

**STATISTICAL ANALYSIS**  
*for Students in*  
**PSYCHOLOGY and EDUCATION**

# STATISTICAL ANALYSIS

*for Students in*

*PSYCHOLOGY and EDUCATION*

ALLEN L. EDWARDS

*Associate Professor of Psychology*

*University of Washington*

RINEHART & COMPANY, INC.

*Publishers*

*New York*

*First Printing*    *May, 1946*  
*Second Printing*    *July, 1947*  
*Third Printing*    *November, 1948*  
*Fourth Printing*    *April, 1950*  
*Fifth Printing*    *January, 1951 .*

**COPYRIGHT, 1946, BY ALLEN L. EDWARDS**  
**PRINTED IN THE UNITED STATES OF AMERICA**  
**BY VAIL-BALLOU PRESS, INC., BINGHAMTON, N.Y.**  
**ALL RIGHTS RESERVED**

## PREFACE

Despite the recognition accorded statistical methods by active workers in psychology, education, and the social sciences, the average undergraduate major in these fields often regards the customary course in statistics as dull and uninteresting. And there is no denying the fact that his actual experience in the course may serve to bolster rather than to change his original opinions. This is apt to be true, I believe, when the instructor assumes a degree of mathematical training, however elementary, which the undergraduate major in the social sciences fails to have. Even when the student has had such training, its value may be largely nullified by the time interval which separates it from the course in statistics.

Another factor producing lack of interest, I believe, is the stress which is often placed upon long and involved problems which are essentially exercises in multiplication, subtraction, division, and addition. The student often regards these problems—and perhaps rightfully so—as so much “busy-work.” Such problems subtract from the time which the student feels could be more profitably spent in learning to appreciate the use and value of statistical techniques in his chosen field.

Under these conditions the student’s memories of statistics are memories of laborious computations and mysterious formulas, and it is these memories which he passes on to next semester’s class.

This text attempts to break the vicious circle. Little stress is placed upon calculative ability. I have tried in most cases to minimize the labor of computations by the use of illustrations and problems constructed with that end in view. In

addition, coding techniques for reducing the size of numbers are introduced early and stressed throughout. I would not change this emphasis in the *introductory* course even if a sufficient number of calculating machines were on hand to make one available to each student. In my opinion, it is not the function of this first course in statistics to train computers and machine operators. Let the beginning student get a picture of the use to which statistical techniques can be put in answering questions in his field of specialization. Let him see that statistical techniques are tools, instruments. Let him understand the simple formulas and the meaning of various statistics. He can then learn machine techniques of calculation if he ever needs to handle large masses of data.

To avoid assumptions concerning the student's mathematical training, a review of elementary principles has been included. An understanding of these should enable the student to follow subsequent developments. Stress on this section of the text will assist greatly in minimizing a major source of confusion for most students. Some theory and derivations are introduced throughout the text, but nothing is presented, I feel, which is beyond the comprehension of the nonmathematically trained student, if he is assisted by the instructor. In the last analysis, I am convinced that statistics, unlike many other college courses, must be taught, not lectured.

The content of the book follows what I hope is a pedagogical as well as a logical order. Correlation is introduced earlier than in most texts because it has been my experience that students follow this development quite easily and that interest and motivation are increased because they see in correlation a technique of practical use. A good case could be made for introducing correlation by way of regression. But since regression is most often used in psychology and education for prediction, it is reserved for a later chapter on this topic.

Tests of significance have been stressed. One chapter has been devoted to the "*t* test," two to the "*F* test," and one

to the " $\chi^2$  test." It has been my experience again that students are able to relate these tests to problems in their own fields and are consequently interested in them. It is not uncommon to hear students exclaim with some degree of elation that for the first time they have some idea of what is meant by the frequent references to "critical ratios" and "significant differences" that they have encountered in their textbooks in other courses.

In discussing tests of significance, I have emphasized small sample theory since, whether the traditional attitude approves or not, more and more research as published in psychological and educational journals is being evaluated by small sample techniques. This does not mean, however, that there is a rigid division between large and small sample theory, but rather, as Kenney has said, that the "continuity between large and small sample theory is an essential part of the newer attitude" (53, II, 123).

There are omissions as well as additions in this text. The reader will look in vain for the customary treatments of partial and multiple correlation. They have been omitted because I have searched without much success to find many applications of these statistical techniques in the literature. That they have their uses as well as their limitations is fully recognized, but I feel that they may be developed more profitably, as far as the student is concerned, in advanced courses, where time spent on these topics will not be at the expense of statistical techniques which are more commonly in use. I have no excuse to offer for certain other omissions—for example, the customary chapter on the reliability and validity of tests, and the usual extended treatment of centiles and scaling techniques—other than the fact that I do not feel that they fall within the general orientation of the rest of the book and that these are problems which might well be taken up in a course in tests and measurements.

