

Living in surroundings in which the mechanical aspects were outstanding apparently has no effect unless practice is involved. For example, there appears to be no marked relationship between the amount of mechanical work done
by the individual's parents and any measure of his mechanical ability. In such a case, however, the amount of information about mechanical devices is somewhat greater, but there seems to be less chance of the individual putting this information to use since in such homes the child is called on less frequently to do tasks of a mechanical nature. Ownership of tools has little effect on the development of ability unless much use of them is made. Similarly, there seems to be little to substantiate the old assumption that men and boys are superior in such ability to the opposite sex. In regard to the effect of age on the development of mechanical ability, the results were as one would expect—there was a fairly uniform tendency for test scores to increase according to chronological age between the levels of eleven and twenty.
CHAPTER III

STANDARDIZED TESTS OF MECHANICAL ABILITY

Development of Aptitude Testing

Any attempt to measure specific aptitudes has been a product of the twentieth century. However, as far back as in the days of Plato some realization of the existence of special aptitudes in individuals existed. Hull in commenting on this fact gives several quotations from Plato's "Republic" which seem of interest to the writer:

"Really, it is not improbable; for I recollect, myself, after your answer, that in the first place, no two persons are born exactly alike, but each differs from each in natural endowments, one being suited for one occupation and another for another. Do you not think so?"

"I do."

".....From these considerations, it follows that all things will be produced in superior quantity and quality, and with great ease, when each man works at a single occupation in accordance with his natural gifts....."

Continuing with this dialogue Plato goes on to propose that persons to be entrusted with the "guardianship" of the state should be given "actions to perform" that would test their qualifications for such a position.

Finally, Plato sketched quite definitely a set of tests for military aptitude. Despite this early conception of the possibility of measuring aptitudes little was done to

bring this effect to a reality. Hull accounts for this slowness by saying "The delay in any serious attempt to realize Plato's Utopian dream of having 'each man work at a single occupation in accordance with his natural gifts' was inevitable. It had to wait the development of experimental and scientific psychology."

In 1879 Wundt founded the first psychological laboratory at Leipzig, Germany, where psychological experiments were conducted, mainly dealing with general laws of mental activity and the likeness of humans, rather than their individual differences. Thus aptitude testing had to await the work of psychologists, outstanding among whom were Cattell and Galton in that they were among the very first to become interested in testing for individual differences. Any scientific investigations of individual differences must be closely associated with statistical findings and so Galton attempted to derive a method by which he could show relationships between variables. Karl Pearson however developed what has been known ever since as the Pearson Coefficient of Correlation. This formula soon began to bring about order in experimental data. Without it the science of testing and analysis of individual differences would not have advanced as rapidly as it has in the last forty years.

(1) Ibid, p. 6.
Of course, preceding any definite movement in aptitude testing, would come the development of intelligence testing. Outstanding men in this work were Binet and Otis. Binet, of course, is immediately connected with the Simon-Binet Tests of Mental Ability. Otis is connected with the development of group intelligence testing. Simultaneously with the development of intelligence testing came the extensive study of the nature of intelligence as represented by such men as Thorndike and Spearman. Following this movement aptitude testing advanced rapidly until today there is a definite movement in developing tests for specific aptitudes. Hull states:

The recognition that if a test is to be of any particular value it must enable us to forecast a particular aptitude or group of aptitudes rather than a measure of some hypothetical or semi-metaphysical faculty constitutes a great advance. With the abandonment of this paralyzing idea of measuring general intelligence as the goal of testing activity, there is now appearing a vigorous and healthy concentration upon the development of tests for the greatest variety of particular concrete aptitudes.

Due to the nature of this study we will now review the present accepted tests of mechanical aptitudes and abilities which are similar in nature to the Clinton tests. These tests are being used quite extensively at the present in educational and vocational fields for the detection of mechanical abilities. In the more advanced industrial circles aptitude testing is also becoming a method of picking

individuals for specialized jobs. An outstanding example of this is the Ford Motor Company.

