

PRINCIPLES OF EMPLOYMENT PSYCHOLOGY

BY

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TO MY MOTHER

PREFACE

THIS book is an outgrowth, in the first instance, of material used for several years in presenting principles of employment psychology to college students, and in the second instance, of practical experience in personnel work and frequent contact with business men interested in psychology in so far as it relates to their problems. Effort is made, on the one hand, to give a fairly comprehensive account of the principles involved for the use of students preparing for practical psychological work in industry, and on the other hand, to avoid a discussion that is too technical for the reader without a psychological background. This does not mean, however, that the treatment is superficial. It is hoped, on the contrary, that the business man reading the book will realize the importance of a careful experimental approach to scientific employment psychology.

Statistical methods must of necessity form a part of the discussion. Although many persons shy at statistics, they are of such wide applicability in employment work that they cannot logically be omitted. No assumption of mathematical knowledge, however, is made, and the effort has been to make any statistical discussion as simple and as clear as possible. Wherever it has proved feasible to describe a method in a general way and relegate the more exacting details to the appendix, this has been done.

The critical psychological reader will notice that no definite stand has been taken regarding the fundamental points of view or metaphysical considerations of theoretical psychology. The author feels that these problems are not germane to the present discussion. The important thing is to predict occupational success whether this is construed from the standpoint of mind or muscle. It is pragmatically justifiable to speak of a "test of attention" regardless of the ultimate nature of attention or whether such a category exists at all. The employment psychologist's task is to arrive at his practical goal regardless of the route taken. Most of us en-

gaged in this field are too busy with our own problems to solve the fundamental issues with which other psychologists are better qualified to deal. In the following discussion it will probably be found that the methods are for the most part objective, but that the terminology is conventional. Experience in presenting psychological principles to the practical man has indicated the desirability of discussing them in terms of everyday vocabulary.

A work of this sort naturally draws rather heavily from experimental material contributed by many psychologists. Such studies as are referred to are cited mainly for illustrative purposes rather than in the nature of a critical review. To this end little mention is made of many details such as the time limit for a mental test, or the actual number of persons involved in a particular experimental study. This is done in order to avoid confusion from too many figures, and does not detract appreciably from the illustrative value of the citation. Reference is always made to the bibliography, however, so that the critical reader may, if he wishes, consult the original article and evaluate it for himself.

The author is indebted to all those who have contributed their bit to the body of psychological knowledge in this general field and whose results have been drawn upon rather extensively. He is especially indebted to H. L. Hollingworth, W. D. Scott, and A. J. Snow, whose contributions have been quoted more extensively. Grateful acknowledgment is likewise made to D. Appleton and Company, New York, for permission to quote from *Vocational Psychology*, by H. L. Hollingworth, *Judging Human Character*, by H. L. Hollingworth, and *Applied Psychology*, by H. L. Hollingworth and A. T. Poffenberger; to the McGraw-Hill Book Company, Inc., New York, for permission to quote from *The Selection and Training of Salesmen*, by H. G. Kenagy and C. S. Yoakum; to James P. Porter, editor, for permission to quote from *The Journal of Applied Psychology*; to A. W. Shaw Company, Chicago, for permission to quote from *Personnel Management*, by W. D. Scott and R. C. Clothier, and *Psychology in Business Relations*, by A. J. Snow; and to The Williams and Wilkins Company, Baltimore, for permission to quote from *Ability to Sell*, by M. J. Ream, and from *The Journal of Personnel Research*.

PREFACE

vii

It is hoped that the book will show the practical man the importance of painstaking scientific technique in employment psychology in contrast with the expeditious but unreliable methods of unscientific pseudo-psychology. On the other hand, it is hoped that students who expect to pursue psychology in a practical way will find herein a fairly adequate background for plunging further into details.

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COLUMBUS, OHIO

CONTENTS

I. INTRODUCTION	1
General psychology — Applied psychology — Psychology in industry — The need for employment psychology — The problem of employment psychology — Fundamental principle of employment psychology — Where employment psychology is most valuable — Employment psychology and human welfare — Outline.	
II. PSYCHOLOGY GOLD BRICKS	14
The intellectual underworld — Astrology — Spiritualism — Phrenology — Physiognomy — Experimental evaluation of character analysis from physiognomy — Summary.	
III. HISTORY OF SCIENTIFIC VOCATIONAL PSYCHOLOGY	46
Individual differences — Early development of mental tests — Comparison of test scores with occupational ability — Psychology in the war — Employment psychology since the war — Summary.	
IV. TYPES OF MENTAL TESTS	60
Classification — Tests of special capacity — Motor control — Sensory capacity — Attention — Learning association — Reaction time — Space perception — Memory — Reasoning — Speed of decision — Ingenuity — Ability to follow directions — Emotion — Honesty — Temperament — Tests of intelligence — Summary.	
V. MENTAL TEST TECHNIQUE	101
Method of administration: Individual <i>vs.</i> group tests — Administration: Method of test response — Administration: Types of test response — Administration: Limitation upon test response — Administration: General precautions — Test material — Test instructions — Incentive — Scoring of tests — Reliability of tests — Summary.	
VI. THE CRITERION	141
Necessity — Estimates by superiors — Production figures — Miscellaneous criteria — Combining heterogeneous criteria — Summary.	
VII. THE SUBJECTS USED IN EVALUATING TESTS	172
General considerations — Applicants for employment as subjects — Employees as subjects — Sampling of subjects — Miscellaneous factors — Summary.	