I have, as any student must, a desire to acknowledge my indebtedness to various individuals. Professor Harold Edgerton of Ohio State University first impressed upon me the

desirability of knowing more about statistical methods and theory. Professor Lloyd G. Humphreys of Northwestern University aroused my interest in small sample theory in 1939 and gave freely of his time in discussions of the subject. It is a pleasure also to acknowledge that I owe much to the various publications of Professor George W. Snedecor, Professor Helen M. Walker, Professor R. A. Fisher, and Professor C. C. Peters. In addition, Professor Walker and Professor Peters were kind enough to clarify, in personal communications, certain points of interpretation.

To Professors Herbert S. Conrad and Robert J. Wherry and Dr. Steuart H. Britt, who read a draft of the manuscript in its entirety, and to Dr. Edward E. Cureton, who read Chapters 10 and 11, and Professor Quinn McNemar, who read Chapter 14, a mere acknowledgment is hardly sufficient reward for the careful and painstaking service which they have rendered. I can only say that their comments proved invaluable in guiding me when I started to work on the revision of the original draft. The present text owes much to their efforts.

I am indebted to Professor R. A. Fisher, also to Messrs. Oliver & Boyd Ltd. of Edinburgh, for permission to reprint Tables C, D, and H, from their book *Statistical Methods for Research Workers*. Professors Peters and Van Voorhis and their publishers, The McGraw-Hill Book Company, kindly granted permission to reproduce Table F from their book *Statistical Procedures and Their Mathematical Bases*. Table E has been reproduced from Professor Snedecor's book *Statistical Methods* by permission of the author and his publisher, the Iowa State College Press. Additional values of  $t$  at the 1 and the 5 per cent levels were also taken from Professor Snedecor's book by permission. Table G was prepared by J. G. Peatman and R. Schafer and is reproduced by their permission and by the consent of Carl Murchison from the *Journal of Psychology*, where it first appeared. Other acknowledgments are made at various points throughout the text.

*Preface*

ix

Phyllis Covington and Jacqueline Charlton shared the major responsibility of typing the manuscript. Sidney S. Culbert assisted in the reading and proofing of the typed copy and Grace French in the checking of various computations. I am grateful to all of them for their assistance.

Finally, I owe a very special debt to Professor W. R. Clark of the University of Maryland, who encouraged me in my varied efforts to arouse student interest in statistical methods, and to my students both at the University of Maryland and at the University of Washington who responded to these efforts.

A. L. E.

*Seattle, Washington*  
*April, 1946*



## CONTENTS

	PAGE
PREFACE	v
CHAPTER	
1. INTRODUCTION	3
1. The text and the student	3
a. Previous mathematical training	3
b. Examples and problems	4
c. Use of tables	4
d. Symbols	5
e. Daily preparation	6
f. Empirical approach	6
2. Statistical terms and statements	7
a. Averages	7
b. Variability	8
c. Relationships	9
3. Functions of statistical methods	10
a. Precise description	10
b. Study of relationships	10
c. Formulation of experimental designs	11
d. Statistical inference	13
e. Prediction	13
2. SURVEY OF RULES AND PRINCIPLES	15
1. Fractions	15
2. Decimals	16
3. Proportions and per cents	17
4. Positive and negative numbers	18
5. Numbers in a series	21

CHAPTER	PAGE
6. Squares and square roots	21
a. Finding squares and square roots	21
b. Locating the decimal point	22
c. Squares and square roots of numbers less than 1	23
7. Summation	23
8. Simple equations	25
3. MEASURES OF CENTRAL TENDENCY AND VARIABILITY	30
1. An experiment on retention	31
2. The range as a measure of variation	31
3. The mean as a measure of concentration	34
4. Some basic symbols	34
5. The average deviation as a measure of varia- tion	36
6. The variance and standard deviation	38
7. The normal distribution curve	39
8. The median as a measure of central tendency	41
9. The semi-interquartile range	45
10. Centiles	45
11. Standard scores	47
12. Other measures of central tendency and vari- ability	49
13. Samples and statistics	50
4. SIMPLIFYING STATISTICAL COMPUTA- TIONS	54
1. The approximate nature of measurements	54
a. Significant figures	55
b. Common practice in reporting statistics	56
c. Rounding numbers	57
2. Coding by subtraction	58
a. The sum of scores	58
b. The sum of squares	60

