WORK-LIMIT VS. TIME-LIMIT SCORES ON THE MINNESOTA PAPER FORM BOARD TEST

by

KARL D. EDWARDS

B. S., Kansas State College, 1940

A THESIS

submitted in partial fulfillment of the

requirements for the degree of

MASTER OF SCIENCE

Department of Education and Psychology

KANSAS STATE COLLEGE
OF AGRICULTURE AND APPLIED SCIENCE

1945

TABLE OF CONTENTS

I. INTRODUCTION

The selection and use of tests is a problem which is constantly before most guidance workers today. There is a constant search for new and better tests and for new or better means of using the tests available. It would, of course, be impossible for all schools to give a comprehensive battery of aptitude tests, but it seems desirable to use in the testing program a test which is an indicator of mechanical aptitude.

The Revised Minnesota Paper Form Board Test by Likert and Quasha is recognized as one of the best of its kind for the measurement of space relationship perception, one of the measurable aspects of mechanical ability. Bingham (2) states,

> Ability not only to perceive the spatial relations of objects but to think correctly about these relations is obviously an important factor in mechanical aptitude. Indeed, it is so essential for many kinds of work that numerous blanks and forms have been developed for use in measuring this kind of ability. One of the most convenient of these is the geometrical construction test known as the Minnesota Paper Form Board recently improved by Likert and Quasha. This is essentially a test of speed in recognition of forms and space relations. It does not measure accurately the level of difficulty of the space problems which a person is able to solve.

Since this test when given according to directions is a time-limit test and so measures speed of recognition of forms and space relations rather than the level of difficulty of the space problems which a person can solve, and since, according to a statement by the authors of the test in the manual of directions, the problems are arranged in order of difficulty,

the problem arises as to whether or not the predictive value of the test could be increased by doubling the time-limit, thus making it essentially a work-limit test and assuring that all subjects would reach the more difficult problems. This problem was further brought to the attention of the writer when he had given the test to a group of tenth grade geometry students. It was observed that many who made high grades in geometry made low scores on the test but that they had solved all or nearly all of the examples correctly as far as they were able to work in the twenty-minute time limit. This observation and the foregoing statement by Bingham lead to the undertaking of the solution of this problem; namely, will the work-limit scores or the time-limit scores on the Revised Minnesota Paper Form Board Test give higher correlations with shop, mechanical drawing, and mathematics grades, and hence be the better predictor of success in mechanical and engineering pursuits?

Work-limit as used in this study refers to the practice of allowing sufficient time for all subjects to complete the test; thus the scores are measures of level of accomplishment and not a measure of rate of recognition of correct spatial relationships. This definition is given because some authors have used the term "work-limit" to indicate the amount of time necessary to complete a given number of tasks or problems. Using this definition, Paterson and Tinker (12) found that there was no significant difference in time-limit and work-limit scores on the Chapman-Cook Speed of Reading Test. However,

the intent of this test is to measure speed, so obviously the time element is the essential factor and must enter into the score in one way or another. Whether speed of recognition or level of accomplishment on the Minnesota Paper Form Board Test will correlate higher with grades in subjects related to engineering and mechanical work became the purpose of this study. Authors are not in agreement on the question of whether or not to time mental tests. The test used in this study, of course, is intended to measure only certain mental aspects of mechanical aptitude. Whipple (15) states,

> It is true that in many instances it seems most obvious and is extremely tempting to compare the work of different S's in terms of speed. But in the author's opinion we have been led astray by this temptation. Certainly if we seek to evaluate the 'higher' mental functions, speed is not the primary index of efficiency, as is borne out by the evidence that speed and intelligence are not very highly correlated. . . . As a general rule it may be said that time measurements become more significant and reliable in proportion as the task becomes more mechanical and less intellectual.

Another rather obvious fact regarding time-limit scores, yet one which is frequently overlooked is further emphasized by Whipple; namely, that a time-limit test always measures the purely motor aspect of time taken in marking the answers as well as the time taken in the mental processes of arriving at the correct answer. It would be difficult to estimate the per cent of the time spent in deciding which is the correct answer as compared with the time spent in marking it in the proper place; but if the test is timed, both the mental processes involved in determining the correct answer and the purely

mechanical process of recording it become components of the score. Of course, this purely mechanical action may be a definite part of mechanical aptitude, but it should be measured by a separate test intended to measure that phase and should not be a part of the score on a test intended to measure only mental processes. Also time spent by a subject in such irrelevant acts as blowing the nose, rubbing the eyes, sharpening or exchanging pencils or adjusting the lead if using an eversharp and a multitude of other such acts constitutes a factor in the score. In a time-limit test there is also the possibility of errors in timing and this possibility increases as the test becomes more and more widely used and quite often by inexperienced and inadequately trained examiners. Errors in timing, of course, tend to make the scores less reliable.

