

## Between-Subjects, One-Way ANOVA (Chapter 10)

Used to compare the means of two or more independent samples.

Source of Variability	Sum of Squares	Degrees of Freedom	Mean Square	F ratio
Between groups	$SS_{\text{Between}} = \sum \left( \frac{(\sum X_{\text{Group}})^2}{n_{\text{Group}}} \right) - \frac{(\sum X)^2}{N}$	$k - 1$	$\frac{SS_{\text{Between}}}{df_{\text{Between}}}$	$\frac{MS_{\text{Between}}}{MS_{\text{Within}}}$
Within groups	$SS_{\text{Within}} = \sum \left( \sum X^2_{\text{Group}} - \frac{(\sum X_{\text{Group}})^2}{n_{\text{Group}}} \right)$	$N - k$	$\frac{SS_{\text{Within}}}{df_{\text{Within}}}$	
Total	$SS_{\text{Total}} = \sum X^2 - \frac{(\sum X)^2}{N}$	$N - 1$		

## Repeated-Measures ANOVA (Within-Subjects, One-Way ANOVA) (Chapter 11)

Used to compare the means of two or more dependent samples.

Source of Variability	Sum of Squares	Degrees of Freedom	Mean Square	F ratio
Subjects	See Chapter Appendix.	$n - 1$		
Treatment	See Chapter Appendix.	$k - 1$	$\frac{SS_{\text{Treatment}}}{df_{\text{Treatment}}}$	$\frac{MS_{\text{Treatment}}}{MS_{\text{Residual}}}$
Residual	See Chapter Appendix.	$(n - 1)(k - 1)$	$\frac{SS_{\text{Residual}}}{df_{\text{Residual}}}$	
Total	See Chapter Appendix.	$N - 1$		

## Between-Subjects, Two-Way ANOVA (Chapter 12)

Used to compare the means of four or more independent samples when there are two explanatory variables.

Source of Variability	Sum of Squares	Degrees of Freedom	Mean Square	F ratio
Between groups	See Chapter Appendix.	$df_{\text{Rows}} + df_{\text{Columns}} + df_{\text{Interaction}}$		
Rows	See Chapter Appendix.	$R - 1$	$\frac{SS_{\text{Rows}}}{df_{\text{Rows}}}$	$\frac{MS_{\text{Rows}}}{MS_{\text{Within}}}$
Columns	See Chapter Appendix.	$C - 1$	$\frac{SS_{\text{Columns}}}{df_{\text{Columns}}}$	$\frac{MS_{\text{Columns}}}{MS_{\text{Within}}}$
Interaction	See Chapter Appendix.	$df_{\text{Rows}} \times df_{\text{Columns}}$	$\frac{SS_{\text{Interaction}}}{df_{\text{Interaction}}}$	$\frac{MS_{\text{Interaction}}}{MS_{\text{Within}}}$
Within groups	See Chapter Appendix.	$N - (R \times C)$	$\frac{SS_{\text{Within}}}{df_{\text{Within}}}$	
Total	See Chapter Appendix.	$N - 1$		

## Pearson $r$ (Chapter 13)

Used to examine the linear relationship between two interval/ratio variables.

$$r = \frac{\Sigma[(X - M_x)(Y - M_y)]}{\sqrt{SS_x SS_y}}$$

## Simple Regression (Chapter 14)

Used to predict an outcome variable ( $Y'$ ) from a predictor variable ( $X$ ).

First, calculate:

$$b = r \left( \frac{s_y}{s_x} \right)$$

where  $b$  = the slope of the regression line  
 $r$  = the observed correlation between  $X$  and  $Y$   
 $s_y$  = the standard deviation of the  $Y$  scores  
 $s_x$  = the standard deviation of the  $X$  scores

Then, calculate:  $a = M_y - bM_x$   
where  $a$  = the  $Y$ -intercept for the regression line  
 $M_y$  = the mean of the  $Y$  scores  
 $b$  = the slope of the regression line  
 $M_x$  = the mean of the  $X$  scores

Finally, calculate the regression line equation:

$$Y' = bX + a$$

where  $Y'$  = the predicted value of  $Y$   
 $b$  = the slope of the regression line  
 $X$  = the value of  $X$  for which one wants to find  $Y'$   
 $a$  = the  $Y$ -intercept of the regression line

## Chi-Square Goodness-of-Fit Test (Chapter 15)

Used to compare the distribution of a nominal or ordinal categorical variable in a sample to the variable's expected distribution.