Stenquist probably should be given the credit for devising the first well-accepted tests of mechanical aptitudes and abilities. Therefore, he is noted for his "Assembly Tests" and his "Mechanical Aptitude Test".

Stenquist Assembly Test of Mechanical Ability

As early as 1915 Stenquist began work on one assembly test. This test, consisting of ten common mechanical contrivances which the testee must assemble, was used extensively on illiterates during the World War and was developed quite rapidly. The test is composed of two series, I and II, which while not equal in difficulty, may be compared as to results by the use of extensive norms which Stenquist has provided.

Some of the assembly items are: cupboard catch, chain, pistol, push button, trap, calipers, and a double action hinge. Thirty minutes is allowed for each form, but if the testee finishes the form early a bonus is added to his score at the rate of one-half of a point for each minute remaining up to thirty. In scoring the assemblies, ten points are given for each complete and correctly assembled contrivance. Partial scores are also possible for only partially completed assemblies.
Stenquist found that the Assembly test correlated with shop teachers' rankings, as follows: .85, .80, .42, .81, .90, .88--thus indicating that it is substantially valid. Conversely, it correlated low with general intelligence (about .20) as would be expected according to the theory of unique traits. Correlations with work in trade courses were high.

Stenquist Mechanical Aptitude Tests

In constructing the aptitude tests Stenquist decided on picture tests as the means of testing. The test was composed of two parts, I and II. In test I a series of ninety-five picture problems are presented before the pupil, who is required to distinguish and select from a group of five pictures one which is closely associated with an item in the other set. The pictures deal only with common mechanical objects and no single trade or highly specialized skills are singled out or included. Part II consists of pictures and problems similar to Part I, but includes in addition, questions, general in nature, but dealing with cuts of machines and machine parts. They call for keen mechanical perception and ability to reason out mechanical problems.

Two criteria(1) were kept in mind in selecting the items

(1) J. L. Stenquist "Measurement of Mech. Ability, Part II" p. 64
and asking the questions.

1. Devices must be general in interest and must not pertain to very highly specialized trades. Common household articles that are of a mechanical nature are most apt to fall within the experiences of everyone.

2. Questions involved must be mechanical as possible in nature, involving a knowledge of, familiarity with, or understanding of the purpose, use, operation, construction, or reason for special size, shape, weight, material, etc., of the device in question.

Stenquist found the reliability to be about .70.

(1) Toops found that the Mechanical Aptitude Tests correlate with general intelligence with a coefficient of about .60—thus the conclusion is that they are inferior to the Assembly Tests as measures of mechanical aptitude. Their main advantage is the relative inexpense in giving the test.

McQuarrie's Mechanical Ability Test

McQuarrie attempted to develop a test that would duplicate on paper a number of psychological laboratory tests that had been used to measure mechanical ability. In his experimental form of the test he used some thirty tests, ranging from simple tapping tests to elaborate puzzles. In each case an attempt was made to devise a paper form that

(1) H. A. Toops Tests for Voc. Guidance of Children 13-16 p. 27
would be as stimulating as the original laboratory test. Experimental testings programs finally eliminated all but seven of the tests. In the selection of these seven, McQuarrie kept in mind such factors as time, ease of explanation, adaptability to both sexes, and the ease of scoring. Similarly, emphasis was placed on devising a test of performance, and not ability to understand directions.

The tests place a premium upon reaction time, speed, and manual skill. The reliability of the whole test was found to be 0.90 with each of three groups of subjects numbering 35, 80, and 250 cases. With group mental tests, a correlation of 0.22 was obtained showing that a unique trait had supposedly been measured. When the test was compared with teacher ratings, the correlation was in no case over 0.48, but, on ratings on mechanical work by the students, the correlations were found to be 0.81 in two different cases, and, in the other case, it was found to be 0.32.

