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**THE EFFECT OF RESTRICTED RANGES OF ABILITY (on G.C.T.) ON CORRELATIONS BETWEEN G.C.T. AND THE THREE FORMS OF THE MECHANICAL APTITUDE TEST.**

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**PROBLEM:** This study was made (1) to determine empirically the shifts in correlation coefficients resulting from shifts in the range of ability of the group tested and (2) to compare these changes with those predicted by means of Kelley's formula for "correcting the correlation coefficient" for different ranges of ability.

**DATA:** The data were secured from the sample of 500 cases used in the standardization of MA-2 and MA-3. This sample was selected in accordance with a number of criteria from 2766 cases. Those criteria were: (a) one-half of the cases had MA-2 first and the other half had MA-3 first, (b) one-half of the cases were from Ft. Knox and the other half from Camp Croft, (c) all cases had taken G.C.T., MA-1, MA-2, and MA-3 (d) the MA-2 and MA-3 Army grade distributions of standard scores for the sample correspond to the distributions of standard scores obtained from the 2766 cases (e) every 6th paper was selected to randomize any other variables.

**PROCEDURE:** The procedure used was to determine:

1. the correlations between G.C.T. standard scores and the standard scores on MA-1, MA-2, and MA-3 for G.C.T. Army grades I + II, I + II + III, and I + II + III + IV.
2. the correlations between G.C.T. standard scores and the raw part scores on MA-2 and MA-3 for the same combinations of Army grades listed above.
3. the estimated correlations between G.C.T. standard scores and standard scores on MA-1, MA-2, and MA-3. This estimation was made by means of the formula  $R^2 = 1 - \frac{\sigma^2(1-r^2)}{\Sigma^2}$

Where R = predicted correlation  
r = obtained correlation

$\sigma^2$  = variance of restricted range  
 $\Sigma^2$  = variance of total range

This formula was given by Kelley as  $\sigma/\Sigma = \sqrt{1-R^2}/\sqrt{1-r^2}$ .

**CONCLUSIONS:**

1. The size of the obtained correlation coefficients is a direct function of the range of ability as measured by Army Grade levels and by the standard deviations.
2. The standard errors of estimate for MA-2 for this sample appear to vary as though from random factors, but the standard errors of estimate for MA-1 and MA-3 appear to be affected by some systematic biases.

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3. The correlations of MA-2 and MA-3 with G.C.T. are quite similar for each level of ability, the correlations of MA-3 with G.C.T. consistently run from +.01 to +.03 higher than those for MA-2 with G.C.T.

4. The correlations of MA-1 with G.C.T. are consistently higher than those for MA-2 and MA-3 with G.C.T. The differences between the correlations of MA-1 and of MA-3 with G.C.T. range from +.15 for Army Grades I + II to +.05 for the entire range of Army Grades.

5. Fisher's z-test of significance when applied to the differences between the correlations of MA-1 with G.C.T. and the correlations of MA-2 and MA-3 with G.C.T. indicates that (a) the differences between the MA-1 and the MA-2 correlations are probably significant and (b) that the differences between the MA-1 and the MA-3 correlations are of doubtful significance.

In terms of chances in 100 of getting differences as large as those or larger, the differences between the correlations of G.C.T. with MA-1 and with MA-2 range from 2 in 100 for the smallest range of ability to 0.1 in 100 for the entire range of values. Fisher, Peter and Van Voorhies, Walker have used as levels of significance, more than 5 chances in 100 as not significant, between 5 and 1+ chances in 100 as doubtful, and 1 or fewer chances in 100 as significant.

In terms of chances in 100 of getting a difference as large as those secured between the MA-1 and the MA-3 correlations, the values secured range from 4 in 100 for grades 1, 2, 3, to 2 in 100 for the entire range of ability.

RESULTS: 1. The correlations between the standard scores for G.C.T. and MA-1, MA-2, MA-3 for different ranges of ability are given in Table I below. The correlations increase with an increase in the range of ability. The standard errors of estimate for these same ranges of ability are included. If the regressions are linear and the standard deviations of the arrays are equal, these standard errors of estimate should show only chance fluctuation around an average value. However, these  $\sigma$  test for MA-1 and MA-3 vary almost too systematically to be explainable by random factors. It may be that these variations are due to a systematic variation from (a) linearity or (b) equal variances. The factor of equal variances for each array (Army Grade on G.C.T.) was checked by computing the standard deviations for each Army Grade.

TABLE I

SHOWING THE CORRELATIONS BETWEEN G.C.T. AND MA-1, MA-2, MA-3, THE STANDARD DEVIATIONS AND THE STANDARD ERRORS OF ESTIMATE FOR VARIOUS COMBINATIONS OF ARMY GRADES (on G.C.T.)