First, calculate expected frequencies:

$$f_{\text{Expected}} = \frac{\% \text{ Expected} \times N}{100}$$

Then, calculate the chi-square value:

$$\chi^2 = \Sigma \frac{(f_{\text{Observed}} - f_{\text{Expected}})^2}{f_{\text{Expected}}}$$

## Chi-Square Test of Independence (Chapter 15)

Used to determine whether two or more samples differ on a nominal or ordinal categorical dependent variable.

First, calculate the expected frequencies for a contingency table:

$$f_{\text{Expected}} = \frac{N_{\text{Row}} \times N_{\text{Column}}}{N}$$

Then, calculate the chi-square value:

$$\chi^2 = \Sigma \frac{(f_{\text{Observed}} - f_{\text{Expected}})^2}{f_{\text{Expected}}}$$

## Writing a Four-Point Interpretation

1. Recap the study. What was done? Why?
2. Present the main results factually. For example, what were the mean scores for the control and experimental groups? Present the results of the hypothesis test in APA format.
3. Explain what the results mean.
4. Make suggestions for future research. What were the strengths and/or weaknesses of this study? What should be done in the next study?

Using and Interpreting  
**Statistics**



THIRD EDITION

# Using and Interpreting **Statistics**

A Practical Text for the Behavioral,  
Social, and Health Sciences

**ERIC W. CORTY**

*The Pennsylvania State University*



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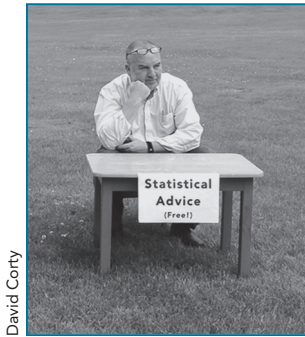
*For Sara, David, and Paul*

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## ABOUT THE AUTHOR



David Corty

**ERIC W. CORTY** has a bachelor's degree in psychology from Vassar College, a doctorate in clinical psychology from Indiana University, and two postdoctoral fellowships, one in neuropsychopharmacology (University of Pennsylvania) and one in human sexuality (Case Western Reserve University). Since 1993, Corty has been a member of the psychology faculty at Penn State Erie, the Behrend College. There, he teaches principles of measurements, abnormal psychology, human sexuality, introductory psychology, and, of course, statistics. The quality of his teaching was recognized in 1997 when he received the Council of Fellows Excellence in Teaching Award and in 2001 when he became a Penn State Teaching Fellow. At present, Corty is the Interim Director of the School of Humanities & Social Sciences at Penn State Behrend.

Corty's work has appeared in more than three dozen peer-reviewed publications. His research on ejaculatory latencies received worldwide attention, including being made fun of on the *Late Show with David Letterman*. His statistics textbook was recognized as Book of the Year by the *American Journal of Nursing* in 1997. Corty serves as a member of the editorial board for *The Journal of Sex & Marital Therapy* and previously was on the editorial board for *The Journal of Consulting and Clinical Psychology*.

Corty was born in Wilmington, Delaware, and still celebrates Delaware Day every December 7th. He now lives in Beachwood, Ohio. He likes to eat and to cook, loves to ride his bicycles, and is sad to report that he has not made much progress on his pool game since the second edition.