## Contents

xiii

CHAPTER	PAGE
3. Coding by division	63
a. The sum of scores	63
b. The sum of squares	65
4. Summary of "coding formulas"	66
5. Grouping measures into classes	67
a. The number of intervals	68
b. Size of the class interval	68
c. Limits of the intervals	69
d. Tallying the scores	70
e. Assumptions concerning grouped scores	70
f. Calculation of the mean and sum of squares	72
g. The "Charlier checks"	74
h. Calculation of the median	75
6. Summary of steps in coding	75
5. THE PRODUCT-MOMENT CORRELATION COEFFICIENT	79
1. The coefficient of correlation	80
a. A perfect positive correlation	80
b. A perfect negative correlation	83
c. A high positive correlation	84
d. A high negative correlation	85
e. A low correlation	86
2. Basic formulas for $r$	87
a. Standard deviations	87
b. Sum of squares method	88
c. Correlation using original measures	90
d. The difference method for $\Sigma xy$	91
e. Correlation using coded scores	91
3. Correlation computed from a scatter diagram	94
a. Preparing the scatter diagram	94
b. The sum of scores and sum of squares	96
c. The sum of cross-products	97
4. Interpretation of correlation	99
a. The range of the correlation coefficient	99

CHAPTER		PAGE
	b. The coefficient of determination	99
	c. Common elements	100
	5. Purpose for which $r$ is to be used	101
	6. Errors of measurement and correlation	102
<b>6.</b>	<b>THE CORRELATION RATIO AND OTHER MEASURES OF ASSOCIATION</b>	<b>106</b>
	1. The correlation ratio	107
	a. A simple method of computation	109
	b. Summary of steps in computing $\eta^2$	110
	2. Biserial correlation	112
	3. Tetrachoric correlation	116
	4. The phi coefficient	117
	a. The $\phi$ coefficient and true dichotomies	118
	b. The assumption of continuity	119
	c. The $\phi$ coefficient and tetrachoric $r$	121
	5. The contingency coefficient	122
	6. Rank-difference coefficient	123
	7. Multiple and partial correlation	125
	8. Summary of measures of association	127
<b>7.</b>	<b>PROBABILITY AND FREQUENCY DISTRIBUTIONS</b>	<b>132</b>
	1. Meaning of probability	133
	2. Combinations	136
	3. Binomial distribution	137
	4. The normal distribution curve	141
	5. The use of Table B	144
	6. Pragmatic considerations	146
	7. Skewed distributions	148
<b>8.</b>	<b>SAMPLING DISTRIBUTIONS</b>	<b>151</b>
	1. Samples and populations	151
	2. Sampling distributions	153
	3. Standard error of the mean	157

## Contents

CHAPTER	PAGE
4. Large samples and the normal curve table	159
5. The concept of fiducial limits	162
6. Small samples and the table of $t$	166
7. Other standard error formulas	168
a. Standard error of the standard deviation	168
b. Standard error of a proportion	168
c. Standard error of a per cent or frequency	170
<b>9. THE <math>t</math> TEST OF SIGNIFICANCE</b>	<b>172</b>
1. An experiment involving paired observations	172
a. Standard error of a mean difference	174
b. Testing the null hypothesis	176
c. Establishing the fiducial limits	177
d. Another method for computing the standard error	178
2. Experiments involving matched groups	180
3. Experiments involving independent groups	181
4. The advantages of pairing observations	183
5. Testing the significance of a proportion	184
6. Testing the significance of $r$	185
a. The direct computation of $t$	187
b. The use of Table D	188
<b>10. ANALYSIS OF VARIANCE: INDEPENDENT GROUPS</b>	<b>192</b>
1. Nature of analysis of variance	192
a. The total sum of squares	194
b. The sum of squares within groups	195
c. The sum of squares between groups	195
d. Generalized formula for $r$ groups	196
e. The variance ratio	198
2. A comparison of $F$ and $t$ in the case of two groups	199
3. The comparison of three groups	202
a. The total sum of squares	202

CHAPTER		PAGE
	b. The sum of squares between groups	203
	c. The sum of squares within groups	204
	d. The variance ratio	205
	4. A more complex analysis	207
<b>11.</b>	<b>ANALYSIS OF VARIANCE: MATCHED GROUPS</b>	<b>217</b>
	1. Analysis of variance of two matched groups	218
	2. Analysis of variance of several matched groups	225
	3. Correlation ratio and analysis of variance	232
	a. The correlation ratio without bias	232
	b. Tables of epsilon-square	233
	c. Epsilon-square and analysis of variance	234
	4. A test of rectilinear relationship	237
<b>12.</b>	<b>THE <math>\chi^2</math> TEST OF SIGNIFICANCE</b>	<b>239</b>
	1. Simple applications of $\chi^2$	239
	a. Observed and expected frequencies	239
	b. Testing a 50 : 50 hypothesis	241
	c. Testing any a priori hypothesis	243
	d. $\chi^2$ calculated from per cents	244
	e. $\chi^2$ applied to more than two categories	245
	2. $\chi^2$ applied to two samples	246
	3. $\chi^2$ applied to more than two groups	250
	4. Testing "goodness of fit"	252
	5. $\chi^2$ and small frequencies	253
	6. $\chi^2$ and the $\phi$ coefficient	254
<b>13.</b>	<b>PREDICTIONS AND THE EVALUATION OF PREDICTIONS</b>	<b>258</b>
	1. Predicting simple characteristics	258
	2. Predicting measurements	261
	a. The regression line	262
	b. The regression coefficient	264
	c. The regression equation	265

