



INTRODUCTORY

# Statistics

*for the*

## BEHAVIORAL SCIENCES

SEVENTH EDITION

JOAN WELKOWITZ | BARRY H. COHEN | R. BROOKE LEA

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# Introductory Statistics for the Behavioral Sciences

*Seventh Edition*

**Joan Welkowitz, Barry H. Cohen, R. Brooke Lea**



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*This book is dedicated  
to Lori, Michael, and Melissa;  
to Emily and Jackson;  
and to the memory of Joan Welkowitz,  
our mentor and brilliant, much-loved friend.*

# ***Preface***

It has been both a joy and a privilege to create this seventh edition of one of the longest-running statistics texts in the behavioral sciences. (This title has been in print continuously since 1971.) In doing so, we tried to maintain the original purpose of this text, as expressed in the preface to the second edition: to introduce and explain statistical concepts and principles clearly and in a highly readable fashion, assuming minimal mathematical sophistication, but avoiding a “cookbook” approach to methodology.

At the same time that we have endeavored to stay true to the original mission of this classic text, we have added a new co-author, Brooke Lea of Macalester College, and have revised and improved nearly all of our chapters, which included updating many of the examples and exercises. Naturally, we took this opportunity to correct any mistakes we and others had noticed from previous editions, and to add some explanatory sentences for the concepts that we know our students have struggled with in the past.

As with the sixth edition of this text, the supplementary materials of this edition will overlap with those for the third edition of Barry Cohen's graduate-level statistics text, *Explaining Psychological Statistics*, also published by John Wiley & Sons. In addition to visiting the Wiley Web site for this text, students and instructors are encouraged to explore the supplemental materials available on Barry Cohen's statistics Web page:  
[www.psych.nyu.edu/cohen/statstext.html](http://www.psych.nyu.edu/cohen/statstext.html).

There are several structural changes in this edition that are worth noting, as described next.

# **1. Numbering of Key Formulas**

All of the important formulas in the text have been given unique numbers (for example, the formulas in Chapter 3 are numbered 3.1, 3.2, etc.), making it much easier to refer to formulas earlier in the same chapter, as well as to formulas in previous chapters. This feature greatly facilitates one of our chief strategies for making statistics understandable—that is, to point out the connections between formulas that look quite different superficially, but nonetheless perform strikingly similar functions.

# **2. Consolidation of the Early Chapters**

To reduce redundancy and to make room for some slightly more advanced material in later chapters, we consolidated the first eight chapters of the previous edition (i.e., Part I, Descriptive Statistics) into just four. We have dropped a few rarely used procedures (e.g., “mean-on-spoke” representations; linear interpolation formulas for percentiles), but retained all of the main computational examples from the previous edition. The added material for which we made room deals mostly with confidence intervals, measures of effect size, and follow-up tests for complex analyses. We also address, rather directly, the basis of the controversy over the nearly universal use of null hypothesis testing in the behavioral sciences.

# **3. Moving Ordinal Tests From the Last Chapter to the Middle of the Text**

We became aware that a significant number of statistics instructors prefer to teach nonparametric alternative tests directly after the parametric tests to which they correspond. To facilitate this approach, we moved the bulk of the chapter on tests for ordinal data so that it now appears immediately after the chapter on two-group  $t$  tests. The ordinal tests corresponding to procedures described in later chapters were incorporated at the ends of those chapters. However, we feel that tests for categorical data do not have the close correspondence to parametric tests that ordinal tests do, so the chapter on the binomial distribution, and the chapter on chi-square tests remain at the end of the text.

## **4. Creation of Separate Correlation and Regression Chapters**

The previous edition presented linear correlation and prediction in one large chapter and then followed it with a chapter about the connection between correlation and the  $t$  test. We have now given correlation and regression their own chapters and folded into the latter the connection these procedures have with the  $t$  test. (In line with the previous point, Spearman rank-order correlation has been added to the end of the correlation chapter.) The result is that we have been able to expand our coverage of important issues (e.g., when can a statistical correlation be used to infer a causal link?). We have also infused these chapters with new examples that help motivate the concepts.

## **5. Updating the Computer Exercises and SPSS Sections**

We expanded Sarah's data set somewhat from the previous edition to create Ihno's data set for this edition and added computer exercises to many of the chapters. We also took this opportunity to update our Bridge to SPSS sections to reflect changes in the most recent versions of SPSS for Windows. (The version current during the writing of this edition is 19.0.) In several chapters we have now included screen shots to illustrate the main SPSS dialog boxes commonly used by researchers to perform the analyses described in this text. In some cases we have also included results boxes from the output that SPSS produces for particular analyses, in order to draw connections between the terms used by SPSS to label its output and the corresponding (sometimes different) terms used in this text.

## **6. Advanced Chapter (18) on the Web**

A number of reviewers of the previous edition of this text requested that we include at least one chapter devoted to more advanced statistical methods, such as ANCOVA, MANOVA, and factor analysis. They did not want to see detailed computations of these advanced procedures, but rather a series of consumer-friendly descriptions of these techniques that could help students to gain a clearer understanding of the results of such methods, as published in the empirical journals they are likely to encounter in advanced psychology courses, when engaged in literature reviews, or when assisting professors with their research. In answer to these requests, we will be posting Chapter 18 of this edition on the Web. Please see [www.psych.nyu.edu/cohen/statstext.html](http://www.psych.nyu.edu/cohen/statstext.html) for further details.