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## PREFACE

### TO THE STUDENT

If you are like many students, this is not a course you have been looking forward to taking. And you probably don't feel like reading a long message about how important this course is. So, I'll be brief and say just five things to introduce the book to you:

1. When the semester is over, you'll find that statistics wasn't as hard as you feared. Learning statistics is like learning a foreign language—the concepts build on each other and require regular practice. The best way to practice is just like the best way to eat: Take small bites, chew thoroughly, and swallow thoughtfully. Work through the “Practice Problems” as they pop up. Make sure you can do them before moving on to new material.
2. The “Review Your Knowledge” exercises at the end of the chapter are just that, a review of the chapter. Do them when you've finished the chapter to make sure that you're comfortable with all of the material in the chapter. Then, do them again before a test as a refresher.
3. The questions in the “Apply Your Knowledge” exercises at the end of the chapter have at least two questions on each topic. Each odd-numbered question is followed by an even-numbered question that asks the same thing. Answers for the odd-numbered questions appear in the back of the book. So if you struggle with an odd-numbered question, you can turn there for help. And then, with that guidance, you should be able to work through the even-numbered question on your own.
4. The book is divided into four parts. At the end of each, you'll find a test that covers the techniques from all chapters in that part. Working these problems can be a great way to determine whether you have truly mastered the material.
5. One last thing: In each chapter, you'll find a boxed feature called “DIY.” I've crafted these projects as a way for you to gain experience gathering data and conducting experiments. I encourage you to work the projects on your own, even if your teacher doesn't assign them.

I hope you enjoy this book half as much as I enjoyed writing it. If you have any comments about it that you'd like to share with me, please write to me at [ewc2@psu.edu](mailto:ewc2@psu.edu).



## TO THE INSTRUCTOR

Welcome to the third edition of *Using and Interpreting Statistics*. I wrote this book because I couldn't find a text that presented the right amount of material in a straightforward manner that engaged students. My approach is applied—I want students to walk away from a first course in statistics with an ability to do what I call the “human side” of statistics, the things that computers can't do. Yes, I teach the math of statistics—how to calculate  $t$ ,  $F$ ,  $r$ ,  $\chi^2$ , confidence intervals, and a variety of effect sizes—but my overall focus is on leading students to an understanding of the logic (and the beauty) of statistics. At the end of the course, I want students to be able to select the appropriate statistical test for a research question. For the statistical tests, I want them to be able to write, in simple language, a complete interpretative statement and to explain what the results mean. In line with the recommendations from the American Statistical Association's *Guidelines for Assessment and Instruction in Statistics Education: College Report* (2010), I aim for a conceptual understanding, not just procedural knowledge.

There are a number of techniques that I use to achieve these goals. The first technique is my clear and approachable writing style, which makes it easier for students to engage with, and actually read, the book. Next, my organization within chapters breaks complex concepts into component parts, so they can be learned in much the same manner as a behavior is shaped. To aid learning, chapters are sprinkled with mnemonic and organizational devices. For example, there are “How to Choose” flowcharts that help students pick the correct statistical procedure, and each statistical test has a series of questions that lead students through the main concepts that need to be covered in an interpretation.

## Features of the Book

**Stat Sheets** Each chapter has a Stat Sheet (collected at the end of the text) that can be pulled out of the book. These tear sheets contain all the formulas, flowcharts, and steps that are necessary to complete a statistical test. The Stat Sheets provide essential guidance when solving problem sets or studying on the go.

**Picking the Right Statistical Test** Knowing what statistical test to use is an important statistical skill, yet many introductory textbooks devote little time to it. Not true for me, as I give it a whole chapter. I thought long and hard about where to place this chapter content, early or late, and I finally decided late, making this chapter the last in the book. In this position, “Selecting the Right Statistical Test” serves as a coda that brings together all the elements of the course, and it presents a unifying view of statistics.

**Six Steps of Hypothesis Testing** Continuity from chapter to chapter reinforces understanding and makes procedures second nature. For example, when I introduce hypothesis testing, I teach a six-step procedure for completing hypothesis tests.

- **Step 1:** Pick a test.
- **Step 2:** Check the assumptions.
- **Step 3:** List the hypotheses.
- **Step 4:** Set the decision rule.
- **Step 5:** Calculate the test statistic.
- **Step 6:** Interpret the results.