## Contents

xvii

CHAPTER	PAGE
d. Regression and correlation coefficients	265
e. The standard error of estimate	267
f. The index of forecasting efficiency	269
g. Predicting in the opposite direction	269
h. Coding and regression coefficients	270
3. Predicting from nonrectilinear relationships	270
14. RESEARCH AND EXPERIMENTATION	277
1. Interpretation of tests of significance	279
2. Samples and research	282
3. Size of the sample	287
4. Control groups	288
a. Control by random selection	289
b. Control by matching individuals	291
c. Control by matching groups	294
d. Single group serving as its own control	294
5. The <i>t</i> test and the assumption of homogeneity of variances	295
6. Additional problems in experimental design	299

## BIBLIOGRAPHY

## APPENDIX

TABLE A. SQUARES AND SQUARE ROOTS OF NUMBERS FROM 1 TO 1,000	307
TABLE B. AREAS AND ORDINATES OF THE NORMAL CURVE IN TERMS OF $x/\sigma$	320
TABLE C. VALUES OF <i>t</i> AT THE 5% AND 1% LEVELS OF SIGNIFICANCE	330
TABLE D. VALUES OF <i>r</i> AT THE 5% AND 1% LEVELS OF SIGNIFICANCE	331
TABLE E. VALUES OF <i>F</i> AT THE 5% AND 1% LEVELS OF SIGNIFICANCE	332
TABLE F. VALUES OF $\epsilon^2$ AT THE 5% AND 1% LEVELS OF SIGNIFICANCE	336
TABLE G. TABLE OF RANDOM NUMBERS	340

<small>TABLE</small>	<small>PAGE</small>
TABLE H. TABLE OF $\chi^2$	342
ANSWERS TO EXAMPLES	343
INDEX OF AUTHORS	353
INDEX OF SUBJECTS	355



## AUTHOR INDEX

- Allport, G. W., 278, 300  
 Anastasi, A., 9, 300  
 Armitt, F. M., 279, 302
- Baker, K. H., 173, 300  
 Bancroft, T. A., 280  
 Barker, R., 12, 277, 300  
 Baxter, B., 232, 300  
 Blakemore, A. M., 129, 302  
 Brownman, D. E., 277, 300
- Camp, B. H., 120, 121  
 Cantril, H., 305  
 Chave, E. J., 271, 305  
 Chesire, L., 117, 300  
 Clark, E. L., 9, 302  
 Clopper, C. J., 170  
 Cochran, W. G., 297  
 Cox, G. M., 297  
 Cureton, E. E., 193  
 Curtis, J. W., 94, 300
- Dallenbach, K. M., 31, 303  
 Dembo, T., 12, 277, 300  
 Dollard, J., 79, 277, 300  
 Doob, L. W., 79, 277, 300  
 Dorcus, R. M., 274, 300  
 Dunlap, J. W., 232, 300
- Edwards, A. L., 12, 277, 278, 300, 301  
 Enlow, E. R., 301  
 Ezekiel, M., 301
- Fisher, R. A., 165, 166, 186, 188, 201,  
 202, 232, 280, 281, 289, 299,  
 301, 330, 331, 340  
 Fosdick, S. J., 124, 301  
 Franklin, M., 191, 303
- Gallup, G. H., 152, 283, 301  
 Galton, F., 262  
 Garrett, H. E., 121, 122, 232, 302  
 Garrett, W. S., 277, 302  
 Gilliland, A. R., 9, 302
- Gossett, W. S., 166  
 Goulden, C. H., 167, 232, 253, 299,  
 302  
 Grant, D. A., 232, 302  
 Greene, E. B., 14, 102, 302  
 Guilford, J. P., 14, 123, 126, 179, 253,  
 302  
 Guthrie, E. R., 278, 302
- Hartmann, G. W., 301  
 Hay, E. N., 129, 302  
 Holman, L. J., 302  
 Horst, P., 258, 302  
 Hull, C. L., 278, 302  
 Hurlock, E. B., 277, 302
- Irwin, F. W., 279, 302
- Jackson, R. W. B., 166, 232, 302  
 Jenkins, J. G., 31, 303  
 Jones, M. C., 278, 303
- Kellar, B., 238, 303  
 Kelley, T. L., 123, 232, 303  
 Kendall, M. G., 123, 306  
 Kenney, J. F., 134, 149, 153, 160,  
 232, 253, 303  
 Kenney, K. C., 301  
 Klineberg, O., 190, 303  
 Koffka, K., 278, 303  
 Krathwohl, W. C., 275, 303  
 Kuo, Z. Y., 256, 303
- Lewin, K., 12, 277, 278, 300, 303  
 Lewis, H. B., 191, 303  
 Likert, R., 103, 303  
 Lindquist, E. F., 126, 130, 157, 186,  
 193, 232, 253, 299, 303  
 Lo, C. F., 131, 304  
 Ludgate, K. E., 277, 304  
 Lynd, R. S., 277, 304
- MacKinnon, D. W., 277, 304  
 McNemar, Q., 180, 181, 279, 281,  
 286, 287, 288, 293, 304