TEST	ARMY GRADES COMBINED	N	CORRELATION WITH G.C.T.	S.D.	$\sigma$ TEST
MA-1	1,2.	204	.54	11.9	10.0
	1,2,3.	363	.66	14.5	11.0
	1,2,3,4.	477	.78	18.0	11.3
	1,2,3,4,5.	500	.80	19.0	11.4
MA-2	1,2.	204	.38	13.8	12.8
	1,2,3.	363	.55	15.2	12.7
	1,2,3,4.	477	.70	17.8	12.8
	1,2,3,4,5.	500	.72	18.4	12.7
MA-3	1,2.	204	.39	12.4	11.4
	1,2,3.	363	.58	14.2	11.6
	1,2,3,4.	477	.73	17.3	11.9
	1,2,3,4,5.	500	.75	18.3	12.1

2. In Table II, it will be noted that the three MA tests gave rather different results as far as standard deviations are concerned. The MA-1 standard deviations were smaller at the extremes, the MA-2 values varied erratically, and the MA-3 standard deviations tended to increase with a decrease in ability. Since these results were all obtained on the same population, it was concluded that (1) these differences are probably a reflection of the inherent test characteristics and not of the specific differences in level of ability of the groups and (2) that the systematic variation in the test's mentioned above is more probably due to a departure of the regression line from linearity.

TABLE II  
SHOWING THE MEAN AND STANDARD DEVIATION FOR THE 3 MA TESTS  
FOR EACH G.C.T. AND ARMY GRADE.

ARMY GRADE	N	MA-1		MA-2		MA-3	
		M	$\sigma$	M	$\sigma$	M	$\sigma$
I	53	125.3	9.7	119.4	12.4	121.4	11.0
II	151	111.7	11.1	111.1	13.6	112.9	12.2
III	159	99.1	12.7	99.2	13.0	100.7	12.1
IV	114	81.5	12.8	84.1	13.9	84.9	13.3
V	23	69.5	11.1	75.0	10.8	75.3	13.7
TOTAL	500	100.1	19.0	100.4	18.4	101.8	18.2

3. The correlations between G.C.T. standard score and the raw part scores on MA-2 and MA-3 are given in Table III below. The trends are comparable to those found in the total standard scores for these Mechanical aptitude tests.

TABLE III

SHOWING CORRELATIONS BETWEEN G.C.T. STANDARD SCORES AND RAW SCORES ON THE PARTS OF MA-2 AND MA-3 TOGETHER WITH THE STANDARD DEVIATIONS OF THE PART SCORES.

TEST	PART	ARMY GRADES COMBINED	N	CORRELATION WITH G.C.T.	S.D.
MA-2	I	1,2.	204	.27	7.1
		1,2,3.	363	.49	7.5
		1,2,3,4.	477	.66	8.4
		1,2,3,4,5.	500	.68	8.6
	II	1,2.	204	.33	8.1
		1,2,3.	363	.44	8.5
		1,2,3,4.	477	.55	8.7
		1,2,3,4,5.	500	.58	8.8
	III	1,2.	204	.32	6.1
		1,2,3.	363	.46	6.5
		1,2,3,4.	477	.63	7.7
		1,2,3,4,5.	500	.66	8.0
MA-3	I	1,2.	204	.23	6.7
		1,2,3.	363	.47	7.1
		1,2,3,4.	477	.64	8.2
		1,2,3,4,5.	500	.66	8.5
	II	1,2.	204	.35	7.1
		1,2,3.	363	.49	7.6
		1,2,3,4.	477	.63	8.5
		1,2,3,4,5.	500	.65	8.8
	III	1,2.	204	.37	5.9
		1,2,3.	363	.51	6.4
		1,2,3,4.	477	.66	7.5
		1,2,3,4,5.	500	.69	7.7

4. The significance of the differences between the correlations of MA-1 with G.C.T. and the correlations of MA-2 and MA-3 with G.C.T. were evaluated by means of Fisher's z-test. This test was applied to the correlations of total scores for each range of ability. It had been used previously in evaluating the part score correlations for the total range of ability (Report of MA-2 and MA-3 standardization). The data are given in Table IV below. The values in the "T" column represent the standard score deviations for the given differences, and these "T"s are evaluated by means of a table of normal curve areas and deviations. The entries in the column headed "chances in 100" represent the chances in 100 of securing by chance deviations, differences as large as these, or larger if there were no difference between the correlations of the total universe. The ratings of doubtful, significant, or nonsignificant, are based on the common use of the 5% level as the edge of the nonsignificant area, from 5% to 1% as doubtful, and 1% or less as significant.

The differences secured between the MA-1 and the MA-2 correlations tend to be significant, while those between the MA-1 and the MA-3 correlations tend to fall in the doubtful range.

