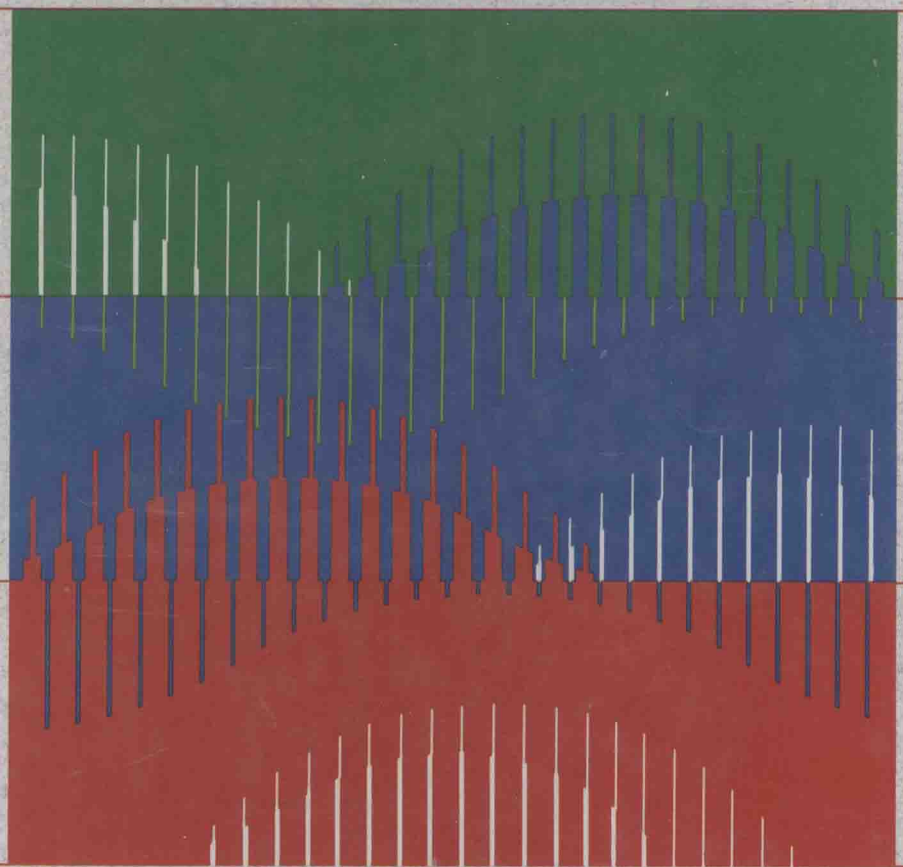
FUNDAMENTALS OF BEHAVIORAL STATISTICS

SEVENTH EDITION



RICHARD P. RUNYON □ AUDREY HABER

SEVENTH EDITION

FUNDAMENTALS OF BEHAVIORAL STATISTICS

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List of Formulas

Listed below are those formulas appearing in the text that the authors have found useful for computations. Following each formula is the page number where it first appears.

Number	Formula	Page
(4.1)	$\text{Percentile rank} = \dfrac{\text{cum}f_{\text{ll}} + \left(\dfrac{X - X_{\text{ll}}}{i}\right) f_i}{N} \times 100$	100
(4.2)	$\text{cum}f = \dfrac{\text{percentile rank} \times N}{100}$	102
(4.3)	$\text{Score at a given percentile} = X_{\text{ll}} + \dfrac{i(\text{cum}f - \text{cum}f_{\text{ll}})}{f_i}$	103
(5.1)	$\bar{X} = \dfrac{X_1 + X_2 + \cdots + X_N}{N} = \dfrac{\Sigma X}{N}$	117
(5.2)	$\bar{X} = \dfrac{\Sigma f X}{N}$	
	$\bar{X}_w = \dfrac{\Sigma f \bar{X}}{N_t}$	
(5.3)	$\text{Median} = X_{\text{ll}} + i\left[\dfrac{(N/2) - \text{cum}f_{\text{ll}}}{f_i}\right]$	
(6.3)	$\text{SS} = \Sigma(X - \bar{X})^2$	
(6.4)	$s^2 = \dfrac{\text{SS}}{N}$	
(6.5)	$s = \sqrt{\dfrac{SS}{N}}$	
(6.6)	$\text{SS} = \Sigma X^2 - \dfrac{(\Sigma X)^2}{N}$	
(7.1)	$z = \dfrac{X - \bar{X}}{s}$ or $\dfrac{X - \mu}{\sigma}$	
(8.2)	$r = \dfrac{\Sigma(X - \bar{X})(Y - \bar{Y})}{\sqrt{\text{SS}_x \cdot \text{SS}_y}}$	
(8.3)	$\Sigma(X - \bar{X})(Y - \bar{Y}) = \Sigma XY - \dfrac{(\Sigma X)(\Sigma Y)}{N}$	