VIII. SPECIAL CAPACITY TESTS: TOTAL MENTAL SITUATION . . .	185
Preliminary procedure for test research — Analyzing the job with a view to selecting tests — Reproduction of the total mental situation — Giving the tests to workers whose criterion is available — Correlation of test score with criterion — Limitations of total situation method — Examples — Critical scores — Summary.	
IX. SPECIAL CAPACITY TESTS: THE MENTAL COMPONENTS OF THE JOB	226
Preliminary selection of tests — Final selection of tests — Weighting the final group of tests — Examples with partial correlation technique — Examples with less statistical refinement — Miscellaneous brief examples — Follow-up procedure — Summary.	
X. INTELLIGENCE AND VOCATIONAL APTITUDE	265
Occupational hierarchy — Intelligence surveys — Correlation of intelligence with the criterion — Critical scores in intelligence — Optimum <i>vs.</i> maximum intelligence — Summary.	
XI. INTERESTS IN EMPLOYMENT PSYCHOLOGY	294
Permanence of interest — Interest and ability — Methods of measuring interest — Evaluation of measurements of interests — Summary.	
XII. RATING SCALES	317
Purpose — Selection of traits to be rated — Weighting the traits — Defining the traits — Man-to-man rating scale — Rating scale for officers — Rating scale for minor executives — Rating by defined groups — Rating scale for executives — Leadership — Graphic rating scale — Reliability of ratings — Validity of ratings — Sources of error in rating procedure — Training rates — Summary.	
XIII. MISCELLANEOUS DETERMINANTS OF VOCATIONAL APTITUDE	371
Value — Academic record — Initial and subsequent success in the same occupation — Personal history or application blank — Letters of application — Recommendations — The interview — Interviewer's rating scale for executives — Summary.	
XIV. TRADE TESTS	431
Trade tests <i>vs.</i> tests of innate capacity — Need for trade tests — Requirements of trade tests — Principles on which trade tests are based — Kinds of trade tests — Methods of developing and standardizing — Examples of trade tests — General precautions — Summary.	
XV. JOB ANALYSIS	467
Nature of job analysis — Purpose — Need — The rôle of psychology in job analysis — Method of securing data — Occupational description — Psychological possibilities in job analysis for employment purposes — Summary.	

CONTENTS

xi

XVI. THE OUTLOOK FOR EMPLOYMENT PSYCHOLOGY	489
Summary of psychological technique applied to employment methods — Present trends — Attitude of workers and management toward employment psychology — Necessity for further research — Essentials for future research — The social implications of employment psychology.	
APPENDIX	
I. ILLUSTRATING THE TECHNIQUE OF CORRELATION	511
II. COMBINING RANKINGS WITH INCOMPLETE DATA	517
III. ILLUSTRATING THE DERIVATION OF A REGRESSION EQUATION	520
BIBLIOGRAPHY	527
INDEX	565

APPENDIX I

ILLUSTRATING THE TECHNIQUE OF CORRELATION

THE notion of correlation is fundamental in employment psychology. We are often concerned with the extent to which two variables or sets of traits or measurements are related. We may wish to determine whether or not estimates of a trait made by acquaintances are at all related to estimates made by unacquainted persons judging purely from physiognomy. We may desire to ascertain to what extent efficiency in a particular mental test is related to efficiency in a job. The ultimate aim is usually to predict one variable in terms of another; hence the need for expressing quantitatively the relation between the two variables. The correlation coefficient is the standard technique for expressing this relation. The present section aims merely to give a simple notion of how correlations are obtained and the meaning of correlations of different magnitudes. The examples cited are made absurdly brief in the interest of avoiding tedious arithmetical computations. With longer examples, the arithmetical procedure would naturally be more arduous. There are available, however, various short-cut procedures which are described in books on statistics. (498, 603.)

One of the simplest correlation procedures is that involving rank differences. Given two series of measures it is possible to rank them both and get the differences in the rank. Consider Example I, which gives data on five men. Let us suppose that these five men make the scores in a mental test indicated in the first column and that some quantitative statement of

EXAMPLE I

NAME	TEST SCORE	JOB SCORE	TEST RANK	JOB RANK	RANK DIFFERENCE	RANK DIFFERENCE SQUARED
Adams	45	75	1	3	2	4
Andrews	43	80	2	2	0	0
Briggs	38	82	3	1	2	4
Brown	36	63	4	5	1	1
Doe	34	68	5	4	1	1

Sum of rank differences squared 10

$$r = 1 - \frac{6 \sum D^2}{N(N^2 - 1)} \qquad \begin{array}{l} \sum D^2 = 10 \\ N = 5 \end{array}$$

$$r = 1 - \frac{6 \times 10}{5(25 - 1)} = 1 - \frac{60}{5 \times 24} = 1 - .50 = .50$$

their ability in the job, such as units of production, gives the scores indicated in the second column. The problem is the extent to which those who make high test scores make high job scores and *vice versa*. It is to be noted that Adams makes the highest test score and is given the rank of 1 (cf. column headed "test rank"); Andrews is next best in the test and is given the rank of 2; Briggs comes third. If, now, we consider their job scores, Briggs is the best of the group and is ranked 1 (cf. the column headed "job rank"); Andrews is second best and gets a rank of 2, while Adams falls in third place. We may now neglect the first two columns and consider only the columns of ranks and determine the difference of rank in each instance. Adams is ranked 1 on the test and 3 on the job and the difference between these figures is 2 (cf. the column headed "rank difference"). Andrews is ranked two in both cases, so the difference is 0; Briggs is ranked 3 on the test and 1 on the job and the difference is 2. Similarly, the differences for Brown and Doe may be computed. These differences give some notion of the extent to which the two series of ranks correspond. If the difference is as great as 4 or 5, it indicates that a person is ranked in one trait very differently from the way in which he is ranked in the other. If the difference is small, it indicates that there is a fair correspondence. In working out the correlation coefficients on the basis of these data, it is necessary to square the rank differences as is done in the last column. The sum of these squares is then obtained. The formula for computing the coefficients is indicated in the example. It must be taken on faith, in the present connection, but its derivation may be obtained in various works on statistics. (692.) In the formula the term $\sum D^2$ means the sum of the differences squared, while N means the number of cases involved — in this instance, 5 men. To solve the formula it is necessary to take 6 times the sum of the differences squared, divide this by N times $N^2 - 1$ and then subtract this quotient from 1. In the present example this works out to an answer of .50. It is rather conventional procedure to carry correlation coefficients out to two decimal places. This particular coefficient indicates a fair degree of correlation, which, of course, is obvious from inspection of the original data, but it would not be so obvious if a large number of individuals had been involved. For purposes of comparison several other examples are added using similar data that give higher or lower correlations than those of Example I. Example II, for instance, indicates a case of what is termed perfect correlation. Briggs, who ranks highest in the test, is also highest in the job. Andrews, who is second in the test, is second in the job, and so on down to Doe, who is poorest in each respect. In this case there are no differences in rank and the correlation coefficient comes out 1.00, which is the maximum possible. This indicates a perfect correspondence between the two variables.