For every subsequent test taught, I follow the same six steps. This is a repetitive, cook-book approach, but it is purposeful: When you are learning to cook, it pays to follow a recipe. At first the steps are rote, then they become a routine, and finally the steps become internalized.

**Interpreting Results** Knowing how to calculate the value of a test statistic is vitally important in statistics and each chapter teaches students these skills. But, the learning outcomes for research methods, as spelled out in the *APA Guidelines for the Undergraduate Psychology Major* (Version 2.0, 2013), stress evaluating the appropriateness of conclusions derived from psychological research. To this end, the coverage of each statistical tests ends with a substantial section on interpreting results. This format also aligns with the APA's emphasis on communication and professional development by exposing students early and often to the presentation of results that they will see in professional articles and that will be expected when they present their own research.

For each statistical test, students learn to address a series of questions to gather information for interpreting the results. For the independent-samples  $t$  test, for example, there are three questions:

1. Was the null hypothesis rejected, and what does this reveal about the direction of the difference between the two populations?
2. How big is the size of the effect?
3. How big or small might the effect be in the population?

Integrating confidence intervals and effect sizes into the interpretation of results for tests, rather than isolating them in a separate chapter, teaches students to use these techniques. Students learn to write an interpretation that addresses four points: (a) why was the study done, (b) what were its main results, (c) what do the results mean, and (d) what are suggestions for future research. This four-point interpretation is used for every test, making a thorough interpretation a natural part of completing a statistical test.

**Practice, Practice, Practice** Learning statistics is like learning a foreign language—concepts build on each other and are best learned with regular and graduated practice. Because of this, a statistics book lives or dies by its exercises. This book has been constructed with that in mind. All the exercises were written by me, so they are consistent in content and tone with the rest of the text. Importantly, three tiers of exercises—reviewing knowledge, applying knowledge, and expanding knowledge—allow professors to assign questions at different levels and give students the opportunity to push themselves to a deeper understanding.

Opportunities for practice are also presented throughout each chapter:

- **Worked Examples.** There are Worked Examples spaced throughout every chapter that students can work along with the text. These lead students through problems step-by-step. The Worked Examples allow students to make sure they know the correct steps for a statistical test and help to develop their statistical thinking.

- **In-Chapter Practice Problems.** Each major section of a chapter concludes with Practice Problems and solutions so that students can practice the material and assess how well they've learned it.
- **End-of-Chapter Exercises.** The end-of-chapter exercises have three tiers, one for students to review their knowledge, another with applied questions, and a third with more challenging problems to stretch understanding. Students have ample opportunities to practice—the  $t$  test chapters, for example, have close to 100 questions each, more than other texts on the market. The applied questions are written so that they build on each other, moving to the final goal of calculating and interpreting a statistical test. These applied questions isolate and test each intermediate step in the process—for example, making sure a student knows how to compute a standard error of the difference before computing a  $t$  value. Finally, the applied questions are paired, with at least two questions for each concept. An answer to the first question is given at the back of the book, so the student can check and correct his or her work.

**Part Tests** In addition to this in-chapter practice, the third edition has been divided into four parts, with a brief introduction and capstone Part Test. These tests offer challenging problems that require students to pick from the various methods and techniques they've learned from the whole text up to that point. By working through these problems, students will gain a deeper understanding of the material, and will be better prepared for course exams.

## More Tools for Students

In addition to the various opportunities for practice, each chapter features an expanded set of learning tools that help students by previewing, reviewing, and rehearsing the chapter's lessons.

**Learning Objectives and Summary** The Learning Objectives at the start of the chapter set up the key concepts for the chapter. They show up again at the end of the chapter to organize the summary, reinforcing the chapter's framework.

**User-Friendly Equations** Whenever an equation is introduced, all the symbols in the formula are defined. This makes it easy for students to plug correct values into formulas.

**DIYs** New to this edition, this feature presents the framework for a do-it-yourself project built around the chapter topic. Appropriate for either group or individual work, the DIYs allow students to create their own data sets and draw their own conclusions.