- Miller, N. E., 79, 277, 300  
 Mowrer, O. H., 79, 277, 300  
 Murray, H. A., 304  
  
 Newcomb, T. M., 274, 301, 304  
  
 Odell, C. W., 304  
  
 Paterson, D. G., 277, 304  
 Pearson, E. S., 170  
 Pearson, K., 106, 120, 125, 127, 128  
 Peatman, J. G., 289, 304, 341  
 Peters, C. C., 4, 113; 126, 127, 130,  
 149, 157, 168, 232, 235, 236, 237,  
 252, 288, 293, 299, 304, 336  
 Peterson, R. C., 11, 278, 304  
  
 Rae, S. F., 152, 301  
 Remmers, H. H., 303  
 Rethlingshafer, D., 278, 304  
 Richardson, M. W., 116  
 Rider, P. R., 253, 304  
 Rogers, C., 278, 304  
 Rosenthal, S. P., 278, 304  
 Rosenzweig, S., 257, 304  
  
 Saffir, M., 117, 300  
 Schafer, R., 289, 304, 341  
 Sears, R. R., 79, 277, 278, 300, 304  
 Shaffer, L. F., 104, 305  
 Shen, E., 232, 305  
 Simon, C. W., 279, 302  
 Skeels, H. M., 278, 305  
  
 Snedecor, G. W., 56, 101, 186, 187,  
 193, 222, 232, 244, 253, 284, 296,  
 299, 305, 330, 331, 332  
 Sorenson, H., 305  
 Stalnaker, J. M., 116  
 Stock, J. S., 50, 51, 286, 305  
  
 Thurstone, L. L., 11, 58, 61, 117, 271,  
 278, 300, 304, 305  
 Tippett, L. H. C., 149, 165, 168, 199,  
 232, 253, 297, 299, 305  
 Tolman, E. C., 278, 305  
 Treloar, A. E., 305  
  
 Upedegraff, R., 278, 305  
  
 Van Voorhis, W. R., 4, 113, 126, 127,  
 130, 149, 157, 168, 235, 236, 237,  
 252, 288, 293, 299, 304, 336  
  
 Walker, H. M., 166, 167, 179, 180,  
 181, 232, 281, 305  
 Watson, K. B., 189, 305  
 Wellman, B. L., 278, 305  
 Wilks, S. S., 180, 306  
 Williams, H. M., 278, 305  
 Wolfe, D., 277, 306  
 Wright, H. F., 279, 306  
  
 Yates, F., 289, 301  
 Yule, G. U., 123, 306  
  
 Zubin, J., 232, 302

## SUBJECT INDEX

- Abcissa**, 81
- Analysis of variance**, 192-231  
of independent groups, 192-214  
of matched groups, 217-231  
nature of, 192-199  
relation to epsilon-square, 232-236  
relation to *t* test in case of two independent groups, 199-201  
relation to *t* test in case of two matched groups, 224-225  
of several independent groups, 202-207  
of several matched groups, 225-231
- Area**, under normal curve, 40, 141-142
- Arithmetic mean**, 34
- Attenuation**, correction for, 102
- Attributes**, prediction of, 258-261
- Average deviation**, 36-38
- Averages**, 7-8, 34  
correlation between, 181  
of rates, 48
- Binomial**, rules for expanding, 137-138
- Binomial coefficients**, 137-138
- Binomial distribution**, 137-140
- Biserial coefficient of correlation**, 112-116, 127-128  
assumptions involved in computing, 113  
computed from widespread classes, 113
- Centiles**, 45-47  
as measures of relative position, 46
- Central tendency**, measures of, 34, 41-45, 49-50
- Charlier checks**, 74
- Chi-square**, 239-255  
applied to an a priori hypothesis, 241-246
- Chi-square—Continued**  
applied to more than two categories, 245-246  
applied to several samples, 250-252  
applied to two samples, 246-250  
calculated from per cents, 244  
correction for small frequencies, 253-254  
degrees of freedom for, 248  
interpretation of, 240  
relation to contingency coefficient, 123  
relation to phi coefficient, 254-255  
sampling distribution of, 241  
as test of "goodness of fit," 252-253
- Class intervals**, 67-70  
assumptions concerning scores within, 70  
influence of number of on accuracy, 68  
midpoint of, 71  
recorded limits of, 69-70  
size of, 68-69  
theoretical limits of, 70
- Coding**, 58-67, 270  
and calculation of correlation coefficient, 91-93  
and calculation of regression coefficient, 270  
corrections for, 60-67  
by division, 63-66  
formulas, 66-67  
by subtraction, 58-63
- Coefficient**, biserial, 112-116  
contingency, 122-123  
of correlation, 9, 79-99  
of determination, 99-100  
of non-determination, 99-100  
phi, 117-122  
point-biserial, 115  
rank-difference, 123-125  
regression, 264, 266, 270
- Combinations**, 136-137
- Common elements**, theory of, 100-101