Example III presents a perfect negative correlation. Adams, who is best in the test, is worst in the job, and Andrews, who is second best in the

test, is second worst in the job, and so on down to Doe, who is worst in the test and best in the job. This, of course, makes the differences in rank as large as possible and the coefficient is -1.00 , which is the maximum possible negative coefficient. It indicates a perfect tendency for the highest scores in one variable to go with the lowest scores in the other.

EXAMPLE II

NAME	TEST SCORE	JOB SCORE	TEST RANK	JOB RANK	RANK DIFFERENCE	RANK DIFFERENCE SQUARED
Adams.....	38	74	3	3	0	0
Andrews.....	43	79	2	2	0	0
Briggs.....	45	82	1	1	0	0
Brown.....	36	68	4	4	0	0
Doe.....	33	62	5	5	0	0

$$\Sigma D^2 = 0$$

$$N = 5$$

$$\rho = 1 - \frac{6 \times 0}{5(25 - 1)} = 1 - \frac{0}{5 \times 24} = 1.00$$

EXAMPLE III

NAME	TEST SCORE	JOB SCORE	TEST RANK	JOB RANK	RANK DIFFERENCE	RANK DIFFERENCE SQUARED
Adams.....	46	67	1	5	4	16
Andrews.....	43	64	2	4	2	4
Briggs.....	38	75	3	3	0	0
Brown.....	36	78	4	2	2	4
Doe.....	34	83	5	1	4	16
						<u>40</u>

$$\Sigma D^2 = 40$$

$$N = 5$$

$$\rho = 1 - \frac{6 \times 40}{5(25 - 1)} = 1 - \frac{240}{5 \times 24} = 1 - 2 = -1.00$$

Example IV involves a correlation of $.80$, which is not perfect, although very high. There are slight discrepancies in rank, enough to spoil the perfection, but from inspection it is obvious that there is a very close relation between the variables and this is reflected in the high coefficient. Example V indicates a 0 correlation — that is, a situation in which there is no apparent relation between the two variables. Inspection reveals that it

would be practically impossible to predict a man's job rank if his test rank were known. This is reflected in the coefficient of 0.

EXAMPLE IV

NAME	TEST SCORE	JOB SCORE	TEST RANK	JOB RANK	RANK DIFFERENCE	RANK DIFFERENCE SQUARED
Adams.....	40	75	3	3	0	0
Andrews.....	48	79	1	2	1	1
Briggs.....	44	85	2	1	1	1
Brown.....	32	68	5	4	1	1
Doe.....	37	64	4	5	1	1
						4

$$\sum D^2 = 4$$

$$N = 5$$

$$\rho = 1 - \frac{6 \times 4}{5(25 - 1)} = 1 - \frac{24}{5 \times 24} = 1 - .2 = .80$$

EXAMPLE V

NAME	TEST SCORE	JOB SCORE	TEST RANK	JOB RANK	RANK DIFFERENCE	RANK DIFFERENCE SQUARED
Adams.....	43	86	2	1	1	1
Andrews.....	48	73	1	4	3	9
Briggs.....	37	68	4	5	1	1
Brown.....	39	77	3	3	0	0
Doe.....	31	80	5	2	3	9
						20

$$\sum D^2 = 20$$

$$N = 5$$

$$\rho = 1 - \frac{6 \times 20}{5(25 - 1)} = 1 - \frac{120}{5 \times 24} = 1 - 1 = .00$$

The method of rank differences, while a very convenient and relatively easily computed correlation procedure, is not ideal because it assumes that the differences between any two adjacent ranks in one variable are all equal. Referring to Adams's test score in Example I, it is actually two points better than Andrews's, while the latter is five points superior to Briggs's, but in ranking them it is assumed that these differences are equal. In this way a striking superiority or inferiority of some individual may be overlooked. A standard method is available which takes into account the

actual magnitude of the scores. Instead of merely considering whether a person who is best in the test is best in the criterion, we are concerned with whether a man who deviates from the average in one respect deviates correspondingly in the other. In Example VI an illustration is given of the

EXAMPLE VI

NAME	TEST SCORE	CRITERION	DEVIATIONS		DEVIATIONS SQUARED		PRODUCT OF DEVIATIONS
			Test	Criteria	Test	Criteria	
			X	Y	x	y	
Adams.....	10	15	+4	+6	16	36	+24
Andrews.....	7	8	+1	-1	1	1	-1
Briggs.....	5	6	-1	-3	1	9	+3
Brown.....	2	6	-4	-3	16	9	+12
Doe.....	6	10	0	+1	0	1	0
Total.....	30	45			34	56	+39-1
Average.....	6	9			6.8	11.2	+38
					2.61	3.34	

$$r = \frac{\sum xy}{N \sigma_x \sigma_y} \qquad \sum xy = 38 \qquad \sigma_x = 2.61$$

$$\qquad \qquad \qquad N = 5 \qquad \qquad \qquad \sigma_y = 3.34$$

$$r = \frac{38}{5 \times 2.61 \times 3.34} = \frac{38}{43.6} = .87$$

computation of correlation by the so-called "products-moments" (that is, products of deviations) method. The first part of the computation is identical with that previously described in connection with standard deviation (p. 161). The original scores are given in the first two columns. Conventional procedure calls these original scores X and Y. The average of each column is computed. The third column gives the deviations of each test score from the average test score. Adams's score of 10 is 4 greater than the average of 6, that is, its deviation is +4; Andrews's test score of 7 is 1 above the average, while Briggs's is 1 below, etc. Deviations of criterion scores from the average are computed similarly. The deviations are denoted by x and y. The deviations are now squared and each column averaged. The square roots of these averages give standard deviations of 2.61 and 3.34 respectively. σ_x denotes the standard deviation of the test scores and σ_y the standard deviation of the criterion. The next step is to take the product of the deviations. For instance, Adams's deviation of +4 in the test is to be multiplied by the corresponding deviation of +6 in the criterion, giving a product of 24. Andrews's figures are +1 and -1 respectively and the product is -1. These products are then