**End-of-Chapter Application Demonstrations** Each chapter culminates in an Application Demonstration problem that usually uses real-life data and employs the techniques learned in the chapter to answer questions about the world in which we live.


**End-of-Chapter Summary** The end-of-chapter summaries are brief journeys back through the main sections of the chapter. Along with the key terms, they provide students with a quick review of the main concepts.

## Noteworthy Changes in the Third Edition

For those of you who are familiar with the second edition of this text, you'll notice some significant changes here. I've mentioned a couple of new features above—the part introductions and tests, and the DIY feature—that will provide additional opportunity for your students to engage with the material. Based on reviewer suggestions and my own experience working with this text, I've also made several other organizational and content changes.

- **Chapter 2** now includes a section on stem-and-leaf plots, including coverage in the SPSS guide.
- The discussion of the importance of  $z$  scores in **Chapter 4** has been expanded. In addition, the review of probability has moved to this chapter, where it follows the discussion of the normal curve.
- **Chapter 5** includes a more in-depth discussion of sampling and a revised introduction to confidence intervals as a practical application of the central limit theorem.
- As a consequence of this revised organization, the discussion of confidence intervals in **Chapter 7** has been simplified, allowing the student to focus on the procedure for the single-sample  $t$  test. In addition, the discussion of effect size now presents  $r^2$  alongside Cohen's  $d$ , making for an easier comparison and contrast of these two measures.
- In **Chapter 8**, the formula for pooled variance is now introduced prior to the presentation of the standard error equation, so students can clearly see how pooled variance is used to calculate the estimated standard error.
- **Chapter 9** now addresses the pitfalls of using  $r^2$ , as well as Cohen's  $d$ , with paired-samples  $t$  tests.
- The coverage of sum of squares in **Chapter 10** now includes the computational formula in addition to the definitional formulas.
- The coverage of one-way, repeated-measures ANOVA and between-subjects, two-way ANOVA in **Chapters 11 and 12**, respectively, has been augmented with the inclusion of in-chapter appendixes that present the formulas for calculating sums of squares for these tests.
- The introduction of one-way, repeated measures ANOVA has been greatly expanded in **Chapter 11** to present the uses of this test.
- The coverage of the Pearson Correlation Coefficient in **Chapter 13** now includes more details about the definitional formula. In addition, a major section has been added to introduce the student to partial correlation.
- The presentation of the formula for calculating cell expected frequencies in **Chapter 15** has been simplified.

Examples and exercise sets throughout the text have been revised and the end-of-chapter SPSS guides thoroughly updated.



## MEDIA AND SUPPLEMENTS

### LaunchPad with LearningCurve Quizzing

*A comprehensive Web resource for teaching and learning statistics*

LaunchPad combines Worth Publishers' award-winning media with an innovative platform for easy navigation. For students, it is the ultimate online study guide, with rich interactive tutorials, videos, an e-Book, and the LearningCurve adaptive quizzing system. For instructors, LaunchPad is a full course space where class documents can be posted, quizzes can be easily assigned and graded, and students' progress can be assessed and recorded. Whether you are looking for the most effective study tools or a robust platform for an online course, LaunchPad is a powerful way to enhance your class.

LaunchPad to Accompany *Using and Interpreting Statistics*, Third Edition, can be previewed and purchased at [launchpadworks.com](http://launchpadworks.com).

*Using and Interpreting Statistics*, Third Edition, and LaunchPad can be ordered together with ISBN-13: 978-1-319-06187-6/ISBN-10: 1-319-06187-7. Individual components of LaunchPad may also be available for separate, standalone purchase.