Number	Formula	Page
(8.4)	$r = \dfrac{\Sigma XY - \dfrac{(\Sigma X)(\Sigma Y)}{N}}{\sqrt{\left[\Sigma X^2 - \dfrac{(\Sigma X)^2}{N}\right]\left[\Sigma Y^2 - \dfrac{(\Sigma Y)^2}{N}\right]}}$	197
(8.5)	$r = \dfrac{\dfrac{\Sigma XY}{N} - \overline{XY}}{s_x s_y}$	197
(8.6)	$r_s = 1 - \dfrac{6\Sigma D^2}{N(N^2 - 1)}$	205
(9.5)	$Y' = \overline{Y} + r\dfrac{s_y}{s_x}(X - \overline{X})$	227
(9.9)	$Y' = \overline{Y} + \dfrac{N\Sigma XY - (\Sigma X)(\Sigma Y)}{N\Sigma X^2 - (\Sigma X)^2}(X - \overline{X})$	228
(9.11)	$z_{y'} = rz_x$	229
(9.16)	$s_{\text{est } y} = s_y\sqrt{\dfrac{N(1 - r^2)}{N - 2}}$	235
(10.3)	$p(A \text{ or } B) = p(A) + p(B) - p(A \text{ and } B)$, the general case	267
(10.4)	$p(A \text{ or } B) = p(A) + p(B)$, where the events are *mutually exclusive*	268
(10.6)	$P + Q = 1.00$ when the events are *mutually exclusive* and *exhaustive*	269
(10.9)	$p(A \text{ and } B) = p(A)p(B)$ when the events are *independent*	273
(10.10)	$p(A \text{ and } B) = p(A)p(B\|A) = p(B)p(A\|B)$ when the events are *not independent*.	274
(12.4)	$\hat{s}^2 = \dfrac{\Sigma(X - \overline{X})^2}{N - 1}$ or $\dfrac{SS}{N - 1}$	333
(12.8)	$s_{\overline{X}} = \dfrac{s}{\sqrt{N - 1}} = \sqrt{\dfrac{\Sigma(X - \overline{X})^2}{N(N - 1)}} = \sqrt{\dfrac{SS}{N(N - 1)}}$	334

(Continued on back endpaper)

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List of Formulas (Continued from front endpaper)