algebraically totaled, giving 38, and we are ready to substitute in the formula. $\sum xy$ denotes the sum of the products of the deviations of the variables — in this case 38; N denotes the number of individuals, and σ_x and σ_y the standard deviations of the two variables as above described. Substituting in the formula the coefficient of .87 is obtained. This has taken into account the actual magnitude of the original measures and not merely their relative standing. It is to be noted that if a given individual's measures are both above or both below the average, the product of the deviations will be plus and the numerator of the fraction in the formula large, while if one is above the average and the other below, the product will be negative and the sum of the products will be somewhat decreased and the coefficient lowered. This type of coefficient gives probably the best indication of the relation between the two measures and is very widely used in all the most careful statistical work.

The foregoing example may be misleading as to the simplicity of the arithmetical work involved. When there are 50 or 100 individuals in the correlation, the work of computation becomes very considerable. In such cases there are, however, various short-cut procedures which decrease very appreciably the routine work. It is beyond the scope of the present discussion to describe these. Some involve grouping the data into classes rather than using the original scores, some are designed to obviate much of the multiplication involved in getting the xy term; some obviate the necessity of computing deviations at all, and others are especially devised for use with some particular type of computing machine. Some of these methods are discussed in current statistical works. (498, 603.)

APPENDIX II

COMBINING RANKINGS WITH INCOMPLETE DATA

THE need was mentioned in Chapter VI of a technique for combining incomplete rankings. If, for instance, several foremen independently rank a group of workers as to their ability in the job, but some foremen rank all the workers and others rank only a limited number, it is inadvisable to average the ranks assigned each worker in order to determine his general standing. A rank near the bottom of the scale made by a foreman who estimates all the workers contributes a more severe penalty to the average than does a rank near the bottom of the scale by a foreman who estimates a smaller number. (Cf. p. 159.) This same problem may arise in rating scale procedure, in evaluating application blanks, recommendations, letters of application, or the results of employment interviews, or in any other situation where a number of judges make an estimate of something and pool their results.

Various methods for combining these incomplete rankings have been suggested. (Cf. 599, 299.) The one to be described is probably as simple and satisfactory as any. (473.) It assumes that the ranks assigned by any foreman or other judge conform to a normal frequency curve. When dealing with quantitative ratings rather than ranks (cf. Chapter VI), a similar assumption was made, and each estimate by a given foreman was converted into its deviation from the average estimate made by that foreman divided by the standard deviation of his estimates. Such converted estimates made by different foremen were then comparable because they were all located on normal frequency curves and the properties of such curves are universal.

These same principles are applicable when the estimates are in the form of ranks. Suppose five workers have been ranked by a foreman, and it is desired to convert these ranks into terms of standard deviation (σ). By consulting tables (derived originally by calculus) we find that in a normal frequency curve the average of the highest 20 per cent of the individuals is theoretically 1.40 σ above the average score or estimate; the average of the next 20 per cent is .53 σ above the average, while the average of the middle 20 per cent coincides with the average of all, so its deviation is 0 σ . Similarly, the average of the next 20 per cent of the individuals is .53 σ below the average or $-.53 \sigma$, while the average of the lowest 20 per cent is -1.40σ . We may then replace the original ranks by these converted figures, thus expressing them in terms of standard deviation and making all such ranks comparable regardless of the number of workers that is ranked. A table

may be derived based on the above considerations which gives similar figures for converting rankings that involve different numbers. A portion of such a table is reproduced in Table LXXIII. It could be carried out to include any desired number of individuals.

TABLE LXXIII. FOR CONVERTING RANKS INTO TERMS OF STANDARD DEVIATIONS ¹

RANK	NUMBER OF INDIVIDUALS RANKED									
	2	3	4	5	6	7	8	9	10	
1	.80	1.10	1.27	1.40	1.49	1.59	1.67	1.71	1.76	
2	-.80	0	.32	.53	.68	.81	.91	.98	1.04	
3		-1.10	-.32	0	.22	.37	.59	.60	.68	
4			-1.27	-.53	-.22	0	.18	.29	.39	
5				-1.40	-.68	-.37	-.18	0	.13	
6					-1.49	-.81	-.50	-.29	-.13	
7						-1.59	-.91	-.60	-.39	
8							-1.67	-.98	-.68	
9								-1.71	-1.04	
10									-1.76	

¹ After Ream.

In using the table, if a given foreman has ranked five men, we look in the column headed 5. To the man whom the foreman ranked first we give a value of 1.40, to the man whom the foreman ranked second a value of .53, and so on. Suppose the next foreman has ranked only four men. We then use the column headed 4 and give his first man a value of 1.27. To illustrate the procedure a simple example is given in Table LXXIV. The left portion of the table gives the original ranks assigned to the workers by three foremen. The third foreman, however, ranked only four of the workers. The next portion of the table gives these same ranks converted into terms of standard deviation by consulting the previous table. The last column gives for each man the average of his converted ranks. It may be noted that if the original ranks had been averaged without conversion Brown and Doe would have the same average of four. With the converted ranks, however, Brown is somewhat inferior to Doe.

APPENDIX

519

TABLE LXXIV. ILLUSTRATING COMBINATION OF INCOMPLETE RANKS BY CONVERSION INTO TERMS OF STANDARD DEVIATION

	ORIGINAL RANKS			CONVERTED RANKS			
	First foreman	Second foreman	Third foreman	First foreman	Second foreman	Third foreman	Average of converted ranks
Adams	1	2	1	1.40	.53	1.27	1.07
Andrews	3	1	2	0	1.40	.32	.57
Briggs	2	4	4	.53	-.53	-1.27	-.42
Brown	4	5	3	-.53	-1.40	-.32	-.75
Doe	5	3		-1.40	0		-.70

Other schemes for handling this sort of data are available. One of them provides a table similar to the preceding, but the results are in terms of something analogous to percentile scores. This obviates the use of decimal points and minus signs. (225.) The method above described, however, is typical of those used for combining incomplete ranks.