- Confidence intervals, 162-165  
 Constant, definition of, 24  
 Constant errors, 283  
 Contingency coefficient, 122-123  
 Control group, 12, 288-295  
   formed by matching on experimental variable, 294  
   formed by matching on related variable, 294  
   formed by pairing individuals, 291-294  
   formed by random selection, 289-291  
   single group serving as own, 294  
 Coordinates, 82  
 Correction, for attenuation, 102  
   for coding, 60-66  
   for small frequencies in calculating chi-square, 253-259  
 Correlation, accuracy of predictions based upon, 261  
   and causation, 79  
   chart, 96  
   and common elements, 100-101  
   as means of reducing standard error, 183  
   multiple, 125-126, 181  
   negative, 83-85  
   partial, 125-126  
   positive, 80, 84-85  
   of ranks, 123-125  
   and regression, 265-267  
   and standard error of mean difference, 179-181  
   tetrachoric, 116-117  
 Correlation coefficient, 9, 79-99  
   computed from coded scores, 91-93  
   computed from original measures, 90-91  
   computed from scatter diagram, 94-99  
   computed from standard scores, 88  
   estimated by phi, 120  
   as mean of product of paired  $z$  scores, 88  
   multiple, 125  
   partial, 125  
   purpose for which used, 101  
 Correlation coefficient—*Continued*  
   as ratio of two averages of variance, 89  
   reduction in size from grouping, 127  
   relation to regression coefficient, 265-266  
   reliability of, 127  
   significance of, 185-189  
   size of, 80, 99  
   zero order, 125  
 Correlation ratio, 83, 107-112, 232-236  
   without bias, 232-236  
   relation of size of to number of class intervals, 127  
   size of, 108  
   summary of steps in computing, 110-111  
 Covariance, 87, 89  
 Cross-products, computation of, 87  
 Curvilinear relationships, 83, 106-111  
 Deciles, 46  
 Decimals, 16-17  
 Degree of confidence, 13, 161-162  
   in rejecting hypotheses, 165  
 Degrees of freedom, 166-167, 168, 170, 177, 179-180, 182-183, 188-189, 197-198, 201, 206, 210, 212-213, 221-223, 235-236, 242, 245-246, 248-249, 252-253, 296  
   in calculating chi-square, 242, 249  
   in determining fiducial limits of mean, 167  
   formulas for in analysis of variance, 207, 231  
   for mean difference between independent groups, 182  
   for mean difference between matched groups, 177, 179, 180  
   in testing "goodness of fit" of normal distribution, 252-253  
   in testing significance of  $r$ , 188  
 Dependent variable, 12  
 Deviation, 36-37  
   of observed from expected frequency, 240  
   significant, 139, 163