The elimination of the time element in mental tests, however, is not accepted by many writers. Thurstone (14) states,

> There is a general prejudice against time-limit examinations based on the assumption that one cannot do one's best when forced to work against time. We gave a series of examinations both with and without the pressure of working against time, and found that in all the examinations the diagnostic value was considerably increased by giving the tests on the time-limit basis. It is true that our best work is not done to the time of a stop-watch but it is also true that, other things being equal, the brightest minds can not only work better but also faster than the less gifted minds. Why should we then not avail ourselves of one of the fundamental differences between brightness and dullness, namely, the difference in normal speed of mental work? It has been established with considerable certainty that an examination is more

diagnostic of the ability measured if we take into consideration the speed with which the student works.

Since there seems to be such disagreement as to the value of timing and since there have been few studies to confirm either viewpoint, the need for such investigation concerning specific tests is evident. It was not the purpose of this study to arrive at an inclusive conclusion as to the merits of time-limit and work-limit methods in administering mental tests in general, but simply to ascertain which method gives higher correlations between this particular test, The Revised Minnesota Paper Form Board, and school subjects related to engineering and mechanical pursuits.

The major emphasis in this study was devoted to the use of the test in the guidance of secondary school students. However, since the test is also intended for use at the college level, and since data for some limited college groups were available, a short summary of the results obtained from them is also presented.

II. METHODS AND PROCEDURE

In order to facilitate scoring and to make it possible to administer the test to the same group on both the twenty-minute and the forty-minute time limits, the Perfo-Score Answer Sheets by J. C. Peterson and H. J. Peterson were used instead of the method of answering on the test booklets as provided in the instructions accompanying the tests. Answering on the Perfo-Score Sheets instead of on the test booklets should in no way affect the scores, since in both cases the answer is registered some little distance from the example being solved, and encircling the correct letter on the Perfo-Score Sheet is a task comparable to the printing of the letter of the correct answer in the proper square on the test booklet. In regard to the use of the separate answer sheet, Dunlap (4) found that the use of the separate answer sheet is entirely satisfactory especially when the test is short enough to enable all the answers to be recorded on one side of the sheet. Since this test consists of 64 problems and the Perfo-Score Sheet used provides for 100 answers, it is entirely satisfactory for answering and also provides facilities for answering the sample problems at the beginning of the test.

In order to make it possible to administer this test to the same group on both the standard twenty-minute time limit and on the double-time basis it was necessary to revise the instructions in accordance with a statement which follows

shortly and also to use the answer sheet in the following manner. A carbon sheet was attached to the back of the answer sheet with the carbon face towards the answer sheet and a strip of light cardboard was attached to provide a solid backing for the answer sheet. Thus, when an answer was marked on the front of the answer sheet, a carbon impression of the circle was also made on the back of the sheet. After the first 20 minutes had elapsed, the carbons were removed and the subjects continued working for another twenty-minute period. Thus, the carbon impressions on the back of the answer sheets provided the basis for counting the scores on the twenty-minute limit and the answers on the front of the sheets gave the scores on the work limit basis. A subject was allowed to go back over those done during the first 20 minutes. Even though a subject did not attempt the items consecutively during the first 20 minutes, the carbon impressions on the back would indicate his score on the twenty-minute limit and the penciled circles on the front would indicate his double-time score.

The question may arise as to whether or not this method will give scores on the work-limit basis which are the same as would be made if the subjects were allowed to work from the beginning without being under the pressure of time for the first 20 minutes. It is acknowledged that it might not. However, since the subjects were allowed to omit problems during the first 20 minutes, and were allowed to answer them later or to change any which they thought had been answered incorrectly during the first 20 minutes, it is logical to

assume that the scores made on the double-time basis do constitute actual work-limit scores. Then there is the added advantage in using this method of having the same group for correlations thus eliminating the sources of error that always exist due to unaccountable and unmeasurable differences between experimental and control groups.