Number	Formula	Page
(12.9)	$t = \dfrac{\overline{X} - \mu_0}{s_{\overline{X}}}$	337
(12.10)	Upper limit $\mu_0 = \overline{X} + (t_{0.05})(s_{\overline{X}})$	344
(12.11)	Lower limit $\mu_0 = \overline{X} - (t_{0.05})(s_{\overline{X}})$	344
(13.1)	$s_{\overline{X}_1 - \overline{X}_2} = \sqrt{\left(\dfrac{SS_1 + SS_2}{N_1 + N_2 - 2}\right)\left(\dfrac{1}{N_1} + \dfrac{1}{N_2}\right)}$	362
(13.2)	$s_{\overline{X}_1 - \overline{X}_2} = \sqrt{\dfrac{SS_1 + SS_2}{N(N-1)}}$, when Ns are equal	362
(13.3)	$t = \dfrac{(\overline{X}_1 - \overline{X}_2) - (\mu_1 - \mu_2)}{s_{\overline{X}_1 - \overline{X}_2}}$	362
(13.4)	$s_{\overline{X}_1 - \overline{X}_2} = \sqrt{\left[\dfrac{N_1 s_1^2 + N_2 s_2^2}{N_1 + N_2 - 2}\right]\left[\dfrac{N_1 + N_2}{N_1 N_2}\right]}$	365
(13.7)	$s_{\overline{X}_1 - \overline{X}_2} = \sqrt{s_{\overline{X}_1}^2 + s_{\overline{X}_2}^2 - 2r s_{\overline{X}_1} s_{\overline{X}_2}}$	373
(13.8)	$t = \dfrac{\overline{D} - \mu_{\overline{D}}}{s_{\overline{D}}} = \dfrac{\overline{D}}{s_{\overline{D}}}$	376
(13.9)	$SS_D = \Sigma D^2 - \dfrac{(\Sigma D)^2}{N}$	376
(13.11)	$s_{\overline{D}} = \sqrt{\dfrac{SS_D}{N(N-1)}}$	376
(14.2)	$SS_{tot} = \Sigma X_{tot}^2 - \dfrac{(\Sigma X_{tot})^2}{N}$	401
(14.5)	$SS_{bet} = \Sigma \dfrac{(\Sigma X_i)^2}{N_i} - \dfrac{(\Sigma X_{tot})^2}{N}$	402
(14.6)	$SS_{tot} = SS_w + SS_{bet}$	402

Number	Formula	Page
(14.7)	$\mathrm{df}_{\mathrm{bet}} = k - 1$	403
(14.8)	$\hat{s}^2_{\mathrm{bet}} = \dfrac{\mathrm{SS}_{\mathrm{bet}}}{\mathrm{df}_{\mathrm{bet}}}$	403
(14.9)	$\mathrm{df}_{\mathrm{w}} = N - k$	403
(14.10)	$\hat{s}^2_{\mathrm{w}} = \dfrac{\mathrm{SS}_{\mathrm{w}}}{\mathrm{df}_{\mathrm{w}}}$	403
(14.11)	$F = \dfrac{\hat{s}^2_{\mathrm{bet}}}{\hat{s}^2_{\mathrm{w}}}$	403
(14.12)	$\mathrm{df}_{\mathrm{tot}} = N - 1$	407
(14.13)	$\mathrm{HSD} = \mathrm{q}_{\alpha}\sqrt{\dfrac{\hat{s}^2_{\mathrm{w}}}{n}}$	408
(14.14)	$\text{est } \omega^2 = \dfrac{\mathrm{SS}_{\mathrm{bet}} - (k-1)\hat{s}^2_{\mathrm{w}}}{\mathrm{SS}_{\mathrm{tot}} + \hat{s}^2_{\mathrm{w}}}$	409
(16.1)	$\text{Power} = 1 - \beta$	452
(16.2)	$\text{Power efficiency of test } \beta = 100\,\dfrac{N_A}{N_B}\,\text{percent}$	464
(17.1)	$p(x) = \dfrac{N!}{x!(N-x)!}P^x Q^{N-x}$	470
(17.2)	$z = \dfrac{x - NP}{\sqrt{NPQ}}$	473
(17.4)	$\chi^2 = \sum_{r=1}^{r}\sum_{c=1}^{c}\dfrac{(f_o - f_e)^2}{f_e}$	478
(18.1)	$U = N_1N_2 - U'$	493
(18.2)	$U = N_1N_2 + \dfrac{N_1(N_1+1)}{2} = R_1$	493

FUNDAMENTALS OF BEHAVIORAL STATISTICS

Preface

It is difficult for us to believe that this text is going into its seventh edition, almost a quarter of a century after it took its first halting steps in the groves of academe. The widespread and continued acceptance of this text in its many editions has been a source of deep satisfaction to its authors.