TABLE IV

SHOWING RESULTS OF FISHER'S Z-TEST FOR THE SIGNIFICANCE OF THE DIFFERENCE BETWEEN CORRELATION COEFFICIENTS FOR THE MA-2 AND MA-3 CORRELATIONS WITH G.C.T. COMPARED WITH THE MA-1 CORRELATIONS WITH G.C.T.

TEST	ARMY GRADES COMBINED	CORRELATIONS WITH G.C.T.	N	T	CHANCES IN 100	RATING
MA-1	1,2.	.54	204	—	—	—
	1,2,3.	.66	363	—	—	—
	1,2,3,4.	.78	477	—	—	—
	1,2,3,4,5.	.80	500	—	—	—
MA-2	1,2.	.38	204	2.05	2.0	doubtful
	1,2,3.	.55	363	2.34	1.0	significant
	1,2,3,4.	.70	477	2.74	0.3	"
	1,2,3,4,5.	.72	500	3.01	0.1	"
MA-3	1,2.	.39	204	1.93	3	doubtful
	1,2,3.	.58	363	1.75	4	"
	1,2,3,4.	.73	477	1.80	4	"
	1,2,3,4,5.	.75	500	1.98	2	"

5. The correlations for the total range of ability, i.e., Grades I to V, were estimated by Kelley's formula using, in turn each of the combinations of Army Grades. In deriving this formula, Kelley assumed that the standard deviations of scores on one variable are equal for each score interval taken on the other variable, i.e., that the  $\sigma_y$  for  $x$ -interval is equal to the  $\sigma_y$  for any other  $x$ -interval of the same width. This condition holds for correlation surface of normally distributed variates, but is not secured for non-normal distributions. Another assumption that is made is that a linear regression is obtained.

It has been shown in Table II that the standard deviations for all the Army Grades are not equal, but that the standard deviations for Grades II, III, and IV are approximately equal. These Army Grades include the same number of standard score points, so that for the middle ranges of ability the conditions assumed by Kelley probably are reasonably approximated.

Peters and Van Voorhis (pp 211-212) present the results of a check on Kelley's formula for the correlation with different ranges of ability. "In 34 trials,  $R$ 's predicted by the formula  $(\sigma/\Sigma)\sqrt{1-R^2}/\sqrt{1-r^2}$  missed the corresponding ones actually computed from the consolidated tables by an average of only .0189 when the algebraic signs of the deviations were disregarded and by only +.0048 when the signs were considered." (pp 211).

In this total sample of 500 under consideration the number of cases is, in general, less than those used in the studies reported by Peters and Van Voorhis.

The results of the present estimation are given in Table V below. In this table the values of  $R$ , the estimated correlation for the total range, were computed from the formula  $R = 1 - \sigma^2(1-r^2)/\Sigma^2$  where  $(r)$  is the obtained correlation for the restricted range,  $\sigma^2$  is the variance obtained for the restricted range, and  $\Sigma^2$  is the variance for the total range of ability.

The errors of prediction in the case of MA-1 and MA-3 are all positive. The difference between the predicted correlation ( $R$ ) and the obtained correlation ( $r$ ) decreases as the number of Army Grades combined is increased. The estimates made from the MA-2 results were quite satisfactory. It is suggested that the consistent positive errors of estimation secured from MA-1 and MA-3 might be traceable to a tendency toward a curvilinear relation between G.C.T. and these two variables, but this hypothesis was not checked.

It is concluded that, when it is necessary to estimate correlation coefficients from restricted ranges, Kelley's formula  $\sigma/\Sigma = \sqrt{1-R^2}/\sqrt{1-r^2}$  will give reasonably accurate results. If the underlying assumptions are met, the estimates will be sufficiently close to the obtained coefficients for most purposes.

TABLE V

SHOWING OBTAINED AND ESTIMATED CORRELATIONS BETWEEN G.C.T. AND MA TESTS FOR THE TOTAL RANGE OF ABILITY, THE ESTIMATIONS BEING MADE FROM VARIOUS COMBINATIONS OF G.C.T. ARMY GRADES.

TEST AND TOTAL S.D.	ARMY GRADES COMBINED	N	S.D.	CORRELATIONS WITH G.C.T.	ESTIMATED CORRELATIONS (R)	OBTAINED CORRELATIONS $r_t$
$\Sigma = 19.0$	1,2.	204	11.9	.54	.85	.80
	1,2,3.	363	14.5	.66	.82	.80
	1,2,3,4.	477	18.0	.78	.80	.80
$\Sigma = 18.4$	1,2.	204	13.8	.38	.72	.72
	1,2,3.	363	15.2	.55	.72	.72
	1,2,3,4.	477	17.8	.70	.72	.72
$\Sigma = 18.3$	1,2.	204	12.4	.39	.78	.75
	1,2,3.	363	14.2	.58	.77	.75
	1,2,3,4.	477	17.3	.73	.76	.75