APPENDIX III

ILLUSTRATING THE DERIVATION OF A REGRESSION EQUATION

In Chapter IX we saw the importance of partial correlation and the regression equation for weighting a number of tests in order to get the best possible prediction of vocational aptitude. A brief indication of the technique was given in that connection. In the present section a regression equation in four variables is worked out in detail by way of illustration of the process. The equation is that already mentioned on p. 242 for predicting ability at finishing tires on the basis of three tests — cancelling adjacent pairs of numbers whose sum is 10, finding consecutive numbers arranged irregularly in a square, and simple visual reaction time. These tests in the previous connection were numbered 3, 5, and 7. In the present section, in the interest of simplicity, they will be renumbered respectively 2, 3, and 4.

The original correlations of the tests with the criterion and with each other (cf. Table XXII) are as follows, where 1 is the criterion and 2, 3, and 4 are the tests just mentioned. For instance, r_{12} — that is, the correlation

	2	3	4
1	.51	.49	-.41
2		.66	-.24
3			-.22

between the criterion and test 2 — is .51, while r_{13} is .49 and r_{14} is -.22. From these correlations, which are termed “zero order” coefficients, it is possible to derive any coefficient of the “first order” like $r_{12.3}$, which means the correlation between the criterion and test 2 with test 3 kept constant. Such coefficients are called “first order” because there is one secondary subscript, that is, one subscript after the point or one variable that is kept constant. There are always two primary subscripts before the point. From coefficients of the first order it is possible to derive those of the second order like $r_{12.34}$, which have two secondary subscripts or two variables that are kept constant. From these we may derive third order coefficients such as $r_{12.345}$, etc.

The formula used in all such computations is of the form:

$$r_{12-3} = \frac{r_{12} - r_{13} r_{23}}{\sqrt{1 - r_{13}^2} \sqrt{1 - r_{23}^2}}$$

The subscripts of the first term in the numerator, it is to be noted, are the same as the primary subscripts of the coefficient for which we are solving. (12.) The second term in the numerator is the product of two factors. Each of these has a subscript (3) the same as the secondary subscript of the coefficient for which we are solving. The primary subscripts of this coefficient for which we are solving appear also in this second term, one in each factor. Putting it in another way, we obtain the subscripts of this second term by combining the secondary subscript of the coefficient for which we are solving (3) first with one of its primaries (1) and then with the other (2). The two subscripts that appear in the denominator of the formula are identical with those in the second term of the numerator.

If we substitute in this formula the zero order coefficients given in the table above we have:

$$\begin{aligned} r_{12-3} &= \frac{.51 - .49 \times .66}{\sqrt{1 - .49^2} \sqrt{1 - .66^2}} = \frac{.51 - .324}{\sqrt{.759} \sqrt{.564}} \\ &= \frac{.186}{.87 \times .75} = \frac{.186}{.653} = .28 \end{aligned}$$

This tells us that the correlation between the criterion and test 2 would be .28 if we had persons with identical ability in test 3. In exactly the same way the other coefficients of the first order may be derived. For instance:

$$r_{24-3} = \frac{r_{24} - r_{23} r_{34}}{\sqrt{1 - r_{23}^2} \sqrt{1 - r_{34}^2}}$$

Here again it is to be noted that the subscripts of the first term in the numerator are the primary subscripts of the coefficient for which we are solving (24), these same primaries appear in the second term — one in each factor — while the secondary subscript (3) appears in both factors and the subscripts in the denominator are the same as those in the second term in the numerator. Substituting the zero order coefficients in this formula:

$$\begin{aligned} r_{24-3} &= \frac{-.24 - .66 \times (-.22)}{\sqrt{1 - .66^2} \sqrt{1 - (-.22)^2}} = \frac{-.24 - (-.145)}{\sqrt{.564} \sqrt{.952}} \\ &= \frac{-.095}{.751 \times .975} = \frac{-.095}{.732} = -.13 \end{aligned}$$

In this same manner all the coefficients of the first order may be computed. In the present problem they are not all necessary, but those that are required for subsequent use are as follows. Their method of derivation is identical with the preceding.

r_{12-2}	.28	r_{14-2}	-.34
r_{12-4}	.47	r_{14-4}	-.36
r_{12-3}	.24	r_{24-2}	-.13
r_{12-1}	.45	r_{24-4}	-.08

From these coefficients of the first order we may now compute those of the second order. The formula is similar in form to the preceding except that we are expressing a coefficient with two secondary subscripts in terms of coefficients with one secondary subscript.

$$r_{14-23} = \frac{r_{14-2} - r_{12-2} r_{24-2}}{\sqrt{1 - r_{12-2}^2} \sqrt{1 - r_{24-2}^2}}$$

The similarity of this formula to the preceding is obvious. The secondary subscript is the same throughout (2). The primary subscripts of the first term in the numerator are the same as the primary of the coefficient for which we are solving (14). The secondary subscript of the coefficient for which we are solving that does not appear as a secondary in the numerator (3) appears in both primaries in the second term of the numerator. The primaries (14) of the coefficient for which we are solving also appear as primaries in the second term in the numerator — one in each factor. The subscripts in the denominator are the same as those in the second term of the numerator. Substituting the proper values in this formula we have:

$$\begin{aligned} r_{14-23} &= \frac{-.34 - .24 \times (-.08)}{\sqrt{1 - .24^2} \sqrt{1 - (-.08)^2}} = \frac{-.34 - (-.019)}{\sqrt{.942} \sqrt{.994}} \\ &= \frac{-.34 + .019}{.971 \times .994} = \frac{-.321}{.968} = -.33 \end{aligned}$$

It is possible to compute this same coefficient by another formula as a check:

$$r_{14-23} = \frac{r_{14-3} - r_{12-3} r_{24-3}}{\sqrt{1 - r_{12-3}^2} \sqrt{1 - r_{24-3}^2}}$$