Reflect for a moment on what has happened to the processing of data during this past quarter century. We have gone from mostly manual calculations, with occasional assistance from slide rules and noisy, recalcitrant mechanical calculators, to large and expensive calculators and computers, to compact, "throw away" pocket calculators and small, inexpensive computers with tremendous data storing and data-processing capabilities. As our grandchildren would say, "It's awesome!"

These changes have, of course, placed different requirements on the teaching of statistics. Less time need be spent on the mechanics of computation, and more time can be devoted to the rationale for research designs and statistical analysis. Our various editions have reflected these changes. But let's not throw out the baby with the bath. Some users of our texts have suggested that the explosion in the availability of sophisticated calculators and computers has made obsolete the use of grouping techniques in descriptive statistics. In some areas, this may well be so. However, vital statistics and census summaries, to name but two, are almost always presented in the form of grouped frequency distributions. Knowledge of grouping techniques is still required for a variety of reasons: to permit comprehension and understanding of both the advantages and the pitfalls of these widely used data summaries. One of our goals, as authors of statistical texts, has been to encourage statistical literacy. In our view, students unfamiliar with grouping techniques have gaps in this literacy.

The advent of the computer is not necessarily an unmixed blessing. Along with all the obvious benefits of the computer, there also arise some risks. There is a temptation to collect the data, then enter them immediately, and with cursory examination at best, into computer data files. In doing so, we lose contact with our raw data and may overlook important aspects of these data. It is for this reason that we have added a section on exploratory data analysis. We hope that this brief introduction to EDA will stimulate our colleagues and their students to delve deeper into these important recent statistical developments.

It was a concern for the scarcity of raw data that prompted us, while preparing the previous edition, to contact several authors of recently published research and request that they make their raw data available to

us. We are happy to say that we have continued to use their data, which we incorporated into a feature: "Statistics in Action." We wish to renew our expression of deep appreciation to S. R. Anthony, H. L. Wagner, and C. J. MacDonald at the University of Manchester, Manchester, England; Deems F. Ortega and Janet E. Pipal at Patient and Family Services, Iowa Lutheran Hospital, Des Moines, Iowa; Kenneth A. Perkins at the University of Pittsburgh and Western Psychiatric Institute and Clinic, Pittsburgh, Pennsylvania; and Norman E. Rosenthal at the National Institute of Mental Health, Clinical Psychobiology Branch, Bethesda, Maryland.

We have also added a feature to this edition: Putting It All Together. This appears at the end of most chapters and ties together the many disparate sections of the chapter. In some cases, a single set of data is subjected to the statistical procedures that were featured in the chapter. In others, some contemporary issue of importance is discussed in the light of a statistical perspective.

Those who desired greater coverage of analysis of variance (ANOVA) should not be disappointed. Chapters 13 and 14 of the previous editions were combined into a single chapter, and the new Chapters 14 and 15 cover ANOVA. All three chapters have a parallel structure—independent-samples designs followed by correlated-measures designs. Thus, Chapter 13 includes Student's *t*-ratio for independent and correlated samples (including before-after measures). Chapter 14 explores one-way ANOVA with both independent and correlated measures (randomized block designs). Finally, Chapter 15 covers two-way ANOVA, including factorial and randomized block factorial designs. For those who use this text in the first course at the graduate level, these two chapters should provide a sound introduction to more advanced statistical procedures.

Nor have the supplementary materials been neglected. The *Study Guide and Solutions Manual* has been expanded to include a greater emphasis on detailed worked solutions. This has been done to assist the student who, after spending considerable time on obtaining the answer, discovers that he or she has made an error. In some cases, the values of computations at varying stages in the analysis are shown so that the student can pinpoint where the error was made. In other instances, detailed solutions are shown. A supreme effort was made to achieve accuracy in the *Study Guide*. The solutions were checked and double-checked, using two independent sets of statistical software.