The O'Conner Wiggly Block Test

The test as constructed by O'Conner is a large block jigsawed into nine pieces. It is the assumption of the originator that the time required to fit these pieces together is a good indicator of innate mechanical aptitude since engineers, mechanics, and draftsmen as a group show marked superiority over a group of unselected workers. This
test is at present being successfully used in the West Lynn Works of the General Electric Company, at which O'Connor is employed. The conclusions of the two authors who wrote the article describing this test was that it was clearly an indicator of mechanical aptitude, since, the test, having been given to a large number of workmen, results noted were that those tending to complete the test in a short period of time tended to be more successful as a group than those who required a long period of time.

In the words of the authors:

Three hundred applicants, whom a trained employer chose as desirable candidates for mechanical occupation, were carefully timed in the block assembly and then assigned mechanical work. Within six months, seventy-four per cent of the D. grade men (those consuming more than six minutes in the block) left their jobs and in comparison only thirty-one per cent of the A. group (less than two and three-quarters minutes assembly time).

The authors claim that the ability measured is strictly mechanical analysis, and is essential, in the solution of mechanical problems, and such operations as tool and die-making, machine repairing, etc.

Shortly after Keane and O'Connor made the first announcement of this test, Remmers of Purdue University


and Schell of George Washington High School, Indianapolis, carried on an experimental study in order to evaluate the reliability and validity of the O'Connor test. This study was made over 109 students in high school shop courses. As a result, they found a reliability of .57 as derived using shop semester grades as a criterion. This score was on an average of 3 trials. Similarly, they obtained validity coefficients of .62 and .42 respectively in machine shop courses and for four shop courses combined.

Link's Spatial Relations Test

Probably the first outstanding test of spatial relationship can be attributed to Link, who began work on such a test shortly after the World War. This test consisted of two boards, each of which contained cut-outs and a number of corresponding blocks in size and shape. The process of testing was a matter of timing the individual in placing and locating the blocks in their respective places. In scoring, two scores were kept—a time score, and an error score. An error was an actual attempt to force a block into a wrong hole. In every case, however, the block had to be in actual contact with the board before it constituted an error.

The Minnesota Mechanical Ability Tests

A great deal has already been said about the Minnesota Board; about their investigation as to the nature of mechanical ability and the corresponding experiments which they carried out. Now it seems well that we give some mention of the Mechanical Ability Test which they produced.

Since the spacial relations test and the assembly tests have much in common with the Clinton tests, a full description of these tests will be given. The Minnesota Spacial Relations Test, as a revised form of Link's Spatial Relations Test, is composed of four boards, equally difficult. Each board contains 60 figures divided into groups of three, containing figures similar in design but which differ in size and angle. The test is mainly this, a test of the individual's ability to discriminate between the three figures of each set as to size and design. The subject selects the objects to fit their respective places in the board. Each block fits snugly when put in the proper place.

The Minnesota Assembly test, as a revised form of the Stenquist assembly test, is composed of a long form and two short forms. The long form, consisting of three boxes, A, B, C, which contain the material for assembling nine, eight and sixteen objects respectively is merely an attempt to get a more definite measure of the individuals' assembly ability due to a lengthened sampling. The two short forms contain ten items each, selected from the long form and
paired so that the two sets are equal in difficulty. The method of administration is the same, except, of course, for the difference in total time allowed.

The devices are common mechanical objects which can be easily assembled or taken apart. These various parts are kept in separate compartments. A screw driver is available to be used in case the testee needs it. Definite and variable time limits are worked out for each object. The individual is stopped at the time limit and directed to go on to the next assembly. If the subject completes the box before the total time is up he is permitted to go back and complete the assembly of objects that he failed to complete in the time allotted him.

In computing the score, 10 points is given for each correctly assembled object. Partial credit is given in case of an incomplete assembly according to the degree to which the subject had completed the task.