This conforms to the specifications mentioned in explaining the other formula for r_{14-23} , only it uses a different set of first order coefficients. In this case the secondary subscript that appears throughout is 3 instead of 2. Substituting:

$$r_{14-23} = \frac{-.36 - .28 \times (-.13)}{\sqrt{1 - .28^2} \sqrt{1 - (-.13)^2}} = \frac{-.36 - (-.036)}{\sqrt{.922} \sqrt{.983}}$$

$$= \frac{-.36 + .036}{.960 \times .991} = \frac{-.324}{.951} = -.34$$

This checks approximately with the result of the other formula. The difference of .01 is due to the fact that the coefficients of the first order were computed merely to two decimal places. If further decimals had been retained, the check would theoretically be perfect. If the proper coefficients of the first order are available, it is possible to compute all of those of the second order in two ways to detect any mistakes in the work up to that point. Making similar computation for the other coefficients that are necessary in the present problem we have:

r_{13-24}	.25
r_{12-24}	.23
r_{14-22}	-.33

Before we can compute the regression equation we need to know the average (or mean) of each variable as well as its standard deviation (σ). These figures are as follows:

	Mean	σ
X_1	.00	.72
X_2	28	10
X_3	19	6
X_4	210	15

The notation X_1 indicates original scores in the criterion and they were so arranged that their mean was 0. Their standard deviation was .72. X_2 denotes score in test 2. Its average was 28 and its standard deviation 10, etc. The formula for the regression equation is:

$$x_1 = \frac{\sigma_{1-234}}{\sigma_{2-134}} r_{12-24} x_2 + \frac{\sigma_{1-234}}{\sigma_{3-124}} r_{13-24} x_3 + \frac{\sigma_{1-234}}{\sigma_{4-123}} r_{14-23}$$

The r factors are the partial correlation coefficients computed previously. The x values represent deviations of a particular measure from the mean of that measure, x_2 , for instance, indicating the deviation of a measure from the mean score in test 2. The σ values, which represent the standard deviation of a variable with the effect of the others eliminated, must be computed thus:

$$\sigma_{1-234} = \sigma_1 \sqrt{1 - r_{12}^2} \sqrt{1 - r_{13-2}^2} \sqrt{1 - r_{14-23}^2}$$

$$\sigma_{2-134} = \sigma_2 \sqrt{1 - r_{23}^2} \sqrt{1 - r_{24-3}^2} \sqrt{1 - r_{12-24}^2}$$

$$\sigma_{3-124} = \sigma_3 \sqrt{1 - r_{32}^2} \sqrt{1 - r_{34-2}^2} \sqrt{1 - r_{12-24}^2}$$

$$\sigma_{4-123} = \sigma_4 \sqrt{1 - r_{42}^2} \sqrt{1 - r_{43-2}^2} \sqrt{1 - r_{14-23}^2}$$

The first factor in each product is the ordinary standard deviation of the variable whose number appears as the primary subscript at the left side of the equation. In $\sigma_{1.234}$ the first subscript is of the zero order (12); the next one is of the first order and is obtained by putting the 2 into the secondary and bringing in another primary (3); for the last factor the 3 goes over into the secondary and the remaining one (4) is brought into the primary. It is to be noted that 1 appears as a primary throughout. The other formulæ embody the following principles: The subscript that appears as the primary at the left of the equation remains as a primary throughout. The last factor always has 1 as one of its primaries. Hence the last factor can always be determined by using as primaries 1 and the primary that appears at the left of the equation and using all the other variables as secondaries. The next to the last factor is obtained by shifting one of the secondaries into the primary, displacing the primary that is not to be a primary throughout. For instance, take $\sigma_{4.123}$. The last factor must have 1 as a primary subscript and also 4 which appears at the left of the equation as a primary. The next to the last factor drops 2 from the secondary and puts it in the primary to replace 1. It cannot replace 4 because that must remain as a primary throughout. The first factor now has this secondary 3 dropped and moved into the primary, replacing 2. Substituting the appropriate values in these equations:

$$\sigma_{1.234} = .72\sqrt{1-.51^2}\sqrt{1-.24^2}\sqrt{1-(-.33)^2} = .72 \times .862 \times .971 \times .944 = .573$$

$$\sigma_{2.134} = 10\sqrt{1-.66^2}\sqrt{1-(-.13)^2}\sqrt{1-.25^2} = 10 \times .751 \times .991 \times .968 = 7.15$$

$$\sigma_{3.124} = 6\sqrt{1-.66^2}\sqrt{1-(-.08)^2}\sqrt{1-.23^2} = 6 \times .751 \times .997 \times .973 = 4.38$$

$$\sigma_{4.123} = 15\sqrt{1-(-.22)^2}\sqrt{1-(-.13)^2}\sqrt{1-(-.33)^2} = 15 \times .975 \times .991 \times .944 = 13.68$$

We are now ready to substitute in the regression equation.

$$\begin{aligned} x_1 &= \frac{.573}{7.15} .25 x_2 + \frac{.573}{4.38} .23 x_3 - \frac{.573}{13.68} .33 x_4 \\ &= .02 x_2 + .03 x_3 - .014 x_4 \end{aligned}$$

There is one further step to take before the equation is in its most useful form. As above given, it involves the deviations of the scores from their mean rather than the actual original scores. If it were to be used in this form, it would be necessary to convert each measure into a deviation and substitute in the equation; then, after x_1 had been obtained, to convert it back into terms of actual score. It is better to make a single transformation for the whole equation so that original scores can be substituted in it directly. This can be done by virtue of the fact that a deviation is simply the original score minus the mean, so that $x_1 = X_1 - M_1$, $x_2 = X_2 - M_2$, etc., where x_1 is the deviation of the criterion, X_1 the original score, and M_1 the mean of the criterion scores, and the same meaning is attached to x_2 , the deviation of a score in test 2, etc. The mean scores have been given above so that we may make the following substitutions:

$$\begin{aligned}x_1 &= X_1 - 0 \\x_2 &= X_2 - 28 \\x_3 &= X_3 - 19 \\x_4 &= X_4 - 210\end{aligned}$$

Making this transformation we have:

$$\begin{aligned}X_1 - 0 &= .02 (X_2 - 28) + .03 (X_3 - 19) - .014 (X_4 - 210) \\X_1 &= .02 X_2 + .03 X_3 - .014 X_4 + 1.82.\end{aligned}$$

This is the final form of the regression equation, and if a given applicant has taken the three tests his scores may be substituted in this equation to obtain his most probable score in the criterion. (Cf. p. 238.)