The instructions for administering the test under these conditions were revised to read as follows:

Examiner: Before distributing test booklets say:

"Do not write anything on this test booklet. (Hold one up.) There is a separate answer sheet on which your name, the name of the test, and all the answers are to be recorded. When you receive the test booklet, let it lie on your desk with page 1 on top, but do not read it until you are told to begin."

Examiner: Distribute test booklets; then say:

"Take your answer sheet out of the booklet and print your name and that of your school and your class in the proper spaces on it. On the line labeled 'subject' write 'Form Board, Series AA (or 'Series BB' if that is the form in use)."

(After sufficient pause for writing on answer sheet, say:)

"You will notice a sheet of carbon paper attached to your answer sheet. This is simply to make a double record of your marks, one on the front and one on the back of your answer sheet. Leave it

attached just as it is while marking your answers."

"Now look at the instructions on page 1 and read them silently while I read them aloud."

(After reading through to end of problem 4 say:)

"For practice we will now record the answers to the sample problems on page 1 of the test booklet on lines 91 to 98 of the answer sheet, since these lines are not used in the actual test. The answer to problem 1 is 'E'. Please record this answer now on your answer sheet by drawing a circle around the 'E' on line 91 of the answer sheet. The answer to problem 2 is 'A'. Record this answer now by drawing a circle around 'A' on line 92 of your answer sheet."

Examiner: Continue this procedure through problem 4; then say:

"What is the correct answer to problem 5?"

(When replies agree say:)

"Yes, 'C' is the correct answer. Please record it by encircling the letter 'C' on line 95 of the practice section of your answer sheet."

Examiner: Follow the same procedure through questions 6, 7, and 8; then say:

"Are there any questions? No questions will be answered after you have started. Is there anything that any of you do not understand?"

(Being sure that none of the subjects open the test

booklets until told to do so, continue reading the directions starting with: "Some of the problems." Omit "Print with capital letters only" and "Make them so that anyone can read them" or indicate that these statements do not apply. When you have finished reading the directions, show the group how the booklet opens, and show them that to get to page 3 the entire booklet must be opened. It is very important to show them how this is done. Show them that there are 64 problems in all. Then say:)

"Remember, all answers are to be recorded on the answer sheet. Record the answer on the first line of your answer sheet by drawing a circle around the letter which precedes your chosen answer. Record the answer to the second problem on the second line of your answer sheet in the same way and continue to record the answer to each problem on the corresponding line of the answer sheet. Be careful to record each answer on the right line."

"If you make an error in marking, simply mark an X through the circle you have made, and then encircle the one intended."

"Are there any questions?"

(If none, say:)

"Open your booklets and start. Ready? Go."

Examiner: Exactly 20 minutes from that time say:

"Stop. You have now worked for exactly 20 minutes.

Now please remove the carbon sheet from your answer sheet and clip the answer sheet back onto the cardboard."

(After sufficient time, say:)

"The carbon circles on the backs of your answer sheets represent your answers on a 20 minute basis. We are now going to allow you another 20 minutes to complete the test and see how many more you can get right. If you wish to go back and change any which you have already answered, you may do so in the same manner as described before. If you finish before the time has elapsed, just lay the test aside and wait quietly until the tests are collected. Are there any questions?"

(If none, say:)

"You may now continue."

(After another 20 minutes, say:)

"Stop."

"Fold your answer sheet in your booklet and turn it so that the page with your name is on top."

(Collect booklets immediately.)

This test was given in this manner during the 1944-45 term to a group of 574 tenth grade students in the Wyandotte High School in Kansas City, Kansas

Grades used are grades earned during the 1944-45 term except in the case of general mathematics in which case they are for the preceding term.

On the college level the test was given to the freshman class at Kansas State College in the fall of 1943. Grades used for this part of the study were those earned during the first semester of the 1943-44 term.

III. RESULTS AND INTERPRETATIONS

In the statistical treatment of the data, the various groups used included all students who took the subjects or combinations of subjects necessary for the particular calculations involved. For the most important part of the study the group used consisted of 112 boys for whom grades were available in algebra, general mathematics, and mechanical drawing. Correlations were calculated by the use of Ayers' formula, one of the common methods of obtaining the product-moment coefficient of correlation (1). The inter-correlations for this group between the time-limit scores, the work-limit scores, the Henmon-Nelson Intelligence Test scores, and grades in general mathematics, algebra, and mechanical drawing are shown in Table I.