- Deviation—Continued  
 from some value other than mean, 59
- Diagrams, scatter, 94  
 for computing tetrachoric correlation, 117
- Differences, sampling distribution of mean of, 281-282
- Distributions, binomial, 137-140  
 frequency, 41  
 leptokurtic, 149  
 normal, 39, 41; 139  
 platykurtic, 149  
 reduced to common scales, 48  
 of sample means, 154-156  
 sampling, 153-156  
 skewed, 148-149  
 truncated, 41
- Epsilon, 232-236  
 Epsilon-square, 232-236  
 comparison with  $F$ , 234-236  
 relation to analysis of variance, 234-236  
 as test of rectilinear relationship, 237  
 use of tables of, 233
- Equations, rules for performing operations upon, 25-27
- Errors, constant, 283  
 of estimate, 262  
 of first kind, 165  
 of measurement, 102  
 of random sampling, 281, 283
- Eta, 107
- Experimental design, 11, 13, 30, 192, 208, 278, 281, 299
- Experimental group, 12
- Experimental variable, 12
- Experiments, nature of, 11
- Fiducial limits, 162-166  
 of mean difference, 177-178, 182  
 of proportion, 169  
 and small samples, 166-170
- Fiducial probability, 162
- Fractions, 15-16
- Frequency, standard error of, 170
- Frequency distributions, 41, 67
- Geometric mean, 49, 89
- "Goodness of fit," chi-square as test of, 252-253
- Graphs, 81-82
- Harmonic mean, 49
- Homogeneity of variance, test of, 296
- Hypotheses, testing of, 160-166, 176, 187-188, 201, 236-237, 240, 243, 247-248, 295-299
- Hypothesis, acceptance of false, 165  
 based upon pooled frequencies, 247  
 of homogeneity of variance, 295  
 of no difference, 279-282  
 null, 176-177, 184-185, 193, 280-281, 234  
 rejection of true, 165  
 and theory, 278-279
- Identities, substitution of in formulas, 26-27
- Independent groups, 181-183, 192-214
- Independent variable, 12
- Index of forecasting efficiency, 269
- Interaction, 208
- Interaction variance, 212-214
- Interval, 41
- Intervals, confidence, 162-165
- Kurtosis, 149
- Least squares, principle of, 272
- Matched groups, 12, 30, 152, 180-181
- Mean, arithmetic, 34  
 calculated from grouped scores, 72-74  
 geometric, 49  
 harmonic, 49  
 as a measure of concentration, 34-36  
 of a set of  $z$  scores, 48  
 standard error of, 157-159
- Mean difference, fiducial limits of, 177-178  
 significance of when variances differ, 297-299

- Mean difference—*Continued*  
 standard error of, 174-176
- Mean square, 33
- Means, variability of in correlation chart, 103-109
- Measurements, approximate nature of, 54-58  
 errors of, 102  
 paired, 11, 80  
 precision of, 67  
 predictions of, 261-273  
 reduced to common scales, 47-48, 88  
 reliability of, 102  
 in social sciences, 147  
 transformed into set of ranks, 125
- Median, 41-45, 75
- Method of least squares, 262
- Midpoint, of class interval, 71
- Mode, 49
- Multiple correlation coefficient, 125-126, 128, 181
- Normal curve, 39-40, 140-144  
 and large samples, 159-162  
 ordinates of, 114, 141-143  
 and standard scores, 142  
 use of tables of, 40, 144-146  
 zone embracing middle 95 per cent of measures, 145
- Normal distribution, 39-40, 139-140  
 fitted to sample set of measurements, 142-144  
 as a mathematical ideal, 146  
 relation of mode, median, and mean in, 148  
 of test scores, 147  
 testing "goodness of fit" of, 252-253
- Null hypothesis, 176-177, 184-185, 193, 234, 280-281
- Numbers, in a series, 21  
 positive and negative, 18-20  
 techniques of rounding, 57-58
- Opinion polls, 283
- Ordinate, 81  
 of normal curve, 114
- Paired associates, method of, 31
- Paired observations, 11  
 advantages of, 183-184  
 reduction in degrees of freedom for, 183-184
- Parameters, 51, 153
- Partial correlation coefficient, 125-126, 128
- Per cents, 17-18  
 calculation of chi-square from, 244  
 standard errors of, 170
- Phi coefficient, 117-122, 128  
 applied to true dichotomies, 118-119  
 and assumption of continuity, 119-121  
 estimate of  $r$  derived from, 120  
 relation to chi-square, 254-255  
 as substitute for tetrachoric  $r$ , 121-122
- Point biserial  $r$ , 114-116, 128
- Population, definition of, 51  
 estimate of mean of, 159  
 estimate of variance of, 192, 222  
 ratio, 240
- Precision, of measurements, 67
- Predictions, 13  
 accuracy of dependent upon correlation, 261  
 of attributes, 258-261  
 based upon means of columns of correlation table, 272  
 errors of, 259, 262  
 evaluation of efficiency of, 259, 269  
 of measurements, 261-273
- Principle of least squares, 272
- Principle of maximum likelihood, 258
- Principle of maximum probability, 258
- Probability, a priori, 134  
 empirical, 134  
 fiducial, 162  
 meaning of, 133-136  
 principle of maximum, 258
- Probable deviation, 49
- Probable error, 49
- Proportions, 17-18  
 standard error of, 168-169  
 testing significance of, 184-185