When more than four variables are involved, the labor of computing the coefficients increases, but the procedure above outlined does not have to be followed, for there are various short cuts available. Even so the technique of partial correlation is tedious, but worth while.

No effort has been made in the foregoing to present the theory of partial correlation. This lies beyond the scope of the present work. For a discussion of the theory reference is made to Yule (692); for short cuts in the computation of partial coefficients, to Kelly (272); and for short cuts that obviate the use of certain coefficients, to Rosenow (490 — appendix).

BIBLIOGRAPHY

FOREWORD

THE bibliography does not include references that:

1. Deal with employment problems, but contain no psychology.
2. Deal with general psychology, but have no relation to employment.
3. Describe mental tests unless actually used for employment purposes — with the exception of a few tests that are especially novel.
4. Discuss vocational *guidance* unless vocational *selection* is at least indirectly involved.

It includes a few miscellaneous articles to which reference is made in the text, a few of historical interest, and a number on general statistics. The topic of job analysis has a large literature that almost borders on psychology and some typical references on this borderline are given.

The bibliography is not classified for the reason that so many of the references would have to appear several times. The reader interested in following up a certain topic will find that the chapter on that topic contains bracketed numbers referring to the outstanding titles in the bibliography dealing with that topic.

All available references have been examined personally and evaluated before inclusion. (A few that were not accessible had to be evaluated by the title alone.) In many instances a business article with a psychological title was found to contain no psychology or merely glittering generalities, and was discarded. The author has tried to include no references that would actually waste the time of a reader interested in employment psychology. The bibliography is up to date of February 1, 1926.

In referring to articles the form of citation used by the *Psychological Review* publications has been followed, namely, the year, then the volume in bold-face figures, and then the pages.

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535

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563

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INDEX

- Academic record and vocational success, 372 ff.
Acquaintance as affecting ratings, 360.
Aerial observers, tests for, 207.
Age
 mental differences due to, 179 ff.
 and turnover, 392.
 and vocational aptitude, 390.
"Alpha" test, 53, 91.
Analysis of job preliminary to selecting tests, 190 ff., 226.
Application blank, 386 ff.
Application letter, 401 ff.
Army Alpha test, 53, 91.
Association, tests of, 72.
Astrology, 17.
Attention, tests of, 68.
Attitude
 of subjects, 114.
 of workers and management, 497.
Automobile drivers, tests for, 256, 458, 461.
Automobile mechanics
 occupational description, 479.
 trade test for, 451.
Average deviation, 160.
Aviators, tests for, 54, 208, 245.
- Billers, tests for, 251.
Binet, 49, 69.
Blonde and brunette traits, 38.
Bricklayers, trade test for, 452, 454.
Bureau of Public Personnel Administration, 58, 496.
- Cabinet workers
 trade test for, 451.
 tests for, 251.
Carpenters, trade test for, 453.
Character analysis. *See* Physiognomy.
Civil service, 495.
Clerical workers
 rating scale for, 343.
 tests for, 246, 278.
Clothing operators, intelligence of, 279.
Cooks, trade test for, 452.
Coöperative research, 492.
Correction of ratings, 347.
- Correlation
 interpretation of coefficient, 29, 213.
 methods
 products-moments, 199, 515.
 rank-difference, 198, 511.
 scatter plot, 200.
 procedure, 29.
 test with criterion, 198.
Criteria, combining heterogeneous, 156 ff., 517.
Criterion
 availability of, 142, 174.
 estimates by superiors, 143.
 miscellaneous types, 154 ff.
 need of, 141, 505.
 production figures, 150 ff.
Critical scores
 in intelligence, 283.
 in special capacity tests, 209, 221.
 upper, 291.
- Decision, tests of, 78.
Defined groups, rating by, 334, 422.
Defining traits in rating scale, 326 ff.
Designer in steel, occupational description, 481.
Deviation
 average, 160.
 standard, 161, 164.
Dial machine operators, tests for, 193 ff.
Directions, tests of following, 80.
- Electrician
 storage battery, trade test for, 453.
 wireman, trade test for, 460.
Emotion, tests of, 81.
Employment psychology
 fundamental principle, 5.
 where valuable, 6.
Engineers vs. salesmen, interests of, 308.
Error, standard, 211.
Estimates by superiors as criterion, 143.
Executives
 intelligence of, 279.
 rating scale for, 332, 334, 341.
Experience, previous, 173.
- Feather factory workers, tests for, 252.