Table I. Correlations between time-limit scores, work-limit scores, intelligence test scores, and grades.

	Alg.	Gen. Math.	Mech. Dr.	Int. test
Time-limit scores	.239	.309	.232	.298
Work-limit scores	.336	.361	.357	.443
Int. test scores	.310	.255	.367	

It will be noted from this table that in each of these three subjects the work-limit scores gave higher correlations than did the time-limit scores, the differences being .097 in algebra, .052 in general mathematics, and .127 in mechanical drawing. It will also be noted that the correlations of the intelligence test scores with the subject grades exceeded

those of the time-limit scores in algebra and in mechanical drawing but were lower than those of the work-limit scores except in mechanical drawing, in which they were practically identical, the difference being .010, which is not a significant difference. Another point might be noted here. The work-limit scores correlated .245 higher with the intelligence test scores than did the time-limit scores.

These differences in correlation, the significance of which will be discussed later, are more meaningful when they are translated into percentages of forecasting efficiency. This means the per cent greater than chance by which one is able to forecast a person's success in a subject by using his test scores. This percent is found by the formula $100(1-k)$ where $k=\sqrt{1-r^2}$. These percentages are shown in Table II.

Table II. Percentages of forecasting efficiency of time-limit and work-limit scores.

	Alg.	Gen. Math.	Mech. Dr.	Int. Scores
Time-limit	2.92%	4.93%	2.68%	4.61%
Work-limit	5.96%	6.70%	6.70%	10.20%

Thus the forecasting efficiency of the time-limit scores in predicting success in algebra is seen to be 2.92 per cent better than chance. For the work-limit scores, the corresponding figure is 5.96 per cent, or a little more than double the time-limit figure. For general mathematics, the time-limit scores give a forecasting efficiency of 4.93 per cent; the work-limit scores give 6.70 per cent. In mechanical drawing the forecasting efficiencies are: time-limit, 2.68 percent; work-limit, 6.70 per cent. In forecasting intelligence test scores, the

efficiency of the time-limit test is 4.61 per cent; that of the work-limit test is 10.20 per cent.

Partial correlations were calculated by the formula

$r_{12.3} = \frac{r_{12} - r_{13}\, r_{23}}{\sqrt{1-r_{13}^2}\,\sqrt{1-r_{23}^2}}$ for both work-limit and time-limit scores with each of the three subjects, the intelligence scores being partialed out. These partial correlations are shown in Table III.

Table III. Comparison of zero order r's and r's with effect of intelligence test scores partialed out.

	Alg.		Gen. Math.		Mech. Dr.	
	Zero r	Partial r	Zero r	Partial r	Zero r	Partial r
Time-limit	.239	.162	.309	.262	.232	.138
Work-limit	.336	.233	.361	.286	.357	.233

This table shows that the partialing out of intelligence as measured by this test reduces the correlations of both work-limit and time-limit scores with all the subjects, but that the correlations of work-limit scores and subjects still remain higher than the corresponding correlations of time-limit scores and subjects. This would seem to indicate that intelligence as measured by the Henmon-Nelson Test is a contributing factor in succeeding on the Minnesota Paper Form Board Test on either the work-limit or the time-limit basis. These partial coefficients may have many implications but from the standpoint of this study the point to be noted is that the correlations of work-limit scores with each subject with intelligence partialed out are in each case almost identical with the correlations of zero order time-limit scores and subjects and are considerably higher than correlations of time-limit scores with intell-

igence partialed out.

Multiple correlations were calculated by the use of Kelley's formula $R_{1(23)} = \sqrt{\frac{r_{12}^2 + r_{13}^2 - 2r_{12}\,r_{13}\,r_{23}}{1 - r_{23}^2}}$ (8). This formula has the advantage over the one involving partial sigmas in that it makes it possible to calculate multiple coefficients directly from the zero order coefficients. Regarding this formula, Kelley states, "Since it is the same as the equation resulting from the solution of a three variable problem by means of determinants, we have additional proof of the identity of the values found by the two techniques."