In attempting to find some test similar to the Clinton S.A.C. Peg Board Test, the writer found many psychological laboratory tests which were similar in nature in that they attempted to measure speed, accuracy, and coordination of muscular movements. However, only one test somewhat similar in design or idea was found. A test used by the Eastman Kodak Company, as described by Link to select girls for operators in the film finishing department, seems to be similar in nature to the Clinton Peg Board. However, the
description of this test is not clear. The test was composed of a special board with holes in which small metal pins were used. With this board as a basis, the Kodak company worked out various tests, such as, measuring finger speed as a form of dexterity, ambidexterity, mental alertness, hand-eye coordination, and ability to follow directions. Speaking of the results of the test, the (1) Company stated that "in no case did a poor operator make a high rating, nor did a high grade operator receive an unsatisfactory rating".

CHAPTER IV

THE CLINTON TESTS OF MECHANICAL ABILITY:
RELIABILITY AND VALIDITY

In studying the Clinton tests several points should be kept in mind; (1) that they are tests of ability to actually do tasks of a mechanical nature, as compared to paper tests that measure discrimination rather than manipulative ability, (2) that the series of tests, and not an individual test, is the best measure of mechanical ability, and, (3) that a test of mechanical ability should measure such traits as muscular speed, coordination, and accuracy, ability to discriminate differences in size and shape, ability to visualize an end result and from this foresight to take component parts and assemble them correctly in as short a time as possible.

In designing these tests, Clinton had these points in mind. These tests as a group measure the various traits listed above very well. It requires about an hour and a half to complete the entire group of tests, taking one form of each test. While the results of one form of each test should give adequate indication of the individual's ability, similar forms can be administered and a more reliable measure of mechanical ability obtained. In physical nature, the tests are sturdy in construction and are durable, so that while the initial cost is high, the tests can be used repeatedly.
It seems that with this bird's-eye view of the tests, a more specific description of the tests individually should be given and the writer will now describe the tests in the following order: the assembly tests, spacial relations, curly cube block tests, and the peg board.

Clinton Assembly Test of Mechanical Ability

The Clinton assembly test (see page 32) is made up of two forms, H and M, equal in difficulty. This is a test of ability to visualize the object in its assembled form from its various disassembled parts, and measures adeptness and degree of accuracy of mechanical assembling. A high score on this test indicates that the person can visualize the end result and can so assemble the component parts that he can complete the assembly in a short period of time, thus indicating not only adeptness at assembling, but also efficiency and accuracy in handling.

Each form of this test contains 12 mechanical devices, arranged in the order of difficulty in a convenient chest, 9" x 36". Each device has a separate compartment in the chest and in it are found all of the parts for the device to be assembled. Naturally, the parts are disassembled, and a screw driver is placed so that the examinee may use it.

The testee is supposed to start with the first device and work upward according to difficulty. He is timed by a stop watch and is allowed four minutes for each test. If
The Clinton Mechanical Test Battery
the subject is not through at the end of four minutes he is directed to go on to the next device, etc. However, if he finishes a device before the time limit is up, the exact time is recorded and the subject is directed to go on to the next device, etc.

After he has finished the 12 devices as outlined, and the time remains, the testee is directed to go back and finish those assemblies that he failed to complete in the four minutes, beginning with the lowest object in the order of difficulty. In no case, however, is the individual allowed more than four additional minutes on an assembly, the time being recorded properly.

Partial credit may be given for incomplete assemblies as each operation is rated as to the degree of completion it reaches. Directions are given in the manual for the scoring and with these directions the scoring is quite objective.

Before the subject starts the test the examiner gives the following explanations and directions to the testee:

This box contains 12 common mechanical devices. When the directions are given, you are to open the box and assemble the mechanical devices as they should be assembled. Proper assembly means to put them in working order.

When the box is open, the lid makes a tray on which you are to work. In each compartment in the box are all the parts for one mechanical

(1) Manual of Directions for the Clinton Assembly Test of Mechanical Ability
device. Take all the parts from the compartment and place them on the tray. Then assemble them.

You will be allowed a certain time for each device. When time is called, go on to the next. Continue in that manner to the end of the test. If you finish before time is called, go to the next. After you have finished the last one, go back to the first device that you failed to complete, and work forward again on time!

Ready, Go!

The parts of the two forms are given below: 115 points are possible for each form.