- Public opinion polls, 152  
margin of error in, 153  
samples used in, 152
- Quadrant, 82  
Quartile, 45
- Random numbers, tables of, 289-290  
Range, 5  
of correlation coefficient, 80, 99  
inclusive, 33-34  
as measure of variability, 8-9, 31-34  
middle 80 per cent, 49  
semi-interquartile, 45  
Rank-difference coefficient, 123-125  
Ranks, method of dealing with ties, 125  
Rates, averaging of, 49  
Rectilinear relationship, test of significance of departure from, 237  
Regression coefficient, 263  
coding of, 270  
and correlation, 265-267  
Regression equation, 265  
Regression line, 83, 262-263  
fitted by method of least squares, 263  
Relationships, between averages and differences, 9  
curvilinear, 83, 106-107  
negative, 79, 85  
positive, 79, 84  
rectilinear, 83  
study of, 9-10, 79-80  
Relative deviates, 47  
Reliability, 13, 153  
Replication, 230  
Research problems, 277-279  
Residual sum of squares, 221-222, 229-230  
Residual variance, 222, 224, 230
- Samples, definition of, 50  
generalizations from, 283  
large, 287
- Samples—*Continued*  
random, 283-286  
reasons for studying, 151-152  
representativeness of, 282, 286  
and research, 282-286  
size of, 287-288  
small, 166-168, 170, 287-288  
used in opinion polls, 283  
Sampling distribution, 153-156, 173  
of chi-square, 241-242  
of correlation coefficient, 186-187  
of difference between correlated means, 181  
of difference between means, 173  
of epsilon-square, 233  
of means, 157  
of standard deviation, 168  
of *t* ratio, 166-167  
of variance ratio, 193, 296  
Sampling, errors of random, 281, 283  
Sampling theory, 153  
Scatter diagram, 94  
Significance, tests of, 57, 297-299  
Significant figures, 55-56  
Skewness, 148-149  
Squares and square roots, 21-23  
Squares, sum of, 39, 51, 60-63, 65, 157, 193-195, 202, 210, 219, 226  
Standard deviation, 27-39  
calculated from grouped scores, 73  
of a distribution of *z* scores, 48  
estimate of population, 157-158  
of a sampling distribution, 156  
standard error of, 168  
Standard errors, 156-159, 168-170, 174-189, 200  
based on pooled sum of squares, 200  
of difference in mean gains, 293  
of estimate, 267-269, 272-273  
of frequencies, 170  
of mean differences, 174, 179-180, 200  
of mean differences of independent groups, 181, 200  
of mean differences when correlation is present, 179-181  
of means, 157-159  
of per cents, 170, 184-185  
of proportions, 168-169, 184-185

- Standard errors—*Continued*  
 relation to population variability, 156  
 relation to sample size, 156  
 of standard deviation, 168
- Standard scores, 47-49, 88, 141  
 mean of distribution of, 48  
 mean of products of paired, 88  
 as measures of relative position, 47-48  
 standard deviation of distribution of, 48
- Statistical inference, 13
- Statistical methods, applications of, 3  
 approaches to study of, 6  
 continuity of development of, 6  
 functions of, 10-14  
 mathematical bases of, 4
- Statistics, 51, 152
- Sum of cross-products, 87  
 computed from correlation chart, 97-98  
 computed from original measures, 90  
 correction for coding, 90  
 difference method of computing, 91
- Sum of squares, 51, 60-63, 65, 157, 193-195, 202, 210, 219, 226  
 computed from correlation chart, 96-97  
 between groups, 193, 195-196, 203-204, 210, 219, 227  
 within groups, 193, 195, 204-205, 210, 219, 227, 230  
 interaction, 212, 230  
 pooling of within groups, 199, 204-205, 210, 219, 227  
 residual, 221-222, 229-230
- Summation, 23-25, 35  
 of an algebraic sum of two or more terms, 24  
 of a constant, 24  
 of a variable, 24  
 of a variable divided by a constant, 25
- Symbols, use of, 5, 34-36
- Test construction, 14
- Tests of significance, 133, 184  
 chi-square, 239-255  
 comparison of  $F$  and  $t$  in case of two groups, 199-202, 218-225  
 epsilon-square, 232-237  
 interpretation of, 279-282  
 $t$  ratio, 166, 187  
 variance ratio, 193, 296
- Tetrachoric correlation, 116-117  
 assumptions involved in computing, 117  
 diagrams for computing, 117  
 and phi coefficient, 121
- Two-way frequency table, 94
- Universe, definition of, 51
- Variability, 8-9  
 in population as related to sample, 156
- Variable, definition of, 23  
 dependent, 12  
 dichotomous, 112-113  
 experimental, 12  
 independent, 12
- Variables, used for matching groups, 293-294
- Variance, analysis of, 192-231  
 assumption of homogeneity of, 295-299  
 definition of, 38  
 estimate of population, 192, 197, 199  
 interaction, 212-214  
 of means of columns in correlation chart, 108-109  
 in one variable associated with second, 99  
 residual, 222, 224, 230
- Variance ratio, 193, 198, 296, 205-206, 213-214, 218, 225, 227, 296
- X-axis, 81-82
- Y-axis, 81-82