Table IV shows the multiple correlations obtained by correlating subject grades with combined time-limit and intelligence test scores, and by correlating subject grades with combined work-limit and intelligence test scores.

Table IV. Correlations of subject grades with time-limit and work-limit scores each combined with intelligence test scores.

	Alg.	Gen. Math.	Mech. Dr.
Time-limit	.239	.309	.232
Int. score	.310	.255	.367
Both in mult.	.344	.351	.388
Work-limit	.336	.361	.357
Int. score	.310	.255	.367
Both in mult.	.381	.376	.426

It can be noted from this table that the correlations using work-limit and intelligence scores are higher than those using the time-limit and intelligence test scores. However, it is also evident from this table that, due to the lower correlation of time-limit with intelligence test scores, the differences in the multiple correlations are less than the

differences in zero order correlations. In algebra the difference in zero order correlations is .097 in favor of the work-limit; when used in multiple correlation with intelligence scores, the difference is only .037. In general mathematics the difference in zero order correlations is .052 in favor of the work-limit; when used in multiple correlation with intelligence scores, this difference is reduced to .025. In mechanical drawing the difference in zero order correlations is .127 in favor of the work-limit; when used in multiple correlation with intelligence scores, the difference is only.040.

Before any conclusions could be drawn concerning the relative merits of the work-limit method over the time-limit method, it was necessary to determine whether or not these differences in correlations are actual or whether they might be due to chance. This was done by finding the standard error of the differences in correlations in each case by the formula $\sigma_D = \sqrt{\sigma_{r_1}^2 + \sigma_{r_2}^2}$ where $\sigma_{r_1} = \frac{1-r_1^2}{\sqrt{N}}$ and $\sigma_{r_2} = \frac{1-r_2^2}{\sqrt{N}}$ and then by dividing the actual differences by the respective standard errors of differences to get the significance ratios. These significance ratios were then used to obtain the levels of confidence at which the differences are significant. These figures are shown for the differences in zero order correlations in Table V and for the differences in multiple correlations in Table VI. It will be noted from these tables that in no case does the level of confidence approach five per cent, the minimum acceptable level for concluding a significant difference.

Table V. Significance of differences between correlations with grades of work-limit scores and time-limit scores.

	Dif. in r's	σ_D	Sig. Ratio	Chances in 100 that dif. is sig.	Level of confidence
Algebra	.097	.122	.79	79	21%
Gen. Math.	.052	.118	.45	67	33%
Mech. Dr.	.127	.121	1.05	85	15%

Table VI. Significance of differences between multiple correlations with grades of work-limit and intelligence scores and time-limit and intelligence scores.

	Dif. in r's	σ_D	Sig. Ratio	Chances in 100 that dif. is sig.	Level of confidence
Algebra	.037	.116	.32	63	37%
Gen. Math.	.025	.116	.22	59	41%
Mech. Dr.	.040	.111	.36	64	36%

However, as pointed out by Garrett (5) and by Lindquist (10-b) to test the differences between correlation coefficients by the formula gives estimated standard errors that are larger than the standard errors actually are. This means that the chances of a significant difference are actually greater than those shown by Tables V and VI. It is impossible to say just how much greater the chances are than those shown by applying the aforementioned formula, since no test of the significance of a difference in correlation coefficients for this situation has been devised. Lindquist (10-b) gives the formula $\sigma_D = \sqrt{\frac{1}{N}\left[k_{12}^2 + k_{13}^2 - \frac{2k_{12}k_{13}r_{23} - r_{12}r_{13}(k_{23}^2 - r_{12}^2 - r_{13}^2 - 2r_{12}r_{13}r_{23})}{k_{12}\,k_{13}}\right]}$ in which $k = \sqrt{1-r^2}$. He points out, however, that its usefulness is impaired by the fact that it can be used only upon the assumptions of normality and random sampling. Though it

would be fallacious to assume either of these conditions in this study, it is interesting to note what results the application of this formula produces in comparison with those obtained by the use of the other formula. One example was chosen and worked through to show this comparison. The example chosen was mechanical drawing, in which, as shown by Table V, the significance ratio obtained was 1.05 indicating a significant difference at the 15 per cent level of confidence. When the formula mentioned by Lindquist was used, the significance ratio was 2.48 which indicates a significant difference at better than the one per cent level. Due to the limitations on this formula already mentioned, this obtained significance ratio is probably higher than the true significance ratio. However, the 1.05 found by the other formula is doubtless too low and the differences in correlation coefficients may be significant. It is impossible to make definite conclusions on the basis of the evidence brought out in this study, but the evidence points toward better diagnostic value of the test for mathematics and mechanical drawing in high school if used on the work-limit basis.