Test H:

1. Patented Door Fastener--two operations, $2\frac{2}{3}$ points each. Total 5 points.

2. Spark Plug--two operations, $2\frac{3}{4}$ points each, Total 5 points.

3. Vernier Caliper--two operations, $2\frac{1}{2}$ points each, Total 5 points.

4. Pipe Wrench--five operations, 2 points each, Total 10 points.

5. Electric attachment Plug--five operations, 2 points each. Total 10 points.

6. Valve Grinding Tool--five operations, 2 points each. Total 10 points.

7. Feed Through Cord Switch--five operations, 2 points each. Total 10 points.

8. Block Plane--five operations, 2 points each. Total 10 points.

9. Sidejaw-Cutting Pliers--five operations, 2 points each. Total 10 points.
10. Ratchet Screw-Driver—five operations, 2 points each. Total 10 points.

11. Flash Light—five operations, 2 points each. Total 10 points.

12. Electrical Key Socket—ten operations, 2 points each. Total 20 points.

Test M:

1. Toggle Bolt—two operations, $2\frac{1}{2}$ points each. Total 5 points.

2. Non-breakable Electric Plug—two operations, $2\frac{1}{2}$ points each. Total 5 points.

3. Tap-wrench and tap—two operations, $2\frac{1}{2}$ points each. Total 5 points.

4. Radio Switch—five operations, 2 points each. Total 10 points.

5. Cupboard Catch—five operations, 2 points each. Total 10 points.

6. Monkey Wrench—five operations, 2 points each. Total 10 points.

7. Attachment Plug and Switch—five operations, 2 points each. Total 10 points.

8. Pruning Shears—five operations, 2 points each. Total 10 points.

9. Bicycle Bell—five operations, 2 points each. Total 10 points.

10. Bench Vise—five operations, 2 points each. Total 10 points.

11. Ford Dash Switch—five operations, 2 points each. Total 10 points.

12. Hand Drill—ten operations, 2 points each. Total 20 points.
Reliability of two forms was determined by correlating Assembly H against Assembly M. Using the Pearson Product Moment formula, a reliability $0.70 \pm 0.03$ was obtained. For a test of this type such a reliability is quite high. If the two forms were put together and the reliability of the two estimated by the Spearman-Brown formula, the reliability would be 0.84. Then by giving both forms, which consumes nearly one hour, one would have a very reliable mechanical assembly test.

Likewise, a validity coefficient of $0.54 \pm 0.03$ was obtained when the tests were correlated with scores on Stenquist's Mechanical Aptitude test, this being accepted as a criterion of mechanical aptitude. If both forms were used, as recommended above, a validity of 0.71 would be had.

Clinton Spacial Relations Tests

The spacial relations test (see plate following page 31) is composed of four forms or boards, W, Z, X, Y. Each form consists of two spacial boards hinged adjacently so that one serves as the top to the other. Each form contains 57 blocks or designs. In an adjacent board, these blocks have corresponding spaces cut out roomy enough that the blocks fit easily and yet quite snugly if they are put in the proper places. Each design has three blocks of somewhat the same shape, but varying in size and corresponding
form. Therefore, the examinee must distinguish between these somewhat similar forms as to size and form.

As already suggested, this test is to determine the examinee's ability to distinguish between spatial and design differences. The assembly score is determined by the number of blocks placed correctly, each placement counting one point, minus the number of errors made in the test. Placing a block in the wrong place constitutes an error. The derived score is the assembly score divided by the time.

(1) The following directions are read to the subject:

Take the blocks or forms from their layouts, and place them in the spaces in the board immediately before you. The blocks fit easily so that you will not have to force them and thus break them. Do not turn the blocks over, but keep the black side up at all times. Work fast, but do not make mistakes by placing them in the wrong spaces. Ready, Go!

Form X correlated with Form Y gave a reliability coefficient 0.54 ± 0.04. Form W against Form Z gave a reliability of 0.73 ± 0.02.