## 7. New Ancillaries

We have added a companion site on the Wiley Web site just for students, which can be found at: [www.wiley.com/go/welkowitz](http://www.wiley.com/go/welkowitz)

The student Web site includes the following items:

- **Basic Math Review:** A review of all the basic math operations you will need to know to perform the statistical exercises in this text. Includes numerous exercises and quizzes with answers.
- **Study Guide:** A lively chapter-by-chapter review of the text with additional exercises and answers. Created by graduate students who recently served as teaching assistants for statistics, it provides another perspective on the material presented in this text.

We have also completely updated the Wiley instructor companion site for the seventh edition, which can also be found at: [www.wiley.com/go/welkowitz](http://www.wiley.com/go/welkowitz)

The instructor Web site includes the following items:

- **Instructor's Manual:** Step-by-step answers to all of the computational exercises in the text.
- **Test Bank:** Multiple choice questions, both conceptual and computational, that can be used to create quizzes to assess the students' mastery of each chapter in the seventh edition.
- **Power Point Slides:** Expanded and updated for this new edition, these slides provide convenient summaries of the important points of each chapter, and can help instructors to organize their lectures around the key concepts for each statistical topic.

Barry H. Cohen

R. Brooke Lea



# ***Acknowledgments***

Thanks are due to our many encouraging friends and relatives, to all of the colleagues and reviewers who made many useful comments on previous editions, and especially to five new reviewers, all of whom gave us helpful reviews of the sixth edition and suggestions for this latest edition: Danica Hays, PhD, Old Dominion University; Faith-Anne Dohm, PhD, Fairfield University; James Sexton, PhD, Argosy University, Washington DC; Litze Hu, PhD, University of Santa Cruz; and Tai Chang, PhD, California School of Professional Psychology. Once again, we want to take this opportunity to thank our many students who, throughout the years, have provided invaluable feedback on our teaching of statistics, as well as on earlier editions of this text and its accompanying workbook. Special thanks go to recent survivors of the “RIP” sequence at Macalester College for their trenchant suggestions for improving the text.

This latest edition surely owes its very existence to Patricia Rossi (Executive Editor) at John Wiley & Sons, whose constant support and prodding have ensured that this text will now begin its 40th year in continuous print. Along the way, Ms. Rossi's efforts on our behalf have been ably aided by several highly competent editorial assistants, as well as more senior staff at Wiley; most recently, Kara Borbely (Editorial Program Coordinator) and Kate Lindsay (Senior Production Editor) have been enormously helpful in getting this edition into print and its ancillaries on the Web. We are also grateful to those responsible for the attractive look and design of this text—especially, Rose Sullivan, Senior Production Manager.

Finally, we are happy to acknowledge a debt of gratitude to Ihno Lee for revising the data set (now named after her)

that we use for the computer exercises, as well as for correcting several errors in the previous edition, and to Grace Jackson and Samantha Gaies, who created a lively and engaging new study guide (available on the Student Companion Web site for this text), which we feel certain will be much appreciated by both the adopters and readers of this text. We also appreciate the careful and accurate help provided by Emily Haselby and Melissa Lazarus in preparing the Instructor's Manual.

Barry H. Cohen

R. Brooke Lea

## **Postscript**

I cannot close this Acknowledgments section without sadly paying homage to the two departed professors, who, along with a colleague now living in Florida, wrote and edited the original text and kept it fresh and alive over the course of several decades. I had the pleasure of working closely with the senior author, Dr. Joan Welkowitz, on the previous edition of this text, and it is not possible to overestimate the continued influence of both her and her former co-author and friend, Jacob Cohen, on this text and on my approach to the teaching of statistics. (No, to my knowledge, I am not genetically related to Jack Cohen.) The one living author of the original text, Robert Ewen, wrote nearly all of the exercises and thought questions you see in this edition. Though many of the exercises and examples in the text have been updated, Dr. Ewen's careful craftsmanship and editorial skills are still visible in this edition.

Finally, I was delighted to keep the close connection between this text and New York University alive by adding Dr. Brooke Lea as a co-author of the present edition. Brooke received his doctorate in experimental psychology at NYU

while Joan Welkowitz and Jack Cohen were still teaching there. Brooke was a student in one of the first statistics classes I taught at NYU, was later my teaching assistant for the same course, and turned out to be instrumental in getting me to write my first text, *Explaining Psychological Statistics*. Moreover, Brooke and I co-authored a statistics manuscript at NYU (playfully titled “The Joy of Stats”), which was later reworked and published in 2004 by John Wiley & Sons as *Essentials of Statistics for the Social and Behavioral Sciences*. The joy is still there. Thanks, Brooke!