Mention should also be made here of another fact brought out in this study. A group of 157 boys who had taken the test by both methods were also enrolled in general shop. This group was not included in the previously discussed part of the study for two reasons. First, there were so few of these boys who had also taken the other subjects included; and second, it is doubtful that the purely mental aspects of mechanical ability are as important factors in success in shop work as they

are in success in mathematics and mechanical drawing. However, correlations of both time-limit and work-limit scores with shop grades were calculated and it is interesting to note that time-limit scores correlated .319 with shop grades while work-limit scores correlated only .275. This is a difference of .044 in favor of the time-limit method. The standard error of this difference obtained by the formula $\sigma_D = \sqrt{\sigma_{r_1}^2 + \sigma_{r_2}^2}$ is .103 which yields a significance ratio of .43. This means that there are 66 chances in 100 that the difference is significant. Since this significance can be regarded only at the 34 per cent level of confidence, it is not a very emphatic indicator, but might suggest that speed of recognition of space relationships is more indicative of ability in work such as that done in shop courses, while level of attainment of recognizing space relationships is more indicative of success in subjects that require the use of the mental processes involved in mathematics and mechanical drawing courses.

Since the work-limit scores gave higher correlations with all subjects used except shop, and since the reliability of the test on a work-limit basis had not been calculated, that was also done to see whether or not the increased validity for this group could be accounted for by increased reliability. The reliability of the test on the time-limit basis as given by the authors in the manual of directions is .85. They do not state the method used in obtaining this figure. In this study the split-half method was used as the test was given only once. The r's for the half-scores were corrected by the

Spearman-Brown formula to give correct r's for the whole test. The reliability on the time-limit was found to be .844, almost identical with that stated by the authors; and on the work-limit basis it was .834. However, as Guilford (6) points out, the reliability coefficient of a time-limit test is augmented to the extent that speed is important in determining the score. Therefore, when two tests are compared for reliability and one is a time-limit test and the other a work-limit test; if the reliability coefficients are equal, the work-limit test would actually be more reliable. Since there is no known correction for this discrepancy between apparent and actual reliability coefficients for time-limit tests, it can only be said that the work-limit basis has some advantage over the time-limit basis from the standpoint of reliability. This may explain in part the increases in validity of the test when given on a work-limit basis.

As was mentioned in the introduction, this study was primarily concerned with the use of the Minnesota Paper Form Board Test at the high-school level. However, a brief summary of the correlations of both time-limit and work-limit scores with college grades and other tests is shown in Table VII. It can be noted from this table that in all cases in which the correlations of time-limit with grades exceeded those of work-limit with grades the groups involved were very small, the largest being only 45. It should also be pointed out that due to the national emergency in the fall of 1943, there were very few men enrolled as freshmen in college; hence, all

groups used here include both men and women. In view of these facts and also the fact that all differences in correlations are small, except in the case of general psychology, one should not depend too heavily upon these results. However, these figures seem to indicate that the work-limit might be a better predictor at the college level, especially since it correlates .126 higher than the time-limit with the Kansas Math Test.

Table VII. Correlations of time-limit and work-limit scores with college grades and other tests.

Subject or test	No. of cases	r_1 for time-limit	r_2 for work-limit	$r_2 - r_1$
Solid geom.	20	.234	.215	-.019
Chem. E I	36	.213	.098	-.115
Chem. I	186	.251	.290	.039
Gen. Psychol.	91	.290	.518	.228
Engg. Dr.	45	.490	.377	-.113
5 Hr. Alg.	50	.200	.204	.004
3 Hr. Alg.	45	.163	.325	.162
Trig.	30	.345	.218	-.127
Elem. Design	89	.261	.329	.068
Rhet. I	235	.254	.258	.004
Kan. Math Test	280	.167	.293	.126
Gen. Int. Test	275	.345	.401	.056