Correlated against the Stenquist Aptitude Test, used again as the criterion, validity coefficient of 0.27 and 0.31 were obtained from Forms X and W respectively. These coefficients were stepped up by the Spearman-Brown Prophecy Formula and thus increased to 0.43 and 0.47. So, by using both forms, the validity can be increased considerably.

(1) Manual of Directions for the Clinton Spacial Relations Tests
The time on each form of the spacial relations consumes about three minutes. If one wishes, he may give two forms of the spacial relations test and thus the reliability of Forms X and Y will be 0.71 and of W and Z will be 0.84. If it is possible to devote twelve minutes of time to this function and give the four forms, the reliability of the test would be 0.87.

Clinton Cube Curly Block Test

This test (see plate following page 31) is composed of two similar forms each containing twenty-seven blocks which are curly or vari-shaped in design. When put together properly each set of the blocks will form a compact five-inch cube. No two blocks are interchangeable since they are cut along different curves and angles. These blocks fit into convenient boxes which open from the top and side.

The aim of the designer in making this test was to build some kind of a test that would measure creative ability as a factor in mechanical ability. When these blocks are assembled on a time basis they also measure ability to judge curves and size in a composite assembly.

In determining the rating of the subject, the assembly score is determined by the number of "contacts" or assemblies made. A "contact" consists of fitting two blocks together so that they fit smoothly in every way.
A possible score of 108 points can be made since 108 contacts are possible. A time limit of twenty minutes is set for each form. This limit does not permit all to finish the test, nor is the full twenty minutes required by all subjects to finish or complete the assembly. Therefore, the derived score would be the assembly score divided by the time required.

Before administering the test the blocks are removed from their boxes and mixed thoroughly so that no two contacts are possible except by chance.

(1) The directions to be read to the examinee are:

Here is a pile of curly or vari-shaped blocks. You are to put them together, and when you have put them together properly you will have a five-inch cube. Work fast, but try to keep from making errors in fitting the blocks. Your time will be limited. You may use both hands.

Ready, Go!

The reliability of the test was determined by correlating Form I against Form II. A coefficient of 0.49 ± 0.045 was obtained. Since this test takes only twenty minutes at the maximum, both forms could easily be given, thus lengthening the test to twice its original length. Increased by doubling the length of the test by giving both forms, a reliability of 0.66 could be obtained.

The validity of the test was obtained by correlating against the Stenquist Aptitude test. This correlation

(1) Manual of Directions for the Clinton Cube Curly Blocks Test
gave a coefficient of 0.25±0.055. If both forms were used as suggested for increasing the reliability, the validity could be increased to 0.40.

Clinton S-A-C Peg Board Test

This test (refer to plate on page 32) is composed of a flat board 12½" x 16" containing a large number of small holes and an equal number of pegs which fit easily but snugly in the holes. The holes are arranged in parallel rows and are evenly spaced. The board has a sliding drawer which contains the pegs. The drawer is quite shallow and gives free access to the pegs without any noticeable hindrance.

It was the belief of the designer that this particular test would measure the speed, accuracy, and muscular coordination of the individual which is so essential to mechanical efficiency. From the scores made on this test there can be little doubt as to the individual differences in these traits.

The subject is allowed three minutes, in each case the score being the number of pegs set in the time allowed. The subject is tested both for his preferred hand and the non-preferred hand. Two minutes relaxation and rest is allowed between the trials. (1)

The directions which the examiner is to read to the testee will describe quite adequately just what is expected

(1) Manual of Directions for the Clinton S-A-C Peg Board Test
of the individual.

This is a test to see how fast you can set the little pegs in the holes in the board. You are to use ONE hand and take only one peg at a time from the peg tray and set it on the board.

Begin setting the pegs in the upper or farthest row from you, and begin in the left-hand corner and set the pegs to the right. When you have completed the top row, begin at the left in the second row, and continue in that manner until time is called.

Work as rapidly as you can all the time.

Ready, Go!

A correlation between the scores on the preferred hand and the scores on the non-preferred hand was 0.62 ±0.037, thus indicating that a person having a high degree of coordination with one hand tends also to have a high degree of coordination with the other hand.