LaunchPad for *Using and Interpreting Statistics*, Third Edition, includes all the following resources:

- The **LearningCurve** quizzing system was designed based on the latest findings from learning and memory research. It combines adaptive question selection, immediate and valuable feedback, and a game-like interface to engage students in a learning experience that is unique. Each LearningCurve quiz is fully integrated with other resources in LaunchPad through the Personalized Study Plan, so students will be able to review using Worth's extensive library of videos and activities. And state-of-the-art question analysis reports allow instructors to track the progress of their entire class.
- An **interactive e-Book** allows students to highlight, bookmark, and make their own notes, just as they would with a printed textbook. Google-style searching and in-text glossary definitions make the text ready for the digital age.
- **Statistical Video Series** consisting of StatClips, StatClips Examples, and Statistically Speaking "Snapshots." View animated lecture videos, whiteboard lessons, and documentary-style footage that illustrate key statistical concepts and help students visualize statistics in real-world scenarios.
  - **StatClips lecture videos**, created and presented by Alan Dabney, PhD, Texas A&M University, are innovative visual tutorials that illustrate key statistical concepts. In 3 to 5 minutes, each StatClips video combines dynamic animation, data sets, and interesting scenarios to help students understand the concepts in an introductory statistics course.
  - In **StatClips Examples**, Alan Dabney walks students through step-by-step examples related to the StatClips lecture videos to reinforce the concepts through problem solving.
  - **Snapshots** videos are abbreviated, student-friendly versions of the **Statistically Speaking** video series, and they bring the world of statistics into the classroom. In the same vein as the successful PBS series *Against All Odds Statistics*, *Statistically Speaking* uses new and updated documentary

footage and interviews that show real people using data analysis to make important decisions in their careers and in their daily lives. From business to medicine, from the environment to understanding the Census, Snapshots focus on why statistics is important for students' careers, and how statistics can be a powerful tool to understand their world.

- **Statistical Applets** allow students to master statistical concepts by manipulating data. They also can be used to solve problems.
- **EESEE Case Studies** are taken from the *Electronic Encyclopedia of Statistical Exercises and Examples* developed by The Ohio State University. EESEE Case Studies offer students additional applied exercises and examples.
- The **Assignment Center** lets instructors easily construct and administer tests and quizzes from the book's Test Bank and course materials. The Test Bank includes a subset of questions from the end-of-chapter exercises with algorithmically generated values, so each student can be assigned a unique version of the question. Assignments can be automatically graded, and the results are recorded in a customizable Gradebook.

## Additional Student Supplements

- **SPSS®: A User-Friendly Approach** by Jeffery Aspelmeier and Thomas Pierce of Radford University is a comprehensive introduction to SPSS that is easy to understand and vividly illustrated with cartoon-based scenarios. In the newest edition of the text for SPSS Version 22, the authors go beyond providing instructions on the mechanics of conducting data analysis and develop students' conceptual and applied understanding of quantitative techniques.
- The **iClicker** Classroom Response System is a versatile polling system developed by educators for educators that makes class time more efficient and interactive. iClicker allows you to ask questions and instantly record your students' responses, take attendance, and gauge students' understanding and opinions. iClicker is available at a 10% discount when packaged with *Using and Interpreting Statistics*, Third Edition.

## Instructor Supplements

One book alone cannot meet the education needs and teaching expectations of the modern classroom. Therefore, Worth has engaged some skilled teachers and statisticians to create a comprehensive supplements package that brings statistics to life for students and provides instructors with the resources necessary to supplement their successful strategies in the classroom.

- **Instructor's Resources.** This guide offers an Instructor's Resource Manual containing classroom activities, handouts, additional reading suggestions, and online resources. The Instructor's Resources also include lecture slides and all of the book's images in either JPEG or Slideshow format and can be downloaded from the book's catalog page at <http://www.macmillanhighered.com/Catalog/product/usingandinterpretingstatistics-thirdedition-corty/instructorresources#tab>.



- **Downloadable Test Bank.** Powered by Diploma, the downloadable Test Bank includes hundreds of multiple-choice questions to use in generating quizzes and tests for each chapter of the text. The Diploma software allows instructors to add an unlimited number of new questions; edit questions; format a test; scramble questions; and include figures, graphs, and pictures. The computerized Test Bank also allows instructors to export into a variety of formats compatible with many Internet-based testing products.



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