- Firemen, tests for, 258.
 Follow-up of tests, 260.
 Fool-proof tests, 195.
- Gold bricks, 14 ff.
 Graphic rating scale, 337 ff., 423.
 Group tests, 103.
 Guessing answer, probability of, 131.
 Gun pointers, tests for, 207.
- Halo effect, 36, 358.
 Height of salesmen, 388.
 Hierarchy of occupations, 265 ff.
 History of vocational psychology, 46 ff.
 Hollerith machine operators, tests for, 251.
 Honesty, tests of, 83.
 Hospital attendants, tests for, 259.
- Incentive in tests, 126, 173.
 Individual differences, interest in, 46.
 Individual tests, 101.
 Information test as measure of interest, 301, 313.
 Ingenuity, tests of, 78.
 Initial success in job prognostic of latter, 383.
 Intelligence
 of departments in an organisation, 273 ff.
 kinds of, 87.
 nature of, 86.
 of occupational groups, 265 ff.
 optimum vs. maximum, 285 ff.
 and physiognomy, 33 ff.
 quotient, 98.
 and stability, 287.
 surveys, 276.
 tests of, 89 ff.
 tests in job analysis, 485.
 and vocational aptitude, 265 ff.
- Interest
 and ability, 10, 296.
 evaluation of measures of, 307.
 measurement of, 298 ff.
 permanence of, 295.
 questionnaire, 298.
- Interview
 employment, 414 ff.
 giving information in, 424.
 improvements in technique, 418.
 for job analysis, 470.
 unreliability of, 415.
- Interviewer
 for job analysis, 471.
- Interviewer, rating scale for use of, 419.
- Janitors, tests for, 259.
 Job analysis, 193, 467 ff.
 interview, 470.
 interviewer, 471.
 need, 468.
 purpose, 467.
 work sheet, 475.
- Journalists, tests for, 260.
- Laboratory for employment tests, 196, 506.
 Lathe operators
 tests for, 208.
 trade tests for, 440.
 Learning, tests of, 70.
 Letter of application, 401 ff.
 Linear scale criterion, 146.
- Machinists, trade test for, 454.
 Maladjusted worker, social implications, 10, 507.
 Man-to-man rating scale, 329 ff., 420.
 Marital status of salesmen, 394.
 Mechanical aptitude, tests of, 94 ff.
 Mechanical interests vs. social, 312.
 Memory, tests of, 75.
 Mental components of occupation, tests for, 226 ff.
 Mental tests. *See* Tests.
 Motor control, tests of, 64.
 Motormen, tests for, 50, 205, 208, 255.
 Multiple correlation, coefficient of, 239 ff.
- National Research Council, 58, 495.
 Normal frequency curve, 162 ff.
- Objective score, 196.
 Objective traits vs. subjective, 356.
 Occupational description, 479. *See also*
 Job analysis.
 Occupational groups, intelligence of, 265 ff.
 Office boys, intelligence of, 278.
 Officers' rating scale, 330.
 Omnibus test, 96.
 Orientation of psychologist taking up
 employment work, 188.
- Painters, trade test for, 451.
 Partial correlation, 55, 135, 233 ff., 520 ff.
 Pattern makers, trade test for, 459.
 Percentile scores, 97, 266.

- Personal history blank, 386.
 Personal history factors in vocational prediction, 386 ff., 397.
 Personnel Research Federation, 58, 496.
 Phrenology, 21 ff.
 Physiognomy
 commercial systems of, 27, 42.
 experimental study of, 28 ff.
 popular belief in, 25.
 Policemen, tests for, 259.
 Previous experience and vocational prediction, 395.
 Probability of vocational success, prediction of, 210 ff.
 Production figures as criterion, 150.
 Psychological Corporation, 58, 496.
 Public speakers, tests for, 260.

 Quartile, 266.
 Questionnaire
 interest, 298.
 job analysis, 470.

 Railway postal clerks, trade test for, 457.
 Ranking workers in criterion, 145.
 Ranks, averaging, 517.
 Rapport, 114, 186, 419.
 Rating scale
 interviewer's, 419.
 in job analysis, 484.
 methods
 defined groups, 334 ff., 422.
 graphic, 337 ff., 423.
 man-to-man, 329 ff., 420.
 officers', 56.
 purpose, 317.
 Ratings, correction of, 347.
 Reaction time, tests of, 72.
 Reasoning, tests of, 77.
 Recommendation blank, 413.
 Recommendations, 409 ff.
 Regression equation, 204, 238 ff., 520 ff.
 Reliability
 of criterion, 149.
 of letters of application, 402.
 of rating scale, 345 ff.
 of tests, 136, 197.

 Salesmen
 intelligence of, 274, 280.
 interest tests for, 314.
 tests for, 248, 457.
 vs. engineers, interests of, 308.
 Sampling of subjects, 176 ff.
- School marks and vocational success, 372 ff.
 Self-estimates, 408.
 Sensory capacity, tests of, 67.
 Sensory defects, 182.
 Sexes, intelligence of, in office, 276.
 Sex of subjects, 178.
 Silk mill operatives, intelligence of, 282.
 Social interests vs. mechanical, 312.
 Space perception, tests of, 74.
 Speed vs. accuracy score, 130.
 Spiritualism, 18.
 Standard deviation, 161, 164.
 Standard error of estimate, 211.
 Stenographers
 tests for, 250.
 trade tests for, 456.
 Subjective traits vs. objective, 356.
 Subjects used in evaluating tests, 172 ff.

 Telegraphers, tests for, 208, 243, 254.
 Telepathy, 19.
 Telephone operators, tests for, 50, 208, 248, 253.
 Temperament, tests of, 84.
 Tests
 administration of, 101 ff.
 capacity vs. proficiency, 62, 431.
 early development of, 48.
 general nature of, 60.
 general vs. special capacity, 62.
 incentive, 126.
 instructions, 120 ff.
 in job analysis, 485.
 limitation on response, 111 ff.
 material
 alternative, 119.
 arrangement, 117.
 difficulty, 115 ff.
 method of response
 oral, 106.
 performance, 108.
 proficiency vs. capacity, 62, 431.
 rapport, 114.
 reliability, 136.
 scoring, 127 ff.
 sensitivity, 119.
 special vs. general capacity, 62.
 time limit, 111.
 type of response, 109 ff.
 work limit, 112.
 written method, 107.
 Time clerks, trade test for, 455.
 Tire finishers, tests for, 227.
 Total mental situation, tests for, 194 ff.

Trade test, 55, 431 ff.
 calibration, 446.
 in job analysis, 485.
 kinds, 434.
 methods of developing, 438 ff.
 need, 431.
 oral, 434, 450.
 performance, 435, 459.
 picture, 434, 453.
 written, 435, 454.
 Training of raters, 362.
 Traits
 defining in rating scale, 326 ff.
 selection of for rating scale, 320 ff.
 Typesetters, tests for, 253.
 Typists, tests for, 249.

Validity
 of letters of application, 405.
 of ratings, 353.
 of tests, 198.
 Vocational guidance vs. vocational selection, 8.
 War, psychology in the, 51 ff.
 Weavers, tests for, 252.
 Weighting tests, 55, 231.
 Weighting traits in rating scale, 323.
 Wireman, trade test for, 460.
 Work sheet for job analysis, 475.
 Worker in his work unit, 9.