IV. CONCLUSIONS AND IMPLICATIONS

1. The reliability of the test is not impaired by using the work-limit method.
2. For the groups studied at the high-school level, the validity was improved so far as mathematics and mechanical drawing were concerned by using the work-limit method but was decreased when shop grades were used as the criterion.
3. Since the differences in validity were not sufficiently large to assure at a high level of confidence that the differences found in the samples tested would exist in other samples, neither method should be adopted exclusively on the basis of this study. However, the indications are that if the purely mental aspects of perception of spatial relationship are to be taken as the criteria, the work-limit method is probably the more valid of the two.
4. Since the work-limit method is as reliable as the time-limit method and appears to be more valid for measuring mental aspects of mechanical ability, and since the test is likely to become more and more widely used by inexperienced testers who are likely to do inaccurate timing, the work-limit method should receive serious consideration.
5. Since present norms are based on time-limit scores, new norms must be developed if the work-limit method is to be used.
6. This study has brought up other related problems which

need to be investigated, some of which are:

(a). Time-limit vs. work-limit methods on other commonly used tests.

(b). The possible combining of both time-limit and work-limit scores for predictive purposes.

(c). Further checking of the work-limit method on this particular test.

7. On the college level, the evidence points toward a slightly higher validity for the work-limit basis; however, further research should be done before any conclusions are drawn.

V. ACKNOWLEDGMENTS

The writer wishes to express his appreciation to Doctor J. C. Peterson for his assistance and advice in conducting this study and for his tests and answer sheets used in the experiment; to Mr. Francis Greggory of Wyandotte High School, Kansas City, Kansas for his assistance in having the tests administered in his classes and for supplying the test scores and subject grades used; to Doctor M. C. Moggie for his assistance with the statistical work; and to his wife, Helen Edwards, for her assistance in recording and tabulation of data.

VI. REFERENCES

(1) Ayers, Leonard P.
(a) A shorter method for computing the coefficient of correlation. Jour. Ed. Res. 1(3):216-221. Mar. 1920.

(b) The application to table of distribution of a shorter method for computing coefficients of correlation. Jour. Ed. Res. 1(4):294-298. Apr. 1920.

(c) Substituting small numbers for large ones in the computation of coefficients of correlation. Jour. Ed. Res. 2(1):502-504. June 1920.

(2) Bingham, Walter Van Dyke.
Aptitudes and aptitude testing. New York. Harper and Brothers. 390 p. 1937.

(3) Darley, John G.
Testing and counseling in the high-school guidance program. Chicago. Science Research Associates. 222 p. 1943.

(4) Dunlap, Jack W.
Problems arising from the use of a separate answer sheet. Provincetown. The Journal Press. 48 p. 1940.

(5) Garrett, Henry E.
Statistics in education and psychology. New York. Longmans, Green and Co. 493 p. 1939.

(6) Guilford, J. P.
Fundamental statistics in psychology and education. New York. McGraw Hill. 533 p. 1942.

(7) Journal of Educational Research
Editorial. 2(1):505-507. June 1920.

(8) Kelley, E. Lowell.
The relationship between the techniques of partial correlation and path coefficients. Jour. Ed. Psych. 20(2):119-124. Feb. 1929.

(9) Kelley, Truman Lee.
Statistical method. New York. The Macmillan Co. 390 p. 1923.

(10) Lindquist, E. F.
(a) A first course in statistics. New York. Houghton Mifflin Company. 242 p. 1942.

(b) Statistical analysis in educational research. New York. Houghton Mifflin Company. 257 p. 1940.

(11) Paterson, Donald G., Elliott, Richard M., Anderson, L. Dewey, Toops, Herbert A., Heidbreder, Edna.
Minnesota mechanical ability tests. University of Minnesota Press. 587 p. 1930.

(12) Paterson, Donald G. and Tinker, Miles A.
Time-limit vs. work-limit methods. Amer. Jour. Psych. 42(5):101-104. Jan. 1930.

(13) Quasha, William H. and Likert, Rensis.
The revised Minnesota paper form board test. Jour. Ed. Psych. 28(3):197-204. March 1937.

(14) Thurstone, L. L.
Intelligence tests for engineering students. Eng. Ed. 13(5):274-275. Jan. 1923.

(15) Whipple, Guy Montrose.
Manual of mental and physical tests. Baltimore Warwick and York, Inc. 367 p. 1924.