Barry H. Cohen

# ***Glossary of Symbols***

*Numbers in parentheses indicate the chapter in which the symbol first appears.*

- $a_{YX}$  Y-intercept of linear regression line for predicting  $Y$  from  $X$  (10)
- $\alpha$  criterion (or level) of significance; probability of Type I error (5)
- $\alpha_{EW}$  experiment-wise alpha (13)
- $\alpha_{FW}$  family-wise alpha (14)
- $\alpha_{pc}$  alpha per comparison (13)
- $b_{YX}$  slope of the linear regression line for predicting  $Y$  from  $X$  (10)
- $\beta$  probability of Type II error (5)
- $1 - \beta$  power (11)
- $cf$  cumulative frequency (2)
- $\chi^2$  statistic following the chi square distribution (12)
- $D$  difference between two scores (7)
- $\bar{D}$  mean of the  $D$ s (7)
- d** effect size involving two populations (11)
- $df$  degrees of freedom (6)
- $df_{Bet}$  degrees of freedom between groups (12)
- $df_w$  degrees of freedom within groups (12)
- $df_1$  degrees of freedom for factor 1 (14)
- $df_2$  degrees of freedom for factor 2 (14)
- $df_{1 \times 2}$  degrees of freedom for interaction (14)
- $\delta$  delta (11)
- $\eta^2$  eta squared; effect size in multiple samples (12)
- f** effect size involving multiple populations (12)
- $f$  frequency (2)
- $f_e$  expected frequency (17)
- $f_o$  observed frequency (17)
- $F$  statistic following the  $F$  distribution (12)
- $g$  effect size involving two samples (7)
- $H$  statistic for the Kruskal-Wallis test (12)

$H_0$	null hypothesis (5)
$H_A$	alternative hypothesis (5)
HSD	Tukey's Honestly Significant Difference (13)
$i$	case number (1)
$k$	a constant (1)
$k$	number of groups (12)
LSD	Fisher's Least Significant Difference (13)
Mdn	median (3)
$MS$	mean square (12)
$MS_{\text{Bet}}$	mean square between groups (12)
$MS_W$	mean square within groups (12)
$MS_1$	mean square for factor 1 (14)
$MS_2$	mean square for factor 2 (14)
$MS_{1 \times 2}$	mean square for interaction (14)
$\mu$	population mean (3)
$n$	number of observations in one of two or more equal-sized samples (7)
$N_T$	total number of subjects or observations (1)
$N_i$	number of observations or subjects in group $i$ (12)
$\omega^2$	omega squared; proportion of variance accounted for in a population (10)
$\pi$	hypothetical population proportion (6)
$p$	probability of attaining results as extreme as yours when the null hypothesis is true (5)
$P$	observed sample proportion (6)
$P(A)$	probability of event $A$ (16)
PR	percentile rank (2)
$\phi$	phi coefficient (17)
$\phi_c$	Cramér's $\phi$ (17)
$q$	studentized range statistic (13)
$r_c$	matched pairs rank biserial correlation coefficient (8)
$r_G$	Glass rank biserial correlation coefficient (8)
$r_{pb}$	point-biserial correlation coefficient (10)
$r_s$	Spearman rank-order correlation coefficient (9)
$r_{XY}$	sample Pearson correlation coefficient between $X$ and $Y$ (9)
$\bar{R}$	mean of a set of ranks (8)

$\rho_{XY}$	population correlation coefficient between $X$ and $Y$ (9)
$s$	sample standard deviation (5)
$s^2$	population variance estimate (5)
$s_D^2$	variance of the $D$ s (7)
$s_{\text{pooled}}^2$	pooled variance (7)
$s_{\bar{X}}$	standard error of the mean (6)
$s_{\bar{X}_1 - \bar{X}_2}$	standard error of the difference (7)
$s_{\text{est}}$	estimate of $\sigma'_y$ obtained from a sample (10)
SIQR	semi-interquartile range (3)
$SS$	sum of squares (3)
$SS_T$	total sum of squares (12)
$SS_{\text{Bet}}$	sum of squares between groups (12)
$SS_W$	sum of squares within groups (12)
$SS_1$	sum of squares for factor 1 (14)
$SS_2$	sum of squares for factor 2 (14)
$SS_{1 \times 2}$	sum of squares for interaction (14)
$\Sigma$	summation sign (1)
$\sigma$	population standard deviation (3)
$\sigma^2$	population variance (3)
$\sigma_p$	standard error of a sample proportion (6)
$\sigma_T$	standard error of the ranks of independent samples (8)
$\sigma_{T_M}$	standard error of the ranks of matched samples (8)
$\sigma_{\bar{X}}$	standard error of the mean when $\sigma$ is known (5)
$\sigma_{\text{est}}$	standard error of estimate for predicting $Y$ (10)
$t$	statistic following the $t$ distribution (6)
$T$	T score (4)
$T_E$	expected sum of the ranks (8)
$T_i$	sum of ranks in group $i$ (8)
$X'$	predicted $X$ score (10)
$\bar{X}$	sample mean (3)
$\bar{X}_i$	mean of group $i$ (12)
$\bar{X}_G$	grand mean (12)
$Y'$	predicted $Y$ score (10)