Correlating this test with the Stenquist Aptitude test a validity coefficient of 0.04 was obtained. While this may seem unusually low, it must be kept in mind that this is purely a motor skills test and that the criterion was a paper test of mechanical aptitude. Therefore, a low correlation is not surprising. Quite likely a correlation between this test and an accepted manipulative criterion would yield a higher coefficient. Likewise, since this test requires only 3 minutes to complete, it could easily be increased to several times its original length and the reliability and validity raised.
Now, since the various tests have been described, and their reliabilities have been found, the following table gives the reliabilities of the tests as a group.

**TABLE I**

**RELIABILITY OF THE CLINTON MECHANICAL ABILITY TESTS**

<table>
<thead>
<tr>
<th>Test</th>
<th>Reliability of One Form</th>
<th>Reliability of Both Forms</th>
</tr>
</thead>
<tbody>
<tr>
<td>Assembly Test</td>
<td>0.70 ± 0.03</td>
<td>0.82 ± 0.018</td>
</tr>
<tr>
<td>Spacial Relations</td>
<td>0.54 ± 0.04</td>
<td>0.71 ± 0.030</td>
</tr>
<tr>
<td>Curly Cube Blocks</td>
<td>0.73 ± 0.028</td>
<td>0.84 ± 0.018</td>
</tr>
<tr>
<td>Peg Board</td>
<td>0.49 ± 0.045</td>
<td>0.66 ± 0.036</td>
</tr>
<tr>
<td>Peg Board</td>
<td>0.62 ± 0.037</td>
<td></td>
</tr>
<tr>
<td>Average Reliability</td>
<td>0.62 ± 0.037</td>
<td>0.75 ± 0.027</td>
</tr>
</tbody>
</table>

In deriving the average of the reliability coefficients, it was not meant that these averages should be understood to be the reliability of the total Test battery. It merely indicates in a general way, the reliability of the battery. As shown in the table, the average reliability of the tests was found to be 0.62 ± 0.037 when determined for one form of each test. When both forms were combined, it was found that the average increased to 0.75 ± 0.027.
TABLE II
VALIDITY OF THE CLINTON MECHANICAL ABILITY TESTS

<table>
<thead>
<tr>
<th>Test</th>
<th>Validity of One Form</th>
<th>Validity of Both Forms</th>
</tr>
</thead>
<tbody>
<tr>
<td>Assembly Test</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Form M</td>
<td>0.54 ± 0.04</td>
<td>0.71 ± 0.03</td>
</tr>
<tr>
<td>Spacial Relations</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Form W</td>
<td>0.31 ± 0.05</td>
<td>0.47 ± 0.045</td>
</tr>
<tr>
<td>Form Y</td>
<td>0.27 ± 0.055</td>
<td>0.43 ± 0.046</td>
</tr>
<tr>
<td>Cube Curly Blocks</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Form I</td>
<td>0.25 ± 0.06</td>
<td>0.40 ± 0.043</td>
</tr>
<tr>
<td>Peg Board</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Preferred Hand</td>
<td>0.04</td>
<td>0.07</td>
</tr>
<tr>
<td>Average Validity</td>
<td>0.31 ± 0.05</td>
<td>0.41 ± 0.048</td>
</tr>
</tbody>
</table>

By the same method, the average validity was found to be 0.31 ± 0.05 when only one form was considered. By combining two forms the average validity would be 0.41 ± 0.048. Since the coefficient of validity of the peg board is extremely low, this has affected the averages a great deal. By omitting the peg board from the calculation, the averages of 0.37 for one form and 0.50 for both forms would be obtained. Since the peg board is largely a motor skills test and the criterion used in this case was not satisfactory, the latter averages would undoubtedly be a better indicator of the average validity of the total test.
In viewing the validity coefficients, it would seem at first sight that the validites of the tests were quite low. However, in determining the validity of any test, the criterion used is the basis upon which this determination is made. If the criterion itself is weak, it is only right to assume that in such a case the coefficients based upon it would be weak or a poor indicator of the true validity of such a test. In this study, scores on Stenquist's Aptitude Test of Mechanical Ability (refer to page 22) were used as a basis for determining the validity. This test, itself, is not a manipulative test. Instead, it calls for visual discriminations and does not measure manipulative ability in any specific way. For this reason, to base the validity of a manipulative test on such a criterion would not be very dependable.
CHAPTER V
SUMMARY