The *Study Guide* continues its sections on "guesstimating" a statistic on the basis of an examination of raw data, rather than using formal computational procedures. These guesstimating techniques yield rapid results that are often astonishingly close to the computed solution. Their use often helps the student better understand some abstruse point. Moreover, a sizable difference between the guesstimate and the computed solution alerts the student to a possible error in the values entered into the computation or the subsequent analysis of the data.

In addition, statistical routines for use with IBM (and IBM-compatible) and Apple personal computers are available for application in instructional settings where computers are used.

In particular, the MYSTAT computer package is available for use with this book; its major features include:

- Available for both Macintosh and IBM-type microcomputers.
- Fits on a single floppy disk; works without a hard disk and without changing disks; not copy protected.
- Outstanding freedom from rounding error, far surpassing mainframe SAS.
- Automatic reporting of the tolerance and exact significance level p for each independent variable, along with its slope, standard error of slope, standardized slope, and t.
- The CATEGORY command, which works like the CLASS command in SAS. For instance, if *religion* is represented by categories numbered 1–8, the commands

```
> category religion = 8
> model attitude = constant + age + religion
> estimate
```

are all that is necessary to produce an analysis of covariance testing the differences in attitude among the 8 religious groups with age controlled statistically.

- The * operator to represent interaction and power terms. For instance, the commands

```
> category religion = 8
> model attitude = constant + age + religion + age*age + age*religion
> estimate
```

add to the previous model a square term for age, and a term for the interaction between age and religion.

- A full-screen data editor that includes the ability to make logarithmic and many other data transformations and combinations, search for specific values, and generate uniform or normal random numbers.
- Ability to find the exact significance level p for any F, including F's calculated by hand or by other packages; see Appendix 2.
- Ability to find slopes and their standard errors for numerical variables even when some variables are categorical; see Section 10.1.6.
- Tests on sets of variables; see Section 5.3.1.
- A full range of regression diagnostics, including leverage, Cook's measure of influence, and studentized residuals. Unlike similar options in SAS, these can be used with both categorical and numerical variables.
- Ability to detect cases with unusual leverage or influence on a particular regression slope. Such cases may not be detected by overall measures of leverage and influence. See Section 14.1.7.

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- A structure that discourages the inappropriate use of what SAS calls "Type I" sums of squares and also what Cohen and Cohen (1983) call "Model II" error terms. This structure has been considered a disadvantage by some writers who don't understand the dangers in these models; see Section 7.5.3.

A textbook of this sort is a collaboration of many individuals, with their contributions meriting more than a mention in the Preface. First, there are those who write unsolicited letters to us to bestow compliments for a job well done or to chastise us whenever we drop the ball. We appreciate both the praise and the censure; the first for boosting our egos and the second for helping to improve our performance of our shared mission—instruction in one of the most important courses in the curriculum. A second group of individuals agree to subject themselves to the agony, without the ecstasy. In short, they read the entire text and make detailed suggestions, many of which are incorporated into the text. They have our undying admiration and appreciation.

We wish to thank the following reviewers for their most generous contribution of their time and talents: Kay Coleman, Boston University; Robert Cudeck, University of Minnesota; Richard Serkes, Tulsa Junior College; James Starr, Howard University; and Lois Tetrick, Wayne State University.

Finally, we would be remiss if we did not acknowledge the exceptionally fine support of our co-producers at McGraw-Hill, Inc. James R. Belser calmly and amiably supervised the production of the book; Maria E. Chiappetta and Jane Vaicunas provided valuable help and support during the revision stages of the manuscript.

We are grateful to the Literary Executor of the late Sir Ronald A. Fisher, F.R.S., to Dr. Frank Yates, F.R.S., and the Longman Group Ltd., London, for permission to reprint Table III from their book *Statistical Tables for Biological, Agricultural, and Medical Research (Sixth Edition, 1974).*

RICHARD P. RUNYON
AUDREY HABER

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