In the first part of this study a review of the theories on the nature of mechanical ability was made. A great deal of disagreement was found among the various investigators, as might be expected due to the intangible nature of such an ability. The consensus of opinion, however, seems to be presented quite well by Harvey, who assumed mechanical ability to be composed of:

1. Specific motor skills;
2. Manipulative, or mechanical ability;
3. Mechanical aptitude (an intellectual factor involving ability to deduce spatial relationship);
4. General intelligence, as labelled "g" by Spearman, since it must pervade all cognitive activity.

With this in mind, further study was made along the line of standardized tests already in the field that had much in common with the Clinton Mechanical Ability Tests. This included the tests developed by Stenquist, MacQuarrie, O'Connor, Link, and the Minnesota Board.

With these tests in mind, as representative of the standardized tests in mechanical ability testing, a study was made of the Clinton Mechanical Ability Tests. It was found that Clinton's tests employed somewhat the same methods as those used by the other test designers mentioned
above. Since the other tests have been accepted as reliable and valid tests, similarity of the Clinton tests to them, would indicate that this group of tests was a fairly reliable battery of Mechanical Ability tests.

Using the Pearson Product Moment method, the reliability coefficient of the Assembly tests was found to be 0.70. Likewise, coefficients of 0.73 and 0.54 were obtained for the Spacial Relations tests. The Cube Curly Blocks tests were found to have a reliability of 0.49. Due to insufficient data, the reliability of the Peg Board could not be determined, but it was found that a correlation coefficient of 0.62 existed between preferred hand and non-preferred hand in this case. The average of the reliability coefficients for one form of each test was found to be 0.62.

By using two forms of each test, however, it was found by the Spearman-Brown Prophecy formula, that the Assembly test reliability was raised to 0.82. Likewise, the reliability of the Spacial Relations Tests was increased to 0.84 and 0.71, respectively. For the Cube Curly Blocks it was found that by using both forms, the reliability was 0.66. The average reliability when two forms of each test were used was 0.75, a significant increase over the average reliability of the single forms.
Having determined the reliabilities of the tests, the validities were computed by using the Stenquist Aptitude Tests of Mechanical Ability as a criterion. For Form M of the Assembly test, a validity of 0.54 was found. The Spacial Relations tests, Forms W and Y yielded validities of 0.31 and 0.27, respectively. A validity of 0.25 was found for the Cube Curly Blocks test. The Peg Board gave a correlation of 0.04. In this case it was believed that the criterion was inadequate since this was purely a motor skills test. An average of the validity coefficients for one form of each test was found to be 0.315. Omitting the Peg Board coefficient from the group, an average validity of 0.37 was obtained.

By using the Prophecy formula and combining both forms, the Assembly test validity was increased to 0.71. Likewise, the Spacial Relations was made more valid by this same procedure since coefficients of 0.47 and 0.43 were obtained. Using the same method the validity of the Cube Curly Blocks could be increased to 0.40. In the case of the Peg Board, the same method yielded a new coefficient of 0.07. The average validity of the two forms of each test was 0.41. By omitting the Peg Board coefficient the validity would be 0.52.

After having studied the nature of mechanical ability, and having reviewed the standardized mechanical ability tests already being used in educational and industrial fields,
the writer feels that the Clinton test is a good test of mechanical ability, if the tests already standardized are used as a basis of judgment. While the validities of the tests did not prove to be high when based on the Stenquist Aptitude Test of Mechanical Ability, it is believed that the validity would be found to be much higher if a better criterion of mechanical